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Friction-Induced Interbank Rate Volatility under Alternative Interest Corridor Systems

Thomas Link*   Ulrike Neyer†

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Abstract[1]

This paper proposes rules for the control of interbank rate volatility under different interest corridor systems when volatility stems from interbank market frictions. Friction-induced volatility will occur if there is heterogeneity in two dimensions (across banks and time) with respect to the degree to which frictions change the relative attractiveness of banks' outside options to using the interbank market. Under a "floor" or "ceiling operating system" (asymmetric scheme), friction-induced volatility can be controlled by implementing a relatively wide interest corridor - which is the inversion of the traditional principle. Under a "standard corridor system" (symmetric scheme), the systematic control of friction-induced interbank rate volatility can never be achieved through corridor width adjustments but requires a switch to an asymmetric corridor scheme.

JEL classification: E52, E58, G21

Keywords: interbank market, monetary policy implementation, interest corridor, floor operating system, transaction costs, excess reserves

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1 Introduction

The design of optimal post-crisis monetary policy implementation frameworks remains an open task (Bindseil (2016), Potter (2016)). A number of issues have to be addressed, like the robustness of any future implementation schemes against recent and coming regulatory reforms.[2] The proposals for an optimal implementation framework in a new regulatory environment range from more far-reaching solutions, such as re-defining the operating target (Bech and Keister (2013)), to less drastic measures, such as only changing some secondary specifications of an established implementation scheme (Jackson and Noss (2015)). This paper addresses the issue of how to design a monetary policy implementation framework that allows for an effective control of interbank rate volatility when volatility stems from market frictions brought about, for instance, by new banking regulations.

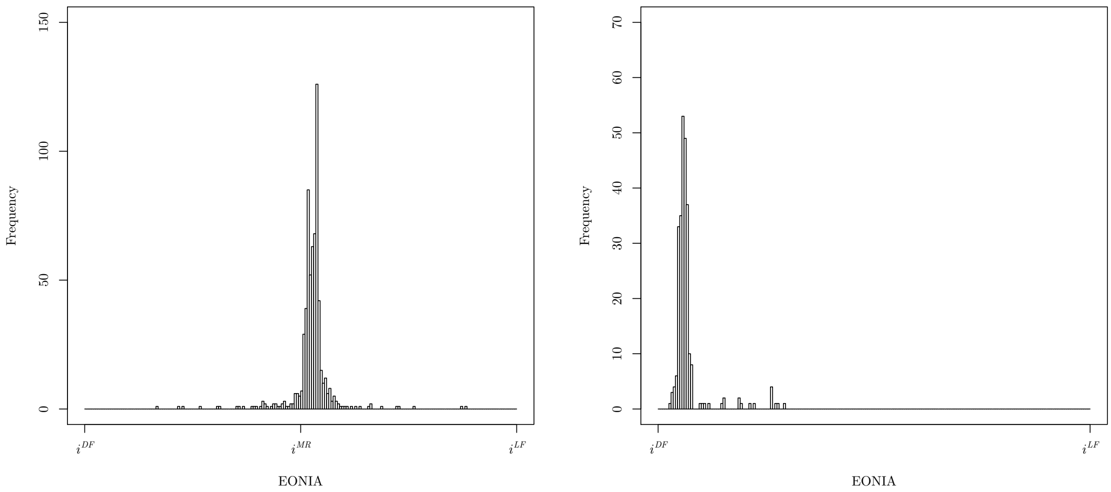
Usually, a monetary policy implementation framework that includes standing facilities is regarded to be effective in controlling the interbank rate. There is a consensus on the rules for the control of interbank rate volatility under interest corridor regimes for the case of volatility that stems from sources other than those represented by frictions. These rules are conventional wisdom and the underlying principle is simple: A central bank operates two standing facilities and thereby creates outside options for banks to using the interbank market.[3] The existence of these options dampens the interest rate effects triggered by liquidity shocks to the banking system. The more attractive these options are made to banks (relative to using the interbank market), the stronger their stabilizing effect on the interbank rate. There are several ways to reach higher attractiveness, such as: (1) narrowing the width of the corridor, i.e., the spread between the rates on the deposit and the lending facility; (2) installing an "asymmetric" corridor system by driving the interbank rate either down or up close to one of the facility rates (which makes recourse to that facility highly attractive).[4] In fact, during the last decade of crises, the ECB

[2]See Bindseil (2016) for a systematic overview of requirements for future monetary policy implementation frameworks.

[3]In this paper, the term "interbank market" always refers to the unsecured overnight segment of interbank money markets.

[4]The notion of "symmetry" in this context refers to the spreads between the central bank's target interbank rate and the two facility rates. A corridor scheme is "symmetric" if the target rate is located in the midpoint of the interest corridor. See, for instance, Whitesell (2006), Bindseil, Camba-Mendez, Hirsch, and Weller (2006), Berentsen and Monnet (2008), Bindseil and Jablecki (2011), Bech and Monnet (2013); for an overview of several options for the design of corridor schemes see Federal Open Market Committee (2015).

successfully followed both of these ways and switched from a relatively broad "standard corridor system" to a more narrow "floor operating system," an asymmetric scheme that is implemented via an ample provision of liquidity. In this vein, volatility was controlled relatively well on average, as illustrated by Figure 1 for two exemplary sub-periods.



(a) 06/06/2003 - 12/05/2005, 645 observations, deposit rate = 1.00%, lending rate = 3.00%.

(b) 07/01/2009 - 07/01/2010, 258 observations, deposit rate = 0.25%, lending rate = 1.75%.

Figure 1: EONIA: Distribution of market rates under (a) standard and (b) floor system. Horizontal axis: EONIA in percentage points. Vertical axis: # observations. *Data: ECB.*

Nevertheless, overall market conditions changed drastically during the last decade – with a notable increase in market frictions. Information asymmetries about counterparty credit risks, market fragmentation, or new regulatory burdens have made transactions in the interbank market less profitable. Accordingly, the ongoing decline in market activity and the shift to transactions in secured segments reflect that options other than using the unsecured overnight interbank market have become relatively more attractive. Theoretically, such shifts can also lead to higher interbank rate volatility – as already pointed out by CGFS (2015), Jackson and Noss (2015), and Bindseil (2016). These studies consider the effects of new banking regulations and argue that concrete measures as a regulatory leverage ratio, large exposure limits, a liquidity coverage ratio, a net stable funding ratio, or suggested risk-based capital requirements for interbank exposures will have an impact on interbank liquidity demand and supply and will lead to higher interbank rate volatility.[5] One rationale for this increase in volatility is that regulatory burdens on banks are bank- and time-specific. Over time, this leads to demand and supply fluctuations in the interbank market that are transmitted into volatility of the interbank rate. More generally, bank heterogeneity, with respect to the degree in which market frictions such as banking regulations increase the relative attractiveness of outside options to using the interbank market, will lead to interbank rate volatility if the heterogeneity changes over time. This is the starting point in the present paper. With regard to the persistence of market frictions in a post-crisis world the question thus is whether, and if so how, a central bank can control friction-induced interbank rate volatility.

The existing literature suggests that the aforementioned rules for the control of volatility under an interest corridor system will hold if volatility arises from aggregate liquidity shocks. However, this paper argues that the control of volatility that arises from specific market frictions is subject to different rules. This is shown in a theoretical analysis based on the seminal model of monetary policy implementation under an interest corridor regime presented in Whitesell (2006). The model is analyzed for two different corridor schemes, in particular for a standard corridor system (a symmetric corridor scheme) and for a floor operating system (an asymmetric corridor scheme). The latter yields direct implications for volatility control under another asymmetric scheme, a "ceiling operating system," which is implemented by driving the interbank rate up close to the lending rate by leaving the banking sector short of liquidity. Interbank market frictions are introduced in the form of broadly defined transaction costs that alter the relative attractiveness of outside options for banks to using the interbank market. Transaction cost heterogeneity across banks captures that banks differ in the degree to which they prefer other options than using the interbank market. Ultimately, transaction cost heterogeneity in two dimensions (cross-section and time) explains interbank rate volatility.

In the frictionless benchmark scenarios the model results are in line with those of the existing literature on volatility control under interest corridor systems. Accordingly, the central bank is able to control volatility that arises from aggregate liquidity shocks by

[5] Jackson and Noss (2015) consider the effects of a minimum leverage ratio and risk-based capital requirements on the cross-section dispersion of market rates in a multi-agent framework that accounts for the over-the-counter character of interbank markets and, crucially, for the different weights of regulatory burdens for individual banks.

increasing the attractiveness of outside options for banks to using the interbank market - concretely, by narrowing the interest corridor or by implementing an asymmetric corridor scheme. But crucially, the model in this paper implies that the control of volatility that stems from market frictions is based on the inversion of this well-known principle: The central bank must create an unattractive outside option to using the interbank market for friction-affected banks while maintaining or improving the availability of an attractive outside option for banks that are not affected by frictions. Under an initially implemented symmetric corridor scheme this can only be achieved by switching to an asymmetric scheme. Under an initially implemented asymmetric scheme, volatility control can require the central bank to increase (!) the width of the interest corridor.

The rationale for these results is that transaction costs make the use of the interbank market less attractive, interbank market activities decline, and banks fall back on using outside options, that is, on using the standing facilities. The drop in interbank demand/supply is transmitted to the interbank rate. Over time, transaction cost heterogeneity in the two dimensions cross-section and time leads to demand, respectively supply, fluctuations that cause interbank rate volatility. While the decline in market activity is stronger the more attractive the outside options for friction-affected banks are, the impact on the interbank rate is stronger the lower the attractiveness of outside options for their potential interbank counterparties is. Thus, interbank rate volatility is higher the higher the attractiveness is of outside options to using the interbank market for friction-affected banks, and the lower the attractiveness of outside options for their potential interbank counterparties. The reason behind these relationships lies in the interest sensitivity of interbank liquidity supply and demand which increases in the attractiveness of outside options for the respective market side. Any measures to reduce interbank rate volatility rely on the exploitation of these properties. Therefore, the control of friction-induced volatility will be possible if the central bank is able to systematically manipulate the attractiveness of outside options for potential lenders and borrowers to a different extent or in opposite directions.

