Monetary policy implementation: *A European Perspective*[1]

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1. Introduction

Monetary policy implementation is one of the most significant areas of interaction between central banking and financial markets. Historically, how this interaction takes place has been viewed as having an important impact on the ultimate objective of monetary policy, for example price stability or stimulating economic growth. In this article, we survey different approaches to monetary policy implementation. We cover briefly some of the historical trends, but give particular attention to the practice that is now (again) very common world-wide; namely, targeting short term interest rates. We discuss various ways this can be done and the implications for financial markets. We emphasize different European approaches, while also providing comparisons with the Fed.

There are three main elements to monetary policy implementation:

- The first element is the *operational target*, which is an economic variable, for example the overnight interbank interest rate that the central bank aims to control on a day-by-day basis through its monetary policy instruments. The target level is decided upon by the central bank's monetary policy decision making committee. The announced target level provides guidance to the central bank's implementation officers and also serves to communicate the stance of monetary policy to the public.

- The second element is the operational framework for controlling the target. This specifies the monetary policy instrument and how they are to be used. These instruments typically consist of standing facilities, open market operations, and reserve requirements.[3] Additional elements of the operational framework are, for example, the list of counterparties eligible for central bank repos and the list of eligible collateral in these.

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[1] Forthcoming in *Financial Markets and Institutions: A European Perspective*, Oxford University Press.

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[3] The term "instrument" has also been used to designate operational and intermediate targets, see e.g. Poole (1970).

- The third element is the day-to-day use of open market operations within this framework, also called *central bank liquidity management*. An important aspect of liquidity management is forecasting the so-called autonomous liquidity factors, e.g. banknotes in circulation and government deposits with the central bank, and mapping them, together with other relevant information, into open market operations volumes in a way that is consistent with the operational target level. The required precision of liquidity management, and thus the quality of autonomous factor forecasts and the frequency of open market operations, depends on the operational framework of monetary policy implementation.

As an example, consider briefly the case of the European Central Bank (ECB), whose operational target is the overnight interest rate. Rather than announcing a specific target rate, the ECB announces the minimum bid rate at which it conducts its weekly reverse open market operations. The ECB ensures that overnight market rates are close to this minimum bid rate by acting on the demand and supply conditions of the deposits of banks with the Eurosystem.[4] To do this, the ECB has at its disposal three main instruments. (i) Weekly open market operations with one week maturity through which the bulk of funds is provided to the market (in 2004 on average EUR 250 billion). (ii) Two standing facilities with overnight maturity, namely a borrowing facility at which banks can always borrow funds against collateral, and a deposit facility at which banks can always deposit excess funds. Both facilities are offered by the ECB at a *penalty rate* of 100 basis points relative to the target rate, and average daily recourse to the facilities is thus rather low (in 2004 each below EUR 0.5 billion). (iii) Reserve requirements of on average EUR 140 billion in 2004 which impose a structural element on the demand for reserves. By using these instruments, and by devoting resources to forecasting autonomous factors, the ECB typically achieves a high degree of control of short term interest rates. For example, in 2004 the ECB's implicit target rate, the minimum bid rate in its weekly repo operations, was constantly 2.00%, while the average overnight rate (EONIA) was 2.05%. The standard deviation of the difference between the overnight rate and the minimum bid rate was 9 basis points, while the standard deviation of first differences in the overnight rate was 10 basis points.

There are many other ways to implement monetary policy, including controlling short term rates, as noted by Borio (2001):[5]

> *Just as there are a hundred ways to skin a cat, so there are a hundred ways to implement monetary policy. These may differ considerably in terms of the interest rates that are the focus of policy, the range of instruments employed, the frequency of operations, the spectrum of counterparties and other technical elements. Such differences reflect a mixture of purely historical factors and different views regarding the fine balance between the pros and cons of the various choices. At the end of the day, however, the proof of the pudding is in the eating. The "eating" here is the central bank's ability to convey its policy signals with the desired degree of clarity and its ability to influence short-term rates with the desired degree of accuracy.*

[4] The ECB and the NCBs participating to the euro collectively constitute the Eurosystem. The ECB is responsible for setting the policy rates and for the decisions relating to the conduct of monetary policy operations, but national central banks (NCBs) participating to the euro are involved as well, as banks have their accounts with the NCBs and also submit bids for repo auctions with NCBs, not with the ECB.
[5] For a comprehensive technical survey of monetary policy implementation techniques of industrialised countries see Borio (1997). For a survey of implementation issues in countries with less developed markets see IMF (2004).