Under an initially implemented standard corridor system this cannot be achieved by simply changing the corridor width: The symmetry of this scheme implies that any corridor width adjustment will have an equal effect on the attractiveness of outside options for friction-affected banks and their counterparties. The attenuating and the dampening effect on interbank rate volatility cancel each other out. In contrast, the corridor width can be perfectly used as an instrument to reduce friction-induced volatility if the central bank implements an asymmetric corridor scheme, i.e., a floor or a ceiling system. For instance, volatility that stems from supply-side frictions under an initially implemented floor system can be controlled by increasing the width of the interest corridor. This measure is the inversion of the traditional principle. It leads to a stabilization of interbank liquidity supply and therewith of the interbank rate by reducing (!) the attractiveness of potential lenders' outside option to using the interbank market (which is the deposit facility). The asymmetry of a floor system thereby guarantees that the lending banks' potential counterparties still have no attractive outside option available. Analogously, widening the corridor is a way of making a ceiling operating system more robust to demand-side frictions.

The rest of this paper is structured as follows. Section 2 briefly reviews the related literature. Section 3 presents the model setup. Section 4 derives optimal bank behavior with respect to the banks' use of the central bank's standing facilities and their interbank market activities. This allows for in-depth analysis of the determinants of banks' liquidity demand, as well as of interbank loan supply and demand. The interbank market equilibrium is identified in section 5. Section 6 discusses the implications for monetary policy implementation and volatility control under a standard corridor system and under a floor operating system. Section 7 has some concluding remarks.

2 Related Literature

The model of monetary policy implementation employed in this paper is based on the seminal model of interest corridor systems proposed in Whitesell (2006). Extended versions of that framework have been introduced in several other works, the two closest to the model presented in this paper are those by Bech and Klee (2012) and Jackson and Noss (2015). Whitesell (2006), in turn, is part of a large body of research that refers to the seminal model of an overnight interbank market in Poole (1968). Poole models a representative commercial bank's reserve management and liquidity demand to describe the price formation in the interbank market in the presence of a central bank that provides outside options for banks to using the interbank market. Poole's starting point is that uncertainty about actual liquidity needs during the day explains a precautionary motive behind bank demand for liquidity. This precautionary liquidity demand serves as an explanatory variable for interbank market activities and therefore plays an important role in the analysis of the interbank market equilibrium (see also, for instance, Baltensperger (1980), Clouse and Dow (1999), Bech and Monnet (2013), or Bucher, Hauck, and Neyer (2017)). Factors that determine bank demand for precautionary liquidity have been used to explain or predict movements, volatility or observed patterns of the overnight interbank rate, for instance, over reserve maintenance periods or on reserve settlement days. Such determinants are the level of daily interbank payment volumes (Furfine (2000)), lending constraints for banks (Cassola and Huetl (2010)), credit constraints particularly for small banks (Ashcraft, McAndrews, and Skeie (2011)), credit risk (Bech and Klee (2012)), fragmentation of the interbank market (Miklos (2014)), regulatory capital requirements (Jackson and Noss (2015)), or broadly defined transaction costs (Bucher, Hauck, and Neyer (2017)). Other determinants with fundamental implications for the optimal design of monetary policy implementation frameworks are reserve requirement schemes (Whitesell (2006), Gaspar, Pérez Quirós, and Rodríguez Mendizábal (2008)) and specifications of the interest corridor like its width (Woodford (2001), Bindseil and Jablecki (2011)) or symmetry (Quirós and Mendizábal (2012), Jackson and Noss (2015)).

Similar to Bech and Klee (2012) and Jackson and Noss (2015), this paper starts with the introduction of interbank market transaction costs in the Whitesell-model. The transaction cost effect on bank demand for precautionary liquidity explains the price formation in the interbank market. However, while the former two works focus on the transaction cost effects on the level of the interbank rate and on its cross-section dispersion, this paper considers the transaction cost effects on interbank rate volatility in a time dimension and proposes rules for the control of this volatility under alternative interest corridor systems.

3 Model Setup

Like in the Whitesell (2006) framework, a one-period economy consists of a large number of commercial banks and a central bank. The central bank provides settlement accounts for banks, conducts open market operations, and operates two standing facilities. Banks are subject to liquidity shocks and can balance their individual liquidity needs by using the interbank market or the central bank's standing facilities.

At the beginning of the period under consideration (henceforth called 'day'), banks settle their due claims and liabilities from the previous period (for instance, these might stem from overnight interbank loans or from previous recourse to the central bank's facilities). Banks which have insufficient reserve balances for this purpose are allowed to overdraw their settlement accounts during the course of the day. After claims/liabilities are settled, the central bank conducts open market operations and thus injects or withdraws liquidity to/from the banking system. The resulting aggregate liquidity position of the banking sector at that time is denoted by $\bar{\Xi}$. Subsequently, an aggregate liquidity shock α occurs with $\tilde{\alpha} \sim \mathcal{N}(0, \sigma_{AS}^2)$ (with $\tilde{\alpha}$ denoting a random variable, α denoting its realization). Positive values of α indicate liquidity inflows to the banking system, negative values of α liquidity outflows, so banks' aggregate liquidity position after the occurrence of the shock is $\bar{\Xi} + \alpha =: \Xi$. Eventually, bank customers make bank transfer payments which reshuffle reserves within the banking sector.[6]

These activities imply that the banking sector's aggregate liquidity position *at noon*, Ξ, as well as an individual bank's liquidity position *at noon*, denoted by ξ, might be positive or negative. There are two types of commercial banks $i \in \{1, 2\}$: Letting $\xi_1 > 0$ and $\xi_2 < 0$, bank 1 is assumed to have a liquidity surplus at noon, bank 2 a liquidity deficit. If the banking sector's aggregate liquidity position at noon $\Xi = \xi_1 + \xi_2$ is strictly positive (negative), the banking sector as a whole exhibits a liquidity surplus (deficit) vis-à-vis the central bank. Banks have to balance their reserve accounts with the central bank overnight. This setting thus describes an arbitrary day in a world where banks are subject to reserve requirements which have to be precisely fulfilled each day (with end-of-day required reserves being normalized to zero). Alternatively, the period might be

[6] In part, this setup is following Bindseil and Jablecki (2011).

interpreted as the last day of a reserve maintenance period where banks are allowed to make use of averaging provisions over the reserve maintenance period. Accordingly, with hypothetical reserve requirements bank 1 would have over-fulfilled reserve requirements at noon to the amount of ξ_1. Bank 2 would not have met reserve requirements but would exhibit a reserve deficiency at noon of $|\xi_2|$.

To balance their liquidity positions *at noon*, banks can use an (overnight) interbank market for central bank reserves. A bank's position in this market is b_i. If $b_i > 0$ ($b_i < 0$), the bank will borrow (lend) the amount $|b_i|$ at rate i^{IBM}. In both cases, transaction costs $\gamma_i |b_i|$ accrue, with $\gamma_i \geq 0$. Following Whitesell (2006), the level of reserve account balances bank i wishes to hold after the closure of the interbank market, its *"target reserve account balance,"* is denoted by T_i with $T_i := \xi_i + b_i$. As intra-day overdrafts are allowed, T_i might be positive or negative.

In the evening, once the interbank market is closed, bank i is hit by an idiosyncratic reserve account shock (a *"late payment shock"*) ϵ_i. The shock ϵ_i is the realization of the random variable $\tilde{\epsilon}_i \sim \mathcal{N}(0, \sigma_i^2)$ with the publicly observable probability density function f_i and the cumulative distribution function F_i.[7] If $\epsilon_i > 0$ ($\epsilon_i < 0$) there will be an inflow (outflow) of funds. The shocks $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ are independent and identically distributed with $f \equiv f_1 \equiv f_2$ and $F \equiv F_1 \equiv F_2$.

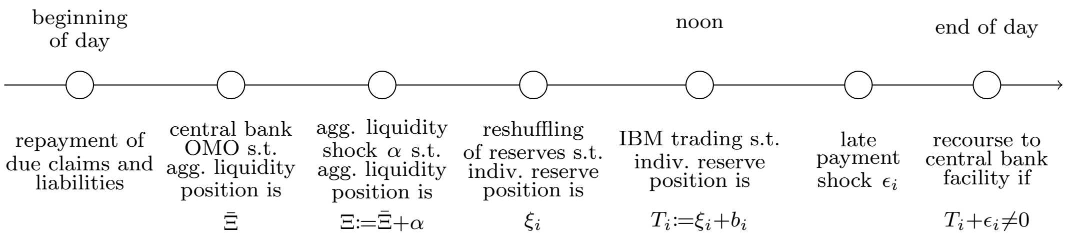


Figure 2: Sequence of events within the period under consideration.

A bank's actual *end-of-day* liquidity position is $T_i + \epsilon_i$. Bank i will face an end-of-day deficit if $T_i + \epsilon_i < 0$ and an end-of-day surplus if $T_i + \epsilon_i > 0$. Banks have to balance their reserve accounts with the central bank overnight. Bank i thus has to take recourse to the

[7] As argued by Whitesell (2006, p. 1179), a bank does not know its actual liquidity needs for the period under consideration at the time it can trade on the interbank market because it is *"[...] subject to unexpected late payments or delayed accounting information [...]"*. The term *"late payment shock"* in this context is used, for instance, in Bech and Monnet (2013), Bindseil, Camba-Mendez, Hirsch, and Weller (2006), and Jackson and Noss (2015).

central bank's lending facility at rate i^{LF} in case of an end-of-day deficit, respectively, to the central bank's deposit facility at rate i^{DF} in case of an end-of-day surplus (banks can obtain/place liquidity from/at the central bank on an overnight basis unlimitedly and without any restrictions). Eventually, at this point in time, bank i learns its actual liquidity costs, denoted by K_i:

$$\begin{aligned} K_i \; &= i^{IBM} \cdot b_i + \gamma_i \cdot |b_i| \\ &- \; \left(i^{LF} \cdot (T_i + \epsilon_i)\right) \cdot 1_{\{\epsilon_i \leq -T_i\}}(\epsilon_i) \\ &- \; \left(i^{DF} \cdot (T_i + \epsilon_i)\right) \cdot 1_{\{\epsilon_i > -T_i\}}(\epsilon_i) \\ \text{with } T_i &= \xi_i + b_i. \end{aligned} \tag{1}$$

Actual liquidity costs include the bank's interest costs, resp. revenues, and its transaction costs that accrue when using the interbank market at noon (first line of equation (1)) and – depending on which of the central bank's facilities the bank uses – the interest costs, resp. revenues, of taking recourse to the lending facility (second line), resp. deposit facility (third line). Which of the facilities bank i uses ultimately depends on the late payment shock and finds expression in the values of the indicator functions $1_{\{\epsilon_i \leq -T_i\}}(\epsilon_i)$ and $1_{\{\epsilon_i > -T_i\}}(\epsilon_i)$.

The rationale behind a bank's interbank market activities is the minimization of its expected liquidity costs. A bank's objective function, yielding its optimal position in the interbank market and therewith its optimal target reserve account balance, is thus given by:[8]

$$\begin{aligned} \mathbb{E}[K_i] = - \; & \left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right) \cdot \xi_i \\ - & \int_{-\infty}^{-T_i} \left[i^{LF} - \left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right)\right] \cdot (T_i + \epsilon_i)\, dF(\epsilon_i) \\ + & \int_{-T_i}^{\infty} \left[\left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right) - i^{DF}\right] \cdot (T_i + \epsilon_i)\, dF(\epsilon_i) \\ \to & \min_{T_i}! \end{aligned} \tag{2}$$

[8] The expression $\frac{b_i}{|b_i|}$ simply captures whether a bank acts as a lender ($\frac{b_i}{|b_i|} = -1$) or borrower ($\frac{b_i}{|b_i|} = 1$) in the interbank market. Of course, optimizing over T_i is equivalent to the optimization over b_i. However, in the following, T_i, which captures a bank's precautionary liquidity demand, is of special interest.

$$\text{with} \quad T_i = \xi_i + b_i.$$

In comparison to Whitesell (2006, p. 1180), the bank's optimization problem is thus extended by two features: Firstly, a bank's pre-trade liquidity endowment ξ_i as well as its position in the interbank market b_i are explicitly considered. This allows for an analysis of the liquidity redistribution within the banking sector via the interbank market. Secondly, interbank market transaction costs γ_i are considered. Bank-specific transaction costs $\gamma_1 \lesseqgtr \gamma_2$ capture the cross-section dimension of transaction cost heterogeneity (the time dimension is considered in section 6). In effect, transaction costs increase the relative attractiveness of banks' outside options to using the interbank market, as the expression in the two square brackets formally shows. In the remainder of this paper, the term $\left[i^{LF} - \left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right)\right]$ will be referred to as "*effective* marginal deficit costs," the term $\left[\left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right) - i^{DF}\right]$ as "*effective* marginal surplus costs." Therewith, line 2 in equation (2) captures bank i's "expected effective deficit costs" and line 3 its "expected effective surplus costs."

With these extending features, equation (2) states the following:[9] The first line reveals the lower bound for a bank's expected liquidity costs. This lower bound is determined by the bank's pre-trade liquidity endowment. This liquidity would be fully traded in the interbank market at any interbank rate $i^{IBM} > i^{DF} + \gamma_i$ as a lending bank, respectively, at any $i^{IBM} < i^{LF} - \gamma_i$ as a borrowing bank if there was no late payment shock. For the interpretation of lines two and three, which reflect the expected liquidity costs due to the late payment shock, it is useful to distinguish between lending and borrowing banks in the interbank market. The second line reveals the expected effective deficit costs of a bank. These are the costs of balancing the expected end-of-day deficit by taking recourse to the lending facility at rate i^{LF}. However, for a bank that has *lent* to the interbank market, and which at the end of the day learns of having placed too much liquidity in the interbank market at noon, the costs of using the lending facility are *effectively* reduced by the interest revenues (minus transaction costs) of the bank's excessive interbank lending. For a borrowing bank, the *effective* costs of using the lending facility are the *additional* costs of using the lending facility instead of the interbank market at noon. The third line

[9] See also Whitesell (2006, p. 1180) for the original framework.

captures the expected effective surplus costs which are the effective costs of placing the expected end-of-day liquidity surplus in the deposit facility at rate i^{DF}. For a lending bank, these costs are the (net) *opportunity costs* of using the deposit facility instead of the interbank market. Analogously, for a borrowing bank, the third line of equation (2) reveals the costs of "over-funding" in the interbank market at noon.

4 Optimal Bank Behavior

4.1 Optimal Target Level of Reserve Balances

The first-order condition for optimal, i.e., for expected cost-minimizing, borrowing/lending in the interbank market and thus for the optimal target reserve account balance T_i is

$$\left[i^{LF} - \left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right)\right] \cdot F(-T_i) \stackrel{!}{=} \left[\left(i^{IBM} + \frac{b_i}{|b_i|} \cdot \gamma_i\right) - i^{DF}\right] \cdot (1 - F(-T_i)) \,. \quad (3)$$

Crucially, as expected liquidity needs due to the late payment shock are zero ($\tilde{\epsilon}_i \sim \mathcal{N}(0, \sigma_i^2)$), T_i represents a bank's demand for precautionary liquidity. With probability $F(-T_i)$, which is decreasing in T_i, (respectively $1 - F(-T_i)$, which is increasing in T_i) the bank faces an end-of-day liquidity deficit (surplus) and has to take recourse to the lending facility (deposit facility). The first-order condition thus implies that the expected marginal return on precautionary liquidity, in the form of avoided illiquidity costs (given by the LHS of (3)), must equal the expected marginal costs of precautionary liquidity (given by the RHS of (3)). Expected marginal costs are in the form of opportunity costs for a bank that lends to the interbank market and in the form of interest costs for a bank that borrows from the interbank market.

For the rest of the paper, it is assumed that the liquidity surplus bank 1 always acts as a lender, whereas the liquidity deficit bank 2 always acts as a borrower in the interbank market. Accordingly, bank 1 increases its target level of reserve balances, T_1, by cutting down its liquidity supply to the interbank market. Respectively, bank 2 increases T_2 by increasing its interbank liquidity demand. This yields a lower bound, respectively an upper bound, for the interbank rate beyond which no interbank trading takes place:

$$\underline{i^{IBM}} := i^{LF} \cdot F(-\xi_1) + i^{DF} \cdot (1 - F(-\xi_1)) + \gamma_1, \tag{4}$$

$$\overline{i^{IBM}} := i^{LF} \cdot F(-\xi_2) + i^{DF} \cdot (1 - F(-\xi_2)) - \gamma_2. \tag{5}$$

4.2 Optimal Precautionary Demand for Reserves in a Frictionless World

In the absence of transaction costs ($\gamma_1 = \gamma_2 = 0$), the case that is discussed by Whitesell (2006), the target reserve account balance that minimizes a bank's expected funding costs is a function of the interbank rate, the rates on the standing facilities, and the parameters of the distribution underlying the late payment shock. T_i is derived from the first-order condition (3) and has the following representation (for an illustration see Figure 3):

$$T_i(\cdot) = \begin{cases} -F^{-1}\left(\frac{i^{IBM} - i^{DF}}{i^{LF} - i^{DF}}\right) & \text{if } \left\{i = 1 \wedge i^{IBM} > \underline{i^{IBM}}\right\} \vee \left\{i = 2 \wedge i^{IBM} < \overline{i^{IBM}}\right\} \\ \xi_i & \text{otherwise.} \end{cases} \tag{6}$$

Under the assumption of ϵ_i being distributed symmetrically around zero, the sign of T_i depends only on whether i^{IBM} is above or below the corridor midpoint rate. This is a crucial result in Whitesell (2006, p. 1180): If i^{IBM} lies in the midpoint of the interest corridor, that is, if effective marginal deficit costs just equal the effective marginal surplus costs, optimal bank demand for precautionary liquidity is always zero.

Explicitly considering bank i's pre-trade liquidity endowment ξ_i in addition to its precautionary liquidity demand allows for the analysis of the bank's activity in the interbank market: Accordingly, bank i's interbank liquidity demand (resp. supply) is the sum of a precautionary component T_i and an exogenous component ξ_i:

$$b_i(\cdot) = T_i(\cdot) - \xi_i. \tag{7}$$

This decomposition also illustrates that endogenous bank behavior in the interbank market is fully explained by banks' precautionary liquidity demand $T_i(\cdot)$. Crucially, it is this precautionary demand which reflects the degree to which the redistribution of liquidity via the interbank market is inhibited in the presence of market frictions. The remainder of this section discusses the determinants of T_i as an explanatory variable of banks' interbank market activities in more detail. The discussion serves as the theoretical base for the analysis in section 6.

Equation (6) reveals that a bank's precautionary liquidity demand decreases in i^{IBM}. Obviously, an increase in i^{IBM} makes precautionary liquidity holdings relatively less attractive: Liquidity surplus banks want to place a higher amount in the interbank market, whereas liquidity deficit banks are willing to cover a higher portion of a potential deficit by borrowing from the central bank's lending facility. Formally, this reads:[10]

$$\frac{\partial T_i}{\partial i^{IBM}} \;=\; \frac{\partial b_i}{\partial i^{IBM}} \;=\; -\;\frac{1}{f(-T_i)(i^{LF}-i^{DF})} \;\leq\; 0. \tag{8}$$

With respect to the interest sensitivity of a bank's demand for precautionary liquidity the first-order condition (3) also reveals that how strongly the probability of facing an end-of-day deficit $F(-T_i)$ reacts to changes in T_i (resp. to changes in b_i) is crucial. If there is only a weak response, interest sensitivity (in absolute value) will be high because then there must be a relatively strong increase or decrease in T_i to have a sufficiently high impact on $F(-T_i)$ to restore optimality after a change in i^{IBM}. As $\tilde{\epsilon}_i \sim \mathcal{N}(0, \sigma_i^2)$, the impact of a change in T_i on $F(-T_i)$ is lower the more T_i deviates from 0 in either direction, i.e., the more precautionary liquidity in absolute terms bank i holds. Formally, this is reflected by

$$\frac{\partial^2 T_i}{\partial (i^{IBM})^2} \;=\; \frac{\partial^2 b_i}{\partial (i^{IBM})^2} \;=\; \frac{f'(-T_i)}{(i^{LF}-i^{DF})^2 \cdot (f(-T_i))^3} \begin{cases} <0 & \text{if } T_i < 0 \\ =0 & \text{if } T_i = 0 \\ >0 & \text{if } T_i > 0. \end{cases} \tag{9}$$

However, for the interest sensitivity of a bank's precautionary liquidity demand it is not only decisive how strongly $F(-T_i)$ reacts to changes in T_i (resp. in b_i) but also how strongly the expected marginal return on and the expected marginal costs of precautionary liquidity react to changes in $F(-T_i)$. This is determined by the width of the interest corridor formed

[10] Equation (8) can be derived explicitly by differentiating (6) or by using (3) and applying the implicit function theorem.

by i^{DF} and i^{LF}. The wider the interest corridor is, the more pronounced the expected marginal return on or marginal cost of precautionary liquidity will react to changes in $F(-T_i)$, that is, the lower is the interest sensitivity of precautionary liquidity demand. This is because the wider the interest corridor is, the larger the spreads between the interbank rate and the facility rates might possibly become. For an individual bank, such large spreads imply relatively high effective marginal deficit or surplus costs. Accordingly, only a relatively small change in T_i, and therewith in the probabilities of using the facilities, is needed to have a sufficiently strong effect on the expected marginal return on or the expected marginal costs of precautionary liquidity to restore optimality after a change in i^{IBM}, as shown formally by (3). Considering symmetric changes of the interest corridor around some given corridor midpoint rate i^{MR}, with $i^{DF} \equiv i^{MR} - w$ and $i^{LF} \equiv i^{MR} + w$, it is

$$\frac{\partial^2 T_i}{\partial w \partial i^{IBM}} = \frac{\partial^2 b_i}{\partial w \partial i^{IBM}} = \frac{1}{2w^2 \cdot f(-T_i)} - \frac{f'(-T_i) \cdot (2 \cdot F(-T_i) - 1)}{4w^2 \cdot (f(-T_i))^3} \geq 0, \qquad (10)$$

which formally shows that the interest sensitivity of bank i's precautionary liquidity demand (in absolute value), and therewith the interest sensitivity of interbank demand (for $i = 2$) and supply (for $i = 1$), decreases in the width of the corridor.