Borio suggests that from a monetary policy perspective, it is doubtful that the implementation details are very important as long as the signaling and the short term rate objectives are achieved. But these are relatively straightforward to meet. Signalling can take the form of publicly announcing the target level. Controlling short term rates can be done for instance by pegging the market rate to a standing facility rate.

However, monetary policy implementation arguably has ramifications and implications beyond the pure monetary policy perspective, for example on financial markets. As shown by Hamilton (1996) and Perez-Quiros and Rodriguez-Mendizábal (2006), the volatility of short term rates is influenced by how monetary policy is implemented. Given the ease with which short term rates can be controlled, one may wonder why central banks often choose frameworks that admit volatility in short term rates. In this paper, we discuss how the choice of the operational framework may also affect other aspects of financial markets, such as the liquidity of interbank credit markets and the market for collateral. If we accept the view that short term rates is the appropriate operational target, we would argue that optimal monetary policy implementation may be less an issue of the efficient transmission of monetary policy and more an issue of financial market efficiency.

The rest of the paper is organized as follows. Section 2 discusses the concept of the operational target of monetary policy and provides an overview of the historical debate and today's central bank practice in this regard. Section 3 discusses the three main instruments of monetary policy implementation in the context of the central bank balance sheet. Section 4 relates balance sheet quantities to short term interbank rates and explains how the central bank can control rates. Section 5 discusses how alternative approaches to monetary policy implementation affect financial markets. Section 6 discusses different methods for conducting open market operations. Section 7 concludes.

2. The operational target of monetary policy

Today, most central banks use short term rates as their operational target. But this has not always been so. In this section, we discuss the rational behind targeting short term rates. We also put the view that short term rates is the appropriate operational target in a historical context by discussing the emergence after WW1 and eventual abandonment of the alternative policy of targeting the monetary base.

2.1 The short term interest rate

Prior to 1914, monetary policy meant first of all controlling short term interest rates, mainly via the use of standing facilities (see in particular the surveys of the Bank of England's monetary policy implementation in the 19th century as provided by Bagehot (1873) and King (1936), or for Germany, Reichsbank 1900). The theoretical foundations of this approach may be traced back to Thornton (1802) and Wicksell (1898). Wicksell (1936: 102) established the concept of the "natural rate" of interest, which he described as follows:

> *"There is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them. This is necessarily the same as the rate of interest which would be determined by supply and demand if no use were made of money and all lending were effected in the form of real capital goods. It comes to much the same thing to describe it as the current value of the natural rate of interest on capital."*

That under stable prices, the rate of interest on money has to correspond to the real rate of interest, which can be thought to be independent of the "monetary sphere" of the economy, is implied by simple arbitrage logic. Today, "neo-Wicksellians," e.g. Woodford (2003), again incorporate this insight as a key building block in their macroeconomic models.

But why focus on the overnight interest rate, and not on a longer term rate, e.g., the 1-, 3-, or 12 month rates? It could be argued that the latter rates are more relevant for monetary policy transmission, as they are the basis of more important decisions. So why not target them directly?

The main problem with targeting longer term rates is the irregularities this may lead to in shorter term rates. Consider as an example the case of a central bank that targets the 90 day rate. Assume for simplicity that the central bank is predictable in its changes of interest rate targets, and that it achieves market rates at its target level with a high degree of precision. Concretely, assume that on day τ, the central bank is expected to reduce its 90 day target rate from 5% to 4%. What does this imply for the overnight rate around day τ, if the expectations hypothesis of the term structure of interest rate holds? The 90-days horizon on τ-1 and on τ overlap by 89 days. The expectations hypothesis, in its simplified linear form, tells us that

$$i_{90,t} = \frac{\sum_{j=0}^{89} i_{1,t+j}}{90},$$

Where $i_{90,t}$ *and* $i_{1,t+j}$ are the 90-day and overnight interest rates on day t and t+j, respectively. Thus, the difference in the 90 days rate between τ-1 and τ has to be translated in terms of overnight rates exclusively into the overnight rates on day τ-1 and τ+89, such that $(i_{1,\tau-1} - i_{1,\tau+89}) = 90(i_{90,\tau-1} - i_{90,\tau})$. Assuming that $i_{1,\tau+89} = 4\%$, this implies $i_{1,\tau-1} = 94\%$. This extreme upward spike is, in a sense, anomalous, particularly since the overall level of rates is being lowered. This volatility in the overnight rate is arguably undesirable, for example because of the importance of the overnight market. It is at this maturity that most unexpected short term liquidity fluctuations are corrected. The average daily volume of interbank overnight lending of 52 panel banks in the euro area is around EUR 40 billion.

In contrast, if a predictable central bank targets an overnight rate of 5% until τ-1, and then moves its target on τ to 4%, the 90 days rate will simply have moved on τ-89 from 5% to approximately 4.99% and will decrease by approximately 1 basis point per day until the change occurs. Therefore, the adaptation of longer term rates takes place in the smoothest possible way if the overnight rate is changed in a predictable way. If the central bank would like to see an earlier decline in the 90 days rates, it simply needs to cut its overnight rate earlier (which under the assumption of predictability, triggers a correspondingly earlier start of the decline of the 90 days rate).

While it is today again generally accepted by central bankers and academics that monetary policy implementation means controlling short term interest rates, from around 1920 to the mid 1980s, "reserve position doctrine" (Meigs 1962) was the dominating view on monetary policy implementation, particularly in the U.S. According to this doctrine, a central bank should, via open market operation, steer some reserve concept, which would impact via the money multiplier on monetary aggregates and the ultimate goals of monetary policy. Although this view is now out of fashion, many monetary policy textbooks still devote substantial attention to concepts, such as the money multiplier and the monetary base, which make sense primarily in a reserve position doctrine framework.

2.2Interest rate targeting in Europe and the US

While there is a high degree of consensus today regarding the targeting of short term rates, there is substantial variation with respect to how this is done. This also means that the volatility of short term rates varies substantially across currency areas. Table 1 sets out some of these differences across several central banks in Europe as well as the U.S. The selected central banks represent the former western Europe – the ECB/Eurosystem, the Bank of England, the Swiss National Bank, and the three Scandinavian central banks – as well as those of the U.S., Russia, and Belarus. This sample will be used throughout this article.[6]

Definition and explicitness of target rate

Although all the central banks in our sample target a short term rate, typically the overnight rate, they vary with the degree of explicitness with which they do so. In the first column in Table 1, we denote central banks that specify the target explicitly by "explicit" and central banks that are less explicit, for instance by specifying only the rate at which they operate in the money market, "implicit". Announcing a rate at which to operate in the money market is also a commitment to provide central bank funds to maintain market rates close to the operations rate, since otherwise some arbitrage condition would be violated and markets would be in disorder. In all cases, changes in the target level are announced right after the meetings of the decision making committee. This improves transparency relative to the old technique of letting the market guess the target level from the central bank's operations. It also sharpens the focus of the markets on the target level.

Precision of control of the overnight interest rate

The second column in Table 1 presents the volatility of the overnight rates in our sample of currency areas in the period 2000-2004.[7] Among the western currency areas, the UK is the highest, with a volatility of 44 basis points (bp) per day. The US is lowest in terms of overnight rate volatility (with 4 bps), while the Swiss National Bank (SNB) reaches an even lower level for its target rate, the 3 month Libor (1.3 bp; the SNB is the only central bank in our sample that targets a maturity of interbank rates above one day). Haldane, Ayuso, and Restoy (1997) have shown that central banks implement monetary policy such that short term interest rate deviations from the target rates tend to be non-persistent, and therefore do normally not imply volatility of medium- and long term rates. It would therefore be wrong to conclude from the overnight volatility figures that monetary policy transmission in the UK is less precise than in the US.

Frequency of potential changes of the interest rate target and size of changes

The third column in Table 3 show the frequency with which the different central banks' decision making bodies meet, for the purpose of assessing the target level. For example, the ECB's

[6] The monetary policy implementation techniques of these central banks are described for instance in the following documents. Danmark: Danmark's Nationalbank (2003a), (2003b); ECB: European Central Bank (2004a) and European Central Bank (2005); Norway: Kran and Ovre (2001); Sweden: Otz (2005); Switzerland: Jordan and Kugler (2004), Jordan (2005); UK: Bank of England (2002), (2004); Clews (2005); US: Meulendyke (1998), Federal Reserve Bank of New York (2005). Also Websites of central bank tend to provide some up-to date information on monetary policy implementation techniques.