In general, the width of the interest corridor is a crucial determinant of a bank's precautionary liquidity demand and thus its interbank liquidity demand/supply: A symmetric increase in the corridor width leads to an increase in a bank's effective marginal deficit and surplus costs and therewith to an increase in the expected marginal return on and the expected marginal costs of precautionary liquidity. The increase in the expected marginal return will outweigh the increase in the expected marginal costs if the bank targets a negative reserve account balance ($T_i < 0$), which implies that the probability of using the lending facility at the end of the day is greater than 0.5. Consequently, the bank will increase the level of its precautionary liquidity holdings. Analogously, if the bank targets a positive reserve account balance, an increase in the corridor width will induce the bank to decrease its target reserve account balance. This formally reads (for an illustration see Figure 3):

$$\frac{\partial T_i}{\partial w} = \frac{\partial b_i}{\partial w} = \frac{2 \cdot F(-T_i) - 1}{f(-T_i) \cdot 2w} \begin{cases} > 0 & \text{for } T_i < 0 \\ = 0 & \text{for } T_i = 0 \\ < 0 & \text{for } T_i > 0. \end{cases} \tag{11}$$

The effect of a change in the width of the corridor on a bank's precautionary liquidity demand (resp. on interbank liquidity demand/supply) is stronger the more T_i deviates from zero. The more T_i deviates from zero, the higher the probability is that one of the facilities will be used after the occurrence of the late payment shock, hence the larger the difference in the changes in the expected marginal return on and the expected marginal costs of precautionary liquidity implied by a change in w. Consequently, as formally reflected by (10), a relatively pronounced change in T_i is needed to restore optimality after a change in the corridor width.

As a bank's precautionary liquidity demand is independent from its pre-trade reserve account balance per construction, a change in the bank's pre-trade reserve account balance is reflected completely in its interbank liquidity demand/supply:

$$\frac{\partial b_i}{\partial \xi_i} = -1. \tag{12}$$

Equations (8) to (12) illustrate that the surplus bank's precautionary liquidity demand, T_1, as well as the deficit bank's precautionary liquidity demand, T_2, are qualitatively affected in the same way by changes in i^{IBM}, w, and ξ. In contrast, as discussed in the next section, interbank market transaction costs will have opposing effects on T_i, for $i = 1, 2$.

4.3 Optimal Precautionary Demand for Reserves in the Presence of Transaction Costs

The impact of interbank market transaction costs on bank i's precautionary demand for reserves depends on whether bank i acts as a lender or as a borrower in the interbank market. Explicit representations of banks' target reserve account balances that minimize their expected funding costs in the presence of transaction costs are given by

$$T_1(\cdot) = \begin{cases} -F^{-1}\left(\frac{i^{IBM}-\gamma_1-i^{DF}}{i^{LF}-i^{DF}}\right) & \text{if } i^{IBM} > \underline{i^{IBM}} \\ \xi_1 & \text{if } i^{IBM} \leq \underline{i^{IBM}}, \end{cases} \tag{13}$$

$$T_2(\cdot) = \begin{cases} -F^{-1}\left(\frac{i^{IBM}+\gamma_2-i^{DF}}{i^{LF}-i^{DF}}\right) & \text{if } i^{IBM} < \overline{i^{IBM}} \\ \xi_2 & \text{if } i^{IBM} \geq \overline{i^{IBM}}. \end{cases} \tag{14}$$

For the surplus bank 1, an increase in γ_1 implies that holding precautionary liquidity becomes more attractive as the alternative of placing excess liquidity in the interbank market becomes more expensive. Formally, transaction costs lead to an increase in effective marginal deficit costs (the term in square brackets on the LHS of equation (3)), and to a decrease in effective marginal surplus costs (the term in square brackets on the RHS of equation (3)). Consequently, bank 1 reduces its interbank liquidity supply. For the deficit bank 2, an increase in γ_2 implies that holding precautionary liquidity becomes less attractive, as borrowing the respective liquidity from the interbank market becomes more expensive. As a result, the deficit bank 2 reduces its liquidity demand in the interbank market. Formally, this reads (for an illustration see Figure 3):

$$\frac{\partial T_1}{\partial \gamma_1} = \frac{\partial b_1}{\partial \gamma_1} = \frac{1}{f(-T_1)\cdot(i^{LF}-i^{DF})} > 0, \tag{15}$$

$$\frac{\partial T_2}{\partial \gamma_2} = \frac{\partial b_2}{\partial \gamma_2} = \frac{-1}{f(-T_2)\cdot(i^{LF}-i^{DF})} < 0. \tag{16}$$

Analogously to the interest sensitivity, the transaction cost sensitivity of bank i's precautionary liquidity demand is higher (in absolute value) the less $F(-T_i)$ reacts to changes in T_i (resp. to changes in b_i) and the less the expected marginal return on or marginal costs of precautionary liquidity react to changes in $F(-T_i)$. Thus, the transaction costs sensitivity of banks' precautionary liquidity demand (in absolute value) is higher the more T_i deviates from zero, and the narrower the interest corridor is. Formally, this is captured by equations (17) to (20):

$$\frac{\partial^2 T_1}{\partial i^{IBM}\partial\gamma_1} = \frac{\partial^2 b_1}{\partial i^{IBM}\partial\gamma_1} = \frac{-f'(-T_1)}{(i^{LF}-i^{DF})^2\cdot\left(f(-T_1)\right)^3}\begin{cases} >0 & \text{if } T_1<0 \\ =0 & \text{if } T_1=0 \\ <0 & \text{if } T_1>0, \end{cases} \tag{17}$$

$$\frac{\partial^2 T_2}{\partial i^{IBM}\partial\gamma_2} = \frac{\partial^2 b_2}{\partial i^{IBM}\partial\gamma_2} = \frac{f'\left(-T_2\right)}{(i^{LF}-i^{DF})\cdot\left(f\left(-T_2\right)\right)^2}\begin{cases} <0 & \text{if } T_2<0 \\ =0 & \text{if } T_2=0 \\ >0 & \text{if } T_2>0, \end{cases} \tag{18}$$

$$\frac{\partial^2 T_1}{\partial w\partial\gamma_1} = \frac{\partial^2 b_1}{\partial w\partial\gamma_1} = \frac{-1}{2w^2\cdot f(-T_1)} + \frac{f'(-T_1)\cdot(2\cdot F(-T_1)-1)}{4w^2\cdot\left(f(-T_1)\right)^3} \leq 0, \tag{19}$$

$$\frac{\partial^2 T_2}{\partial w\partial\gamma_2} = \frac{\partial^2 b_2}{\partial w\partial\gamma_2} = \frac{2}{2w^2\cdot f\left(-T_2\right)} - \frac{f'\left(-T_2\right)\cdot(2\cdot F(-T_2)-1)}{4w^2\cdot\left(f\left(-T_2\right)\right)^3} \geq 0. \tag{20}$$

5 Interbank Market Equilibrium

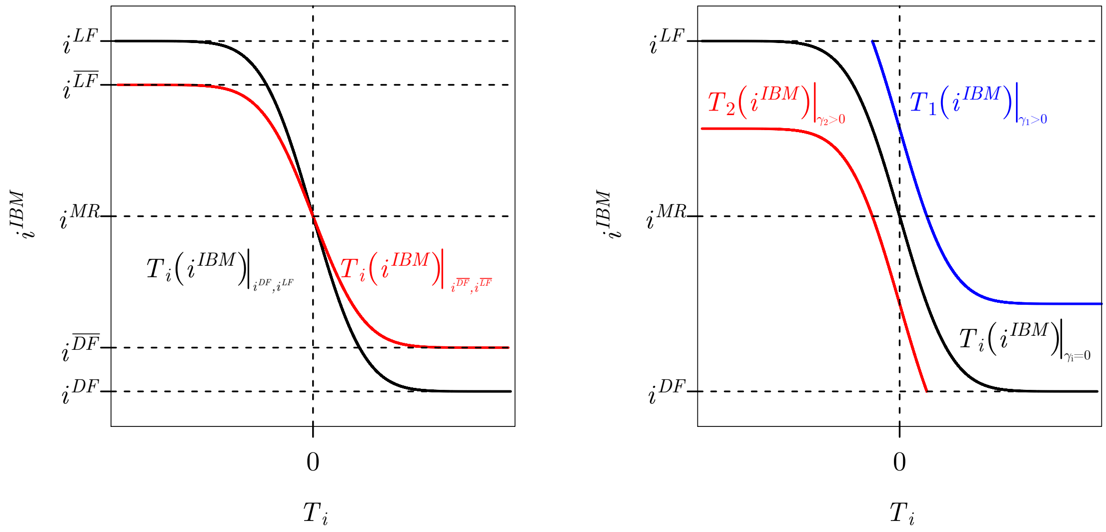
Indicating the equilibrium variables with the superscript *, the interbank market clearing condition reads

$$\sum_i b_i^*(\cdot) = 0. \tag{21}$$

Considering (7) and denoting the aggregate of banks' precautionary liquidity demand with $T \coloneqq \sum_i T_i$ and the banking sector's aggregate liquidity endowment with $\Xi = \sum_i \xi_i$, the market clearing condition (21) can be rewritten as

$$T^*\left(i^{IBM^*}, i^{DF}, i^{LF}, \gamma_1, \gamma_2, \sigma_i\right) = T_1^*\left(i^{IBM^*}, \gamma_1, \cdot\right) + T_2^*\left(i^{IBM^*}, \gamma_2, \cdot\right) \stackrel{!}{=} \Xi. \tag{22}$$

Equation (22) illustrates that the interbank market will clear at an interbank rate at which the banking sector's aggregate precautionary liquidity demand T is equal to its pre-trade



(a) Corridor width effect.