[7] This is measured as the standard deviation of first differences.

Governing Council currently meets only once a month for this purpose (until 2000, it met every fortnight). The Fed's FOMC meets every eighth week. The other central banks in our sample are within this range.

The frequency of meetings does not appear to be very correlated with the number of actual changes: while the Fed changed rates 21 times since 2000 which is the record amongst western hemisphere central banks, the ECB changed its rates only 13 times (see column 4). The frequency of actual changes could be related to the size of changes to the target level. However, there is not much variation across central banks here. These changes are mostly 25 bp or 50 bp (column 6). No central bank did a smaller rate change, while three implemented higher ones, namely Switzerland (75 bp), Norway (100 bp), and Belarus (2500 bp).

Gradual or exhaustive changes of the interest rate target level

On this issue, the Bank of England and the Fed appear to present two very different approaches. Goodhart (2000) suggests that the target adjustments of the Bank of England would be such as to generate a martingale in the target rates:[8] *"When I was a member of the MPC I thought I was trying, at each forecast round, to set the level of interest rates, on each occasion, so that without the need for future rate changes, prospective (forecast) inflation would on average equal the target at the policy horizon."* Under such an approach, it should, after each change, be equally likely that target rates go up or down with the next change, regardless of the direction of the current change. The Fed in contrast has for a long time followed a gradual approach in adjusting target rates to changing economic conditions, creating auto-correlation of changes of target rates (see e.g. Rudebusch 2002). Since 1999, the Fed also has been hinting explicitly in its announcements of decisions on the direction and speed of future changes. Interpreting these verbal hints has become an important element of Fed watching. Despite the rhetoric, we see in Column 5 that the Bank of England and the Fed typically change target rates in a gradual way; only 13% and 10%, respectively, of rate changes represent a change in direction.

Column 5 of Table 1 indicates that in the period 2000-2004, the central banks with the most gradualist approach has been the US Fed (21 changes with 2 changes of direction) and the ECB and Denmark (both 13 changes with only one change of direction), while Sweden having done least changes with most changes in direction (3) seems to be the one taking the most exhaustive steps.

[8] The latter question is not to be confounded with the one of whether the actual overnight rate follows a martingale within the reserve maintenance period.

Table 1: Specification of operational targets and technique of changing level of target variable for selected central banks

	1. Type of operational target and description ("implicit" = through operations rate; "explicit" = explicit reference to targeted market rate)	2. Vol. of daily changes of ONR in bp. (2004)	3. Normal frequency of reconsider ation	4. Number of changes of target rate (2000-04)	5. % of which are changes in direction (total number)	6. Min/max change in basis points
Euro area	implicit – minimum bid rate in weekly repos	10	Once a month	13	8% (1)	25/50
UK	implicit - Rate of fixed rate repo operations	22	Once a month	16	13% (2)	25/50
Sweden	implicit - Rate of weekly fixed rate repo operations	19	Eight times a year	13	23% (3)	25/50
Denmark	implicit – "Discount rate" which is he main policy rate, without direct relation to market rates; „lending rate" fixed tender rate around which overnight rates fluctuate (at currently 15 bp above discount rate)	10	Once a month	13	8% (1)	25/50
Norway	implicit - Deposit rate	16	Every six weeks	16	13% (2)	25/100
Switzer-land	explicit - Target range for the three-month Libor for Swiss Francs. This target range extends over one percentage point. Normally, the SNB keeps the rate in the middle of the target range.	1.3*	Quarterly	12	17% (2)	25/75
Belarus	The refinancing rate is an administrative rate which is largely adopted by the financial sector as a reference rate. Policies for steering the overnight rate to this are under development.	-	Once a month	44	7% (3)	100/2500
Russia.	The main target is the appreciation of real exchange rate of ruble – set annually. Shorter-term targets are not disclosed to public	-	-	-	-	-
US	explicit - Overnight interest rate (federal funds rate)	5	8 weeks	21	10% (2)	25/50

* In the case of Switzerland, the target rate is the three month Libor, and not the overnight rate

3. The central bank balance sheet and the three main instruments of monetary policy implementation

The central bank balance sheet is the starting point for understanding monetary policy implementation. The items in the central bank balance sheet fall into three distinct categories; autonomous factors, monetary policy operations, and reserves of banks, as illustrated in Table 2.