(b) Transaction cost effect.

Figure 3: Individual banks' precautionary liquidity demand T_i for $i = 1, 2$ and its determinants. Horizontal axis: Quantity of precautionary liquidity demanded. Vertical axis: Interbank rate. (a) Impact of corridor width (see also Whitesell (2006)). (b) Impact of borrowers' (red line) and lenders' (blue line) transaction costs on their individual precautionary liquidity demand, respectively.

liquidity endowment Ξ. Hence, the liquidity in the banking sector is redistributed via the interbank market such that each bank ends up with its optimal level of precautionary liquidity holdings.

However, a crucial distinguishing feature of the model presented in this paper as compared to the Whitesell (2006) framework is that individual banks might differ in their precautionary liquidity demand because of different interbank market transaction costs. Crucially, the difference in the quantities of precautionary liquidity demanded by the two types of banks (T_1^* and T_2^* in equation (22)) will reflect the *degree* to which the liquidity redistribution via the interbank market is inhibited (i.e., the extent to which transaction costs reduce the interbank market transaction volume). The larger this difference is, the smaller is the extent to which banks use the interbank market to balance their pre-trade liquidity surplus/deficit, respectively, the heavier is their reliance on the standing facilities to balance their reserve accounts at the end of the day.

The equilibrium interbank rate i^{IBM^*} is implicitly given by equation (23) which is obtained by inserting (13) and (14) into (22):

$$F^{-1}\left(\frac{i^{IBM^*}-\gamma_1-i^{DF}}{i^{LF}-i^{DF}}\right)+\xi_1+F^{-1}\left(\frac{i^{IBM^*}+\gamma_2-i^{DF}}{i^{LF}-i^{DF}}\right)+\xi_2 \stackrel{!}{=} 0. \tag{23}$$

The equilibrium level of individual banks' precautionary liquidity demand T_i^* and therewith the equilibrium interbank transaction volume $b^* := b_2^* = -b_1^*$ is implicitly given by

$$F(-T_1^*)-F(-T_2^*)+\frac{\gamma_1+\gamma_2}{i^{LF}-i^{DF}} \stackrel{!}{=} 0, \tag{24}$$

which is obtained from the first-order condition (3) for bank $i = 1, 2$.

6 Implications for Monetary Policy Implementation

This section derives specific rules for the control of friction-induced interbank rate volatility under a standard corridor (section 6.1) and under a floor operating system (section 6.2). A comparative static analysis of the interbank market equilibrium is conducted, in each section at first in a frictionless benchmark scenario (sections 6.1.1 and 6.2.1) and then, when friction-induced volatility is formalized, in the presence of interbank market frictions (sections 6.1.2 and 6.2.2). Eventually, model simulations illustrate how the dispersion of interbank rates (as a proxy for volatility) depends on market frictions and, crucially, on the width of the interest corridor. Section 6.3 summarizes the findings.

6.1 Standard Corridor System

6.1.1 Interbank Rate and Volatility Control in a Frictionless World

Comparative Statics. The frictionless scenario ($\gamma_1 = \gamma_2 = 0$) considered in this section is the benchmark scenario for the subsequent section. The following main results are in line with the respective findings of Whitesell (2006) and those of the existing literature on standard corridor systems, i.e., corridor implementation schemes that are characterized by standing facility rates which form a symmetric corridor around the central bank's targeted interbank rate i^{target} such that $i^{DF} = i^{target} - w$ and $i^{LF} = i^{target} + w$. The target rate thus corresponds to the mid-point rate of the interest corridor $i^{MR} := \frac{1}{2} \cdot (i^{DF} + i^{LF})$.

A crucial feature of this implementation scheme with regard to the central bank's steering of the interbank rate is that banks' precautionary liquidity demand at the target rate $T(i^{target})$ is zero (Whitesell (2006), Woodford (2001)). This property holds independently of the absolute level of the facility rates, the width of the interest corridor, and the level of banks' pre-trade liquidity endowments $\xi_1,\ \xi_2$:

Property 1 (Demand for Precautionary Liquidity):

$$T(i^{target}) = 0 \ \ \textit{for any} \ \ i^{target} = i^{MR}, \ \textit{and for any} \ \ w,\ \xi_1,\ \xi_2. \tag{25}$$

Formally, Property 1 follows directly from the first-order condition (3), which in the absence of transaction costs will be satisfied at $i^{IBM} = i^{MR}$ if bank i targets a reserve account balance of zero. In particular, $T_i = 0$ implies that the bank will face an end-of-day liquidity deficit and surplus with the same probability; and exactly this is what optimality requires when the effective marginal deficit and surplus costs are of equal height, i.e., when $i^{LF} - i^{IBM} = i^{IBM} - i^{DF}$ which is the case at $i^{IBM} = i^{MR}$.[11]

With a predictable aggregate demand for precautionary liquidity (equal to zero at i^{target}), the only source of deviations of the interbank rate from the central bank's target is the central bank's inability to perfectly control the liquidity conditions in the banking system. In this paper, such an aggregate liquidity shock is captured by the realization of the random variable $\tilde{\alpha}$. In the absence of transaction costs, the interbank market will clear at $i^{target} = i^{MR}$ if the banking sector's aggregate liquidity position $\Xi = \bar{\Xi} + \alpha = 0$. This means that also its aggregate precautionary liquidity demand at i^{target} must be zero, as revealed by equation (22). However, with $\tilde{\alpha} \sim \mathcal{N}(0, \sigma^2_{AF})$ and a central bank that therefore chooses $\bar{\Xi} = 0$, the banking sector's pre-trade liquidity position after the occurrence of the shock, at noon, is $\Xi = \alpha$. The implicit differentiation of (23) formally shows the interest rate effects that are produced by any liquidity imbalances:[12]

[11] See also Whitesell (2006), p. 1180-1181.

[12] Recall that $\Xi = \xi_1 + \xi_2$.

Property 2 (Liquidity Effect):

$$\frac{\partial i^{IBM*}}{\partial \xi_1} = \frac{\partial i^{IBM*}}{\partial \xi_2} = -\frac{(i^{LF} - i^{DF}) \cdot f(-\xi_1 - b_1^*) \cdot f(-\xi_2 - b_2^*)}{f(-\xi_1 - b_1^*) + f(-\xi_2 - b_2^*)} < 0. \tag{26}$$

It is conventional wisdom that these effects (and thus the effect of an aggregate liquidity shock on the interbank rate) are weaker the narrower the interest corridor is. Equation (11) reveals this property: The narrower the interest corridor is, the more attractive the facilities are as outside options for banks to using the interbank market and thus the larger the interest sensitivity (in absolute value) of banks' precautionary liquidity demand is (if $\gamma_1 = \gamma_2 = 0$). This leads to

Property 3 (Corridor Width Effect): *Narrowing the corridor width reduces possible deviations of the interbank rate from its target, i.e.,*

$$\frac{\partial i^{IBM*}}{\partial w} = \frac{\frac{i^{IBM*} - i^{MR}}{f(-\xi_1 + b^*)} + \frac{i^{IBM*} - i^{MR}}{f(-\xi_2 - b^*)}}{w \cdot \left(\frac{1}{f(-\xi_1 + b^*)} + \frac{1}{f(-\xi_2 - b^*)}\right)} \begin{cases} > 0 & for\ \Xi < 0 \\ = 0 & for\ \Xi = 0 \\ < 0 & for\ \Xi > 0. \end{cases} \tag{27}$$

Distribution of Interbank Rates and Model Simulations. Of course, the employed one-period model does not explain the evolution of interbank rates over time but it does predict how a time series of interbank rates consistent with the model parameters would be distributed. The dispersion of this distribution is then a proxy for interbank rate volatility. Thus, implications for the sources of, the nature of, and the measures to control interbank rate volatility can be drawn from the results of the comparative static analysis by mapping them into a parameter space with a time dimension. In this regard, the employed model yields some empirically testable hypotheses, formulated in the following as *"Implications."* Properties 1–3 imply, respectively:

Implication 1 (Source of Interbank Rate Volatility): *The only source of interbank rate volatility is the aggregate liquidity shock α. Banks' precautionary liquidity demand does not cause any interbank rate volatility since at the target rate $T(i^{target})$ is zero with certainty and thus stable over time, i.e., from period to period or from "day to day."*[13]

[13] See also Whitesell (2006), Woodford (2001).

Implication 2 (Distribution of Interbank Rates): *The distribution of a time series of interbank rates consistent with the model is determined by the distribution of aggregate liquidity shocks.*

Implication 3 (Dispersion of Interbank Rates and Corridor Width Effect): *Regarded over time, the dispersion of interbank rates is lower the smaller the width of the interest corridor set by the central bank is. Thus, the corridor width can be systematically used to reduce interbank rate volatility.*

Figure 4(a) illustrates the relationship between the corridor width and interbank rate volatility that stems from aggregate liquidity shocks. For specifically chosen parameter values, the model was solved for 10,000 draws of $\tilde{\alpha}$. The dispersion of simulated interbank rates (a proxy for interbank rate volatility) is increasing in the corridor width.[14]

6.1.2 Interbank Rate and Volatility Control in the Presence of Transaction Cost Heterogeneity

Comparative Statics. Interbank market transaction costs increase the relative attractiveness of outside options for banks to using the interbank market. Thus, transaction costs induce banks to substitute away from the use of interbank loans to balance their reserve accounts at noon toward an increased reliance on the central bank's standing facilities at the end of the day. Such shifts are reflected in the levels of banks' precautionary liquidity demand:[15]

Property 4 (Transaction Cost Effect on Precautionary Liquidity Demand): *In the presence of transaction costs banks will target a higher (if they are potential interbank lenders), resp. lower (if they are potential interbank borrowers), level of precautionary liquidity holdings than in the frictionless case. Accordingly, the interbank market transaction volume will be lower, i.e., the liquidity redistribution via the interbank market will be inhibited, formally stated by*

$$\frac{\partial b^*}{\partial \gamma_1} = \frac{\partial b^*}{\partial \gamma_2} = -\frac{1}{(i^{LF} - i^{DF}) \cdot (f(-T_1^*) + f(-T_2^*))} < 0, \tag{28}$$

[14]This simulation approach follows Whitesell (2006).

[15]Recall that with the convention $b^* := b_2^* = -b_1^*$ it is $T_1^* = \xi_1 - b^*$ and $T_2^* = \xi_2 + b^*$.

$$\frac{\partial T_1^*}{\partial \gamma_i} = -\frac{\partial b^*}{\partial \gamma_i} > 0 \; for \; i = 1, 2, \tag{29}$$

$$\frac{\partial T_2^*}{\partial \gamma_i} = \frac{\partial b^*}{\partial \gamma_i} < 0 \; for \; i = 1, 2. \tag{30}$$

The existence of transaction costs leads to the following key property of the standard corridor system:

Property 5 (Demand for Precautionary Liquidity): *Transaction costs imply that the banking sector's aggregate demand for precautionary liquidity at the target rate may differ from zero, i.e.,*

$$T(i^{target}) \lesseqgtr 0 \quad if \; \gamma_1, \gamma_2 \geq 0. \tag{31}$$

Formally, Property 5 is implied by equations (15) and (16) which show that the banking sector's aggregate precautionary liquidity demand T is an increasing function of potential lenders' transaction costs and a decreasing function of potential borrowers' transaction costs. The quantities of precautionary liquidity demanded by banks thereby depend on the width of the interest corridor. A narrow corridor leads to relatively large deviations from zero of banks' precautionary liquidity demand at i^{target} (as discussed in section 4.3 and as formally captured by equations (19) and (20)).

So, with regard to the central bank's liquidity management there are two cases that have to be distinguished: (1) There is no heterogeneity in the cross-section dimension, i.e., $\gamma_1 = \gamma_2$. This implies that $T_1(i^{target}) = -T_2(i^{target})$ so that $T(i^{target}) = 0$, independent of which banks will be active on which side of the interbank market. This means that there is no uncertainty about $T(i^{target})$ and also no need for the central bank to accommodate any demand for precautionary liquidity by the banking sector as a whole. (2) There is transaction cost heterogeneity in the cross-section dimension, i.e., $\gamma_1 \neq \gamma_2$, implying that $T_1(i^{target}) \neq -T_2(i^{target})$ and $T(i^{target}) \neq 0$. Since bank customer payments reshuffle reserves within the banking sector after the central bank has conducted its open market operations and before interbank trading takes place, the central bank does not know 'in the early morning' which banks will be active on which interbank market side 'at noon.' Hence, the banking sector's aggregate precautionary liquidity demand is uncertain and the establishment of adequate liquidity conditions in the early morning to hit the targeted interbank rate requires the central bank to estimate $T(i^{target})$. Forecast errors result in deviations of the equilibrium interbank rate from the target level. Formally, the interest rate effects of such unobservable transaction cost heterogeneity are captured by:

Property 6 (Pass-through of Transaction Costs on the Interbank Rate):

$$\frac{\partial i^{IBM*}}{\partial \gamma_1} = \frac{f(-T_2^*)}{f(-T_1^*)+f(-T_2^*)} > 0, \tag{32}$$

$$\frac{\partial i^{IBM*}}{\partial \gamma_2} = \frac{-\ f(-T_1^*)}{f(-T_1^*)+f(-T_2^*)} < 0. \tag{33}$$

As formally stated by the following Property 7, the magnitude of these effects depends on the width of the interest corridor:

Property 7 (Corridor Width Effect): *Possible deviations of the interbank rate from its target are reduced either by a widening or a narrowing of the corridor width, i.e.,*

$$\frac{\partial^2 i^{IBM^*}}{\partial w \partial \gamma_1} = \frac{\frac{\partial b^*}{\partial w} \cdot \left(\frac{-\xi_1-\xi_2}{\sigma^2} \cdot f(-\xi_1+b^*) \cdot f(-\xi_2-b^*)\right)}{\left(f(-\xi_1+b^*)+f(-\xi_2-b^*)\right)^2} \begin{cases} >0 & for\ \Xi < 0 \\ =0 & for\ \Xi = 0 \\ <0 & for\ \Xi > 0, \end{cases} \tag{34}$$

$$\frac{\partial^2 i^{IBM^*}}{\partial w \partial \gamma_2} = \frac{\frac{\partial b^*}{\partial w} \cdot \left(\frac{-\xi_1-\xi_2}{\sigma^2} \cdot f(-\xi_1+b^*) \cdot f(-\xi_2-b^*)\right)}{\left(f(-\xi_1+b^*)+f(-\xi_2-b^*)\right)^2} \begin{cases} >0 & for\ \Xi < 0 \\ =0 & for\ \Xi = 0 \\ <0 & for\ \Xi > 0. \end{cases} \tag{35}$$

Equations (34) and (35) give the formal description that the corridor width cannot be used systematically to make the interbank rate robust to bank-specific transaction costs under a standard corridor system. The intuition is simple. While, as argued in section 4.2, the high interest sensitivity of interbank liquidity demand and supply under a narrow corridor from the central bank's perspective is desirable in a frictionless world, it is ambivalent in the presence of transaction costs. The following considerations for the case of supply-side transaction costs illustrate this ambivalence: Lending transaction costs lead to a drop in interbank liquidity supply. This drop is larger the more interest-sensitive the supply is.

Hence, the upward pressure on the interbank rate implied by a transaction cost-induced drop in supply is larger the more interest-sensitive the supply is. This is the case under a narrow corridor where banks have relatively attractive outside options available and depend less on the interbank market. Now, the ambivalence of a narrow corridor in this respect is revealed when the demand side of the interbank market is considered. If demand is highly interest-sensitive, the equilibrium interbank rate is relatively robust to transaction-cost induced changes in supply. So, in a comparative static view, a reduction in the corridor width, which makes both the interbank demand and supply more interest-sensitive, has two opposing effects on the interbank rate and on the magnitude of the lending-transaction-cost effect on the interbank rate. The sign of the overall effect depends on the extent to which a corridor-width reduction increases the interest sensitivity of demand compared to the extent to which a corridor-width reduction increases the interest sensitivity of supply. Demand effects will dominate if there is a scarcity of aggregate liquidity, $\Xi < 0$, supply effects will dominate if there is an excess of aggregate liquidity, $\Xi > 0$. Both effects will be of the same magnitude if aggregate liquidity conditions are balanced and, in this case, the lending-transaction-cost effect on the interbank rate will even be independent of the corridor width (see equation (34)).

So a decrease in the corridor width under aggregate liquidity scarcity conditions in the presence of lending transaction costs always reduces the implied deviation of the interbank rate from the central bank's target. But there are perverse outcomes under excess liquidity conditions. There, the adequate corridor width depends on the constellation of the absolute size of the aggregate liquidity surplus and the level of lending transaction costs. If lending transaction costs are the main reason for the deviation of the interbank rate from its target – and not the liquidity effect – attenuation of the lending-transaction cost effect is more important than attenuation of the liquidity effect implied by $\alpha > 0$: If there is only a small liquidity surplus in conjunction with relatively high lending transaction costs, this leads to an upward deviation of the interbank rate from the target level. In this case, an increase in the corridor width, which exerts a downward pressure on the interbank rate and decreases the pass-through rate of lending transaction costs, reduces the deviation of the interbank rate from its target.

In the presence of transaction cost heterogeneity ($\gamma_1 \neq \gamma_2$), whether a relatively wide or narrow corridor is suitable for minimizing the deviations of the interbank rate from its target thus depends on the sign of the banking sector's pre-trade liquidity position Ξ. However, the sign of Ξ under a standard corridor system is determined by the aggregate liquidity shock. Therefore, there is no general rule the central bank could follow in order to implement a standard corridor system that is relatively 'robust' to lending transaction cost effects and – with an analogous argumentation – to borrowing transaction cost effects.[16]

Distribution of Interbank Rates and Model Simulations. Again, implications for the sources of and the measures to control the volatility of a time series of interbank rates in a multi-period world consistent with the model can be drawn by mapping the comparative static results into a parameter space that has a time dimension. Now, the interesting case is the one where interbank rate volatility stems from market frictions. This might be the case in a world where new banking regulations are fully phased in, as discussed in Bindseil (2016), CGFS (2015), and for the cross-section dispersion of interbank rates in Jackson and Noss (2015). The ultimate rationale for the increase in volatility caused by banking regulations is that the financial weights of regulatory burdens that banks have to carry are bank- and time-specific. Transaction cost heterogeneity, as introduced in this paper, captures the nature of such frictions in the cross-section dimension and can easily be thought further into a time dimension:

Definition (Transaction Cost Heterogeneity in Two Dimensions): *Transaction cost heterogeneity in the two dimensions cross-section and time is present if, regarded over time, potential interbank lenders' and borrowers' transaction costs γ_1 and γ_2 change independently from period to period (or from "day to day").*

In a world with transaction cost heterogeneity in two dimensions, regarded over time, Properties 4 to 7 have the following implications:

Implication 4 (Two Sources of Interbank Rate Volatility): *Transaction cost heterogeneity in the two dimensions cross-section and time is a source of interbank rate volatility in addition to the first source that lies in the aggregate liquidity shock. This is*

[16]These results can be derived formally from (17), (18), (19), and (20)

because banks' precautionary liquidity demand at the target rate $T(i^{target})$ will be unstable over time, i.e., from period to period or from "day to day," if γ_1 and γ_2 change independently over time. Moreover, $T(i^{target})$ is uncertain at the time the central bank conducts open market operations. Hence, the central bank cannot perfectly offset daily fluctuations in $T(i^{target})$ by adequate provision of liquidity. The daily fluctuations in $T(i^{target})$ cause fluctuations in interbank liquidity demand/supply that are transmitted into the interbank rate.

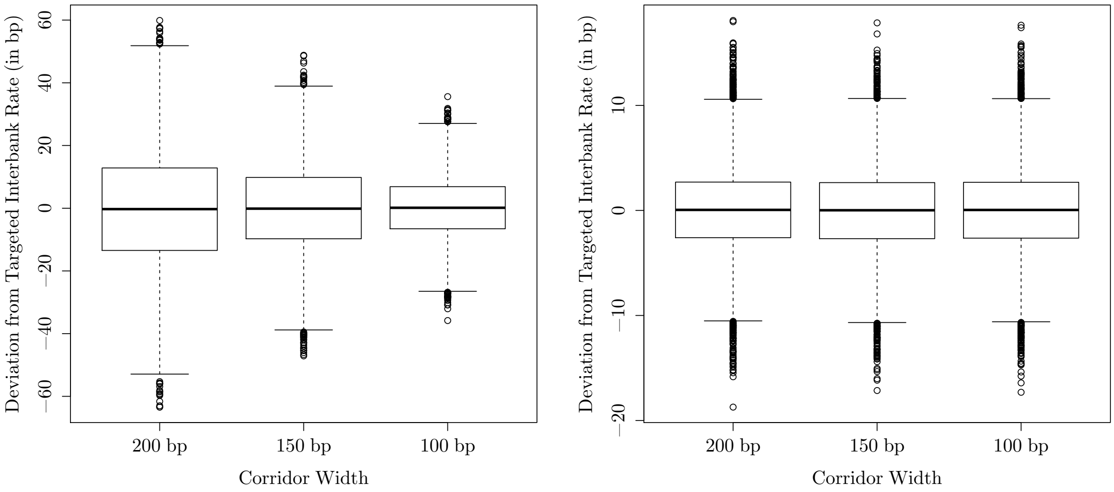
Implication 5 (Distribution of Interbank Rates): *The distribution of a time series of interbank rates consistent with the model is determined by the distribution of the time series of potential lenders' and borrowers' transaction costs and by the distribution of aggregate liquidity shocks.*

Implication 6 (Dispersion of Interbank Rates and Corridor Width Effect): *The dispersion of a time series of interbank rates that is explained by transaction cost heterogeneity under a standard corridor system cannot be systematically lowered by adjusting the width of the interest corridor. This is a direct implication of Property 7. Thus, the width of the interest corridor is not an instrument for the systematic control of interbank rate volatility that stems from transaction cost heterogeneity. For the special case in a world without an aggregate liquidity shock, such that the banking sector's aggregate liquidity position at noon is always balanced ($\Xi = 0$), volatility stemming from frictions is not even correlated with the corridor width.*

Figure 4(b) illustrates the neutral relationship between the corridor width and volatility that stems from transaction cost heterogeneity for the special case of a world without an aggregate liquidity shock, i.e., of a world in which $\alpha = 0$.[17] The crucial point is that the dispersion of a time series of interbank rates in this special case is determined only by the dispersion of the time series of transaction costs and is thus independent of the corridor width. In order to illustrate this relationship, the model was solved for 10,000 draws of lending and borrowing transaction costs from a truncated normal distribution.

[17] Of course, in a multi-period world consistent with the model, regarded over time the sequence of potential lenders' and borrowers' transaction costs can be arbitrarily distributed and do not need to converge (as time evolves) to any specific probability distribution.

In summary, the results above suggest that a central bank which chooses to operate a standard corridor system in the presence of transaction cost heterogeneity will be confronted with a kind of "white noise" volatility stemming from frictions that cannot be controlled through adjustments in the corridor width.[18]



(a) Aggregate liquidity shock effects.

(b) Transaction cost heterogeneity effects.

Figure 4: Distribution of simulated interbank rates under a standard corridor system for different values of the corridor width. Basic parameter values are: $\tilde{\epsilon}_i \sim \mathcal{N}(0,1)$, $\bar{\Xi} = 0$. Subfigure (a) shows the results of 10,000 draws of $\tilde{\alpha}$ for each corridor width and for $\tilde{\alpha} \sim \mathcal{N}(0, 0.5^2)$, $\gamma_1 = \gamma_2 = 0$. Subfigure (b) shows the results of 10,000 independent draws for γ_1 and γ_2 (for each corridor width) from the truncated normal distribution $\mathcal{N}(0, 0.1^2)|_0^{0.4}$ with $\tilde{\alpha}$ kept constant at zero.

6.2 Floor Operating System

6.2.1 Interbank Rate and Volatility Control in a Frictionless World

Comparative Statics. A floor operating system is an asymmetric corridor scheme where the central bank's targeted interbank rate corresponds to the rate on the deposit

[18]With regard to the control of volatility stemming from aggregate liquidity shocks, the model implies a further property that also is in line with conventional wisdom. Considering $\frac{\partial b^*}{\partial w} = \frac{\gamma_1+\gamma_2}{2w^2\left(f(-T_1^*)+f(-T_2^*)\right)} \geq 0$ for the case of $\gamma_1 + \gamma_2 > 0$ reveals that the central bank faces a trade-off in achieving the objectives of relatively low interbank rate volatility that is caused by aggregate liquidity shocks and a high level of market activity. The decrease in market activity caused by transaction costs is the more pronounced, the narrower the interest corridor and thus the more attractive the outside option of using the facilities in the presence of transaction costs is (formally implied by equations (19) and (20)). Even in a scenario where frictions are a main source of volatility, this trade-off remains since there is no general rule of how to control volatility that stems from frictions through corridor width adjustments. In contrast, in a frictionless world, the interbank market transaction volume is independent of the corridor width, i.e., $\frac{\partial b^*}{\partial w} \overset{\gamma_1=\gamma_2=0}{=} 0$.

facility (for analytical traceability let $i^{target} = i^{DF} + \delta$ for some small $\delta > 0$).[19] The implementation of this scheme by itself – through an ample central bank provision of liquidity – produces a relatively stable interbank rate that will fluctuate only marginally around the target rate. The corridor width of a floor operating system as an instrument to control interbank rate volatility therefore plays a less relevant role – at least in the frictionless benchmark scenario considered in this subsection.

The basic idea when implementing a floor operating system is to exploit the following two properties of banks' aggregate precautionary liquidity demand:

Property 8 (Demand for Precautionary Liquidity):

$$T(i^{target}) >> 0 \quad for \quad |i^{target} - i^{DF}| \approx 0. \tag{36}$$

Property 9 (Interest Sensitivity of T): *Using equation* (9) *for* $\frac{\partial^2 T_i}{\partial (i^{IBM})^2}$ *it is*

$$\frac{\partial^2 T}{\partial (i^{IBM})^2} = \frac{\partial^2 T_1}{\partial (i^{IBM})^2} + \frac{\partial^2 T_2}{\partial (i^{IBM})^2} > 0 \quad if \quad T > 0. \tag{37}$$

Eventually, the interbank market will clear at the targeted rate if there is virtually zero risk for banks to become illiquid at the end of the day due to the late payment shock, that is, if $F(-T_i^*) \approx 0$.[20] This will be the case if the banking sector's aggregate liquidity endowment at noon after the realization of the aggregate liquidity shock, Ξ, still sufficiently exceeds its expected liquidity needs (which are zero), that is, if $\Xi = T(i^{target}) >> 0$.

Thus, in order to implement an interbank rate close to i^{DF} the central bank must use its open market operations in the early morning to provide an ample amount of liquidity $\bar{\Xi} >> 0$ such that only extreme left-tail events described by $\alpha << 0$ could increase the probability of and end-of-day deficit for banks significantly above zero. So, with $\bar{\Xi} \to \infty$, the liquidity risk posed by left-tail events converges to zero, that is, $F(-T_i^*)$ will remain close to zero and will be insensitive even to relatively large pre-trade aggregate liquidity shocks. The first-order condition (3) illustrates that this insensitivity of the CDF $F(\cdot)$

[19] See, for instance, Federal Open Market Committee (2015). The "asymmetry" of this scheme lies in the difference of the spreads between i^{target} to i^{DF} and to i^{LF}.

[20] This property is implied by equation (8) in section 4.2.

translates into a high interest sensitivity of demand for precautionary liquidity, which in turn translates into a high interest sensitivity of interbank demand and supply.[21]

Therewith, the interbank rate will be insensitive to aggregate liquidity shocks if the interbank liquidity demand and supply curves always intersect at their highly interest-sensitive regions even after large aggregate pre-trade liquidity drains. This will be the case if the banking sector's aggregate liquidity endowment $\bar{\Xi}$ (which is the central bank's choice) is sufficiently large.[22] Thus, the principle of tight interbank rate control under a floor operating system with $\Xi > 0$ relies on a relatively weak liquidity effect (as implied by Property 9).

Distribution of Interbank Rates and Model Simulations. Mapping the comparative static results for the frictionless benchmark scenario under a floor operating system into a parameter space with a time dimension yields the same implications for the source of interbank rate volatility and the distribution of interbank rates as in the benchmark scenario under a standard corridor system. Thus, the only source of interbank rate volatility is the aggregate liquidity shock $\tilde{\alpha}$ with the distribution of a time series of interbank rates consistent with the model being determined by the distribution of aggregate liquidity shocks. However, with regard to the role played by the corridor width in attenuating the effects of aggregate liquidity shocks on the interbank rate, there is the following:

Implication 7 (Dispersion of Interbank Rates and Corridor Width Effect): *Although, regarded over time, the dispersion of interbank rates is lower the smaller the width of the interest corridor is, a key feature of a floor operating system is that this effect of the corridor width on the dispersion of interbank rates is negligible. The corridor width as an instrument to control interbank rate volatility is less relevant.*

[21] Formally, this is captured by Property 9 which is implied by equation (9) in section 4.2. See also Poole (1968, p. 774).

[22] However, in the attempt to stabilize the interbank rate through expansionary liquidity provision, the central bank possibly faces a trade-off in achieving the objectives of a low interbank rate and a high level of market activity (see, for instance, Federal Open Market Committee (2015)). In the absence of transaction costs, this trade-off only arises in the trivial case when an increase in the central bank's liquidity supply $\bar{\Xi}$ involves a decrease in the extent to which banks' pre-trade liquidity endowments differ, i.e., a decrease in $|\xi_1 - \xi_2|$. This decrease might be the natural result of large-scale security purchases by the central bank in the open market, which could leave a large number of banks endowed with an excess of central bank reserves. Formally: $\frac{\partial b^*}{\partial \xi_1} = \frac{f(-T_1^*)}{f(-T_1^*)+f(-T_2^*)} > 0$, $\frac{\partial b^*}{\partial \xi_2} = -\frac{f(-T_2^*)}{f(-T_1^*)+f(-T_2^*)} < 0$.

This crucial property is illustrated by Figure 5(a) which shows that the dispersion of simulated interbank rates (as a proxy for interbank rate volatility) is relatively low even under a relatively wide interest corridor.

6.2.2 Interbank Rate and Volatility Control in the Presence of Transaction Cost Heterogeneity

Comparative Statics. Transaction cost heterogeneity in the two dimensions cross-section and time can make the interbank rate more volatile – as is the case under a standard corridor. However, the central bank is able to exploit some of the properties implied by the characteristic asymmetry of a floor system to reduce friction-induced interbank rate volatility in a systematic manner. The control of volatility that stems from supply-side transaction costs even involves the implementation of a relatively wide (!) interest corridor.

The mechanisms at work are tied to the asymmetry in the pass-through rates of lending and borrowing transaction costs that exists under a floor system. Under permanent excess liquidity conditions established in a floor system, $\Xi > 0$, the banking sector as a whole has to – and in particular the liquidity surplus banks have to – rely more on the deposit facility, implying that the interest sensitivity of interbank liquidity supply is always greater than or equal to the interest sensitivity of demand. So the pass-through rate of lending transaction costs is always greater than or equal to the pass-through rate of borrowing transaction costs. The crucial point is that the central bank can systematically use the corridor width to reduce the pass-through rate of one market side's transaction costs – although at the expense of the other side's pass-through rate of transaction costs. If the corridor width is increased, it is the pass-through rate of lending transaction costs that decreases because it is the surplus banks which react most strongly to the decline in the attractiveness of outside options – arguing analogously to the case considered in section 6.1.2. So under permanent excess liquidity conditions Property 7 is reduced to the special case of

Property 10 (Corridor Width Effect):

$$\frac{\partial^2 i^{IBM^*}}{\partial w \partial \gamma_1} = \frac{\frac{\partial b^*}{\partial w} \cdot \left(\frac{-\xi_1 - \xi_2}{\sigma^2} \cdot f(-\xi_1 + b^*) \cdot f(-\xi_2 - b^*) \right)}{\left(f(-\xi_1 + b^*) + f(-\xi_2 - b^*) \right)^2} < 0 \; for \;\; \Xi > 0, \tag{38}$$

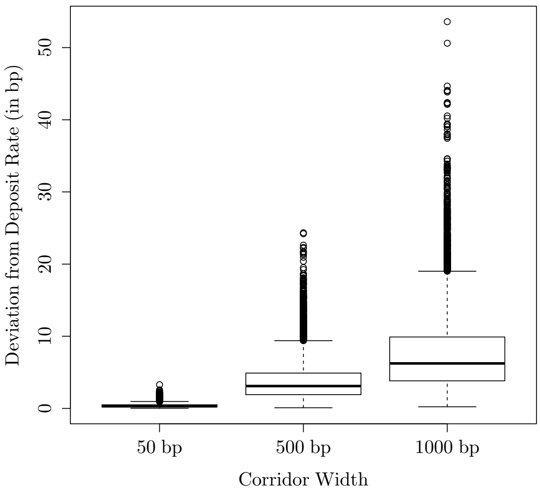
$$\frac{\partial^2 i^{IBM^*}}{\partial w \partial \gamma_2} = \frac{\frac{\partial b^*}{\partial w} \cdot \left(\frac{-\xi_1 - \xi_2}{\sigma^2} \cdot f(-\xi_1 + b^*) \cdot f(-\xi_2 - b^*) \right)}{\left(f(-\xi_1 + b^*) + f(-\xi_2 - b^*) \right)^2} < 0 \; for \;\; \Xi > 0. \tag{39}$$

Under a floor system, demand-side effects are less of a concern for the central bank. On the one hand, potential borrowers' transaction costs bring the interbank rate even closer to the central bank's target. And on the other hand, borrowing transaction costs only involve a relatively small drop in the deficit banks' precautionary liquidity demand (due to the relatively low interest sensitivity of demand) such that the demand for interbank liquidity (at low interbank rates close to i^{target}) and therewith the equilibrium interbank rate will be relatively insensitive to transaction costs, too. As the interbank rate is inherently robust to demand-side frictions under a floor system, volatility control would require the central bank to implement a corridor system that makes the interbank rate robust to supply-side frictions. As captured by Property 10, this is achieved by implementing a relatively wide interest corridor.[23]

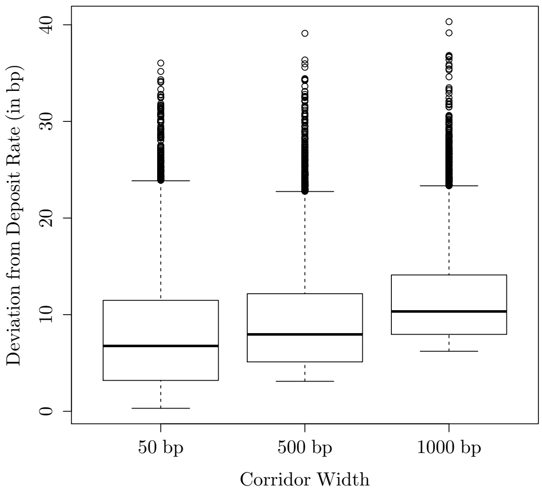
Distribution of Interbank Rates and Model Simulations. The implications of the comparative static results for the sources of interbank rate volatility and the distribution of interbank rates under a floor system are the same as under a standard system in the presence of transaction costs. With transaction cost heterogeneity in the two dimensions cross-section and time in addition to the aggregate liquidity shock representing the two sources of interbank rate volatility, the distribution of a time series of interbank rates consistent with the model is determined by the distribution of the time series of potential lenders' and borrowers' transaction costs and by the distribution of aggregate liquidity shocks. But Property 10 yields the following:

[23] The ultimate reason for this stabilizing effect is that effective marginal surplus costs and thus opportunity costs of liquidity banks hold in excess of their expected liquidity needs increase in the corridor width. Consequently, targeting large quantities of precautionary liquidity, and thus the outside option of using the deposit facility, become relatively unattractive for surplus banks (i.e., for potential lenders). A wide corridor stabilizes potential lenders' precautionary liquidity demand, therewith interbank liquidity supply and ultimately the interbank rate.

Implication 8 (Dispersion of Interbank Rates and Corridor Width Effect): *A high dispersion of a time series of potential lenders' transaction costs leads to a relatively pronounced increase in the dispersion of a time series of interbank rates. A high dispersion of a time series of potential borrowers' transaction costs only leads to a relatively small increase in the dispersion of a time series of interbank rates. Thus, demand-side effects are less of a concern. With regard to the control of friction-induced interbank rate volatility the main implication is thus that the dispersion of a time series of interbank rates that is explained by the dispersion of a time series of potential lenders' transaction costs can be systematically lowered by increasing the width of the interest corridor, as illustrated by Figure 5(b).*[24]



(a) Aggregate liquidity shock effects.



(b) Transaction cost heterogeneity effects.

Figure 5: Distribution of simulated interbank rates under a floor operating system for different values of the corridor width. Basic parameter values are: $\tilde{\epsilon}_i \sim \mathcal{N}(0,1)$, $\bar{\Xi} = 5$. Subfigure (a) shows the results of 10,000 draws of $\tilde{\alpha}$ for each corridor width and for $\tilde{\alpha} \sim \mathcal{N}(0, 0.5^2)$, $\gamma_1 = \gamma_2 = 0$. Subfigure (b) shows the results of 10,000 draws for γ_1 (for each corridor width) from the truncated normal distribution $\mathcal{N}(0, 0.1^2)|_0^{0.4}$ with γ_2 and $\tilde{\alpha}$ kept constant at zero.

[24]At that, a possibly desirable property is that the central bank faces no trade-off in achieving the objectives of low volatility that stems from supply-side frictions and high levels of market activity. The reason is that a relatively wide corridor promotes market activity in the presence of transaction costs (formally stated by $\frac{\partial b^*}{\partial w} = \frac{\gamma_1+\gamma_2}{2w^2\left(f(-T_1^*)+f(-T_2^*)\right)} \geq 0$).

6.3 General Rules for the Control of Interbank Rate Volatility

The analysis in the last section has some direct implications for the counterpart of a floor operating system, a "ceiling operating system." This is an asymmetric corridor scheme where the targeted interbank rate corresponds to the central banks' lending rate. It is implemented by leaving the banking sector significantly short of liquidity, which drives up the interbank rate. Similar to a floor system, this scheme is robust against aggregate liquidity shocks even for a relatively wide interest corridor. However, under a ceiling system, potential interbank borrowers have the more attractive outside option to using the interbank market in the presence of market frictions. Thus, as the pass-through rate of potential borrowers' transaction costs on the interbank rate is larger than that of potential interbank lenders, supply-side effects are less relevant under this scheme. So, if the main source of volatility lies in borrowing transaction costs, friction-induced interbank rate volatility can be controlled systematically by increasing the corridor width of a ceiling system.

Further implications of the different pass-through rates of supply- and demand-side frictions under an asymmetric corridor scheme are then the following: In principle, in a scenario where market frictions that cause interbank rate volatility are only present on the interbank supply-side and where the central bank has initially implemented a standard corridor system, the switch to a ceiling system by itself could be a measure to reduce volatility. Analogously, in a world where volatility under an initially implemented standard system stems from demand-side frictions, it could be controlled by switching to a floor system.

7 Concluding Remarks

Interbank market frictions can lead to higher interbank rate volatility. Bank- and time-specific transaction costs can cause fluctuations in interbank liquidity demand and supply that will be transmitted into interbank rate volatility. New banking regulations that pose additional financial burdens on interbank market participants will have such a volatility effect (Bindseil (2016), CGFS (2015), Jackson and Noss (2015)). Thus, eventually central banks could actually be confronted with interbank rate volatility that stems from market frictions.

The aim of this paper was to point out that the control of interbank rate volatility which has its origin in market frictions may be subject to different rules than the control of volatility that stems from aggregate liquidity shocks to the banking sector. As proposed in this paper, a central bank's options to control volatility that stems from frictions in general are switching from a symmetric to an asymmetric corridor scheme and changing the width of an asymmetric corridor – which might even involve an increase in the corridor width. The appropriate option is thereby determined by the type of the corridor scheme initially implemented as well as by whether volatility is mainly caused by demand- or supply-side frictions.

In particular, narrowing the corridor, which is typically considered to be *the* universal measure to reduce volatility under an interest corridor regime, may not have the intended effects if volatility stems from market frictions. The theoretical model employed in this paper was analyzed for two scenarios where this has been the case: Under a standard corridor system (a symmetric corridor scheme), the corridor width cannot be used systematically at all to control friction-induced volatility. Under a floor operating system (an asymmetric corridor scheme), the control of volatility stemming from supply-side frictions even requires the central bank to widen the interest corridor – which is the inversion of the traditional principle.

With regard to the euro area where the ECB currently operates a (de facto) floor system with historically low overnight unsecured interbank market activity and a historically low volatility of the EONIA, the model in this paper yields two main implications: (1) Should the EONIA become more volatile again in the future, it might be an increase and not a decrease in the corridor width that could reduce volatility – with the beneficial side-effect of promoting market activity. (2) Should the ECB eventually return to a standard corridor system, as implemented in pre-crisis times, it could be confronted with a kind of "white-noise" volatility whose control would require the usage of instruments other than the width of the interest corridor.

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