Table 2: The central bank balance sheet

Assets	***Liabilities***
Autonomous factors	
Foreign reserves	*Banknotes in circulation*
Investment assets	*Government deposits*
…	*Capital and reserves*
	…
Monetary policy operations	
*Reverse open market operations**	
*Outright holdings of securities**	
Borrowing facility	*Deposit facility*
	Reserves of banks *(including those to fulfil required reserves)*

*It is assumed that that open market operations supply, rather than remove, liquidity, as is the case in the Euro area and the US. Whether open market operations supply or remove liquidity depends on the size of autonomous factors and reserve requirements. In our sample, the central banks of Norway, Denmark, Belarus and Russia have to absorb liquidity through open market operations, mainly due to their large foreign reserves position.

3.1 Autonomous liquidity factors

Autonomous factors are items which are not controlled by the monetary policy function of the central bank, such as banknotes in circulation, foreign exchange reserves, government current accounts, holdings of securities for investment purposes, and possibly others. Transactions affecting these items normally include a leg in the domestic currency and therefore affect the reserves of banks with the central bank. For central banks like the ECB that supply funds through open market operations, it is therefore important to forecast the autonomous factors accurately. Failure to do so may lead the short term rate to deviate from its target. The weekly frequency of operations in the euro area means that autonomous factor forecasts over a one week horizon are particularly important.

Consider as one example of an autonomous factor banknotes in circulation, which is typically one of the largest if not the largest single item in the central bank balance sheet. The amount of euro banknotes, displayed below, exhibits weekly, monthly and seasonal patterns. These patterns reflect regularities such as withdrawing of cash before the weekend, the payment of salaries, the summer holiday season, and Christmas shopping. The forecasting model for banknotes applied by the European Central Bank in its day-to-day forecasting is discussed in more detail in Cabrero et al (2002).

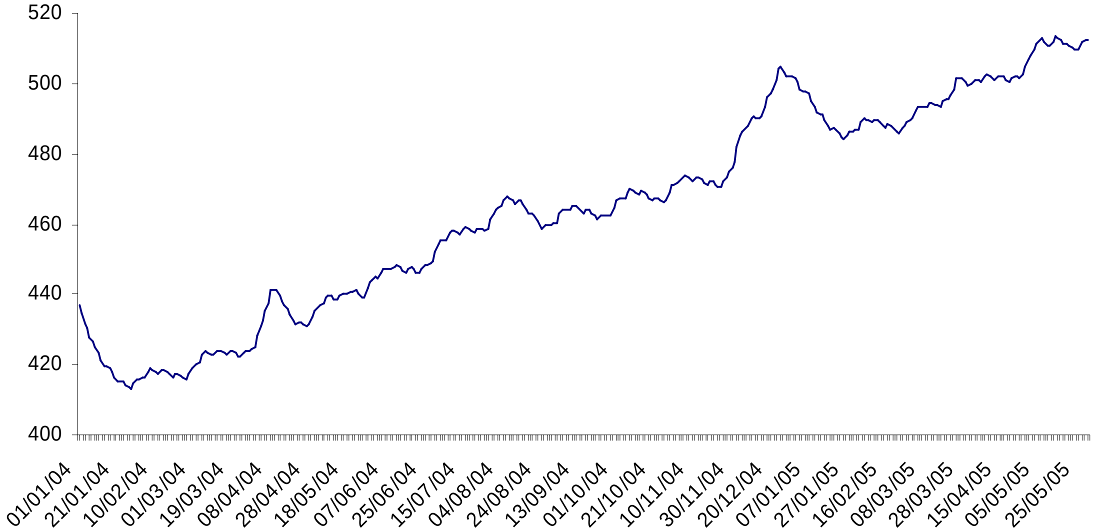

Figure 1 :Banknotes of the Eurosystem, January 2004 – May 2005, in billions of euro

Source: European Central Bank

The Eurosystem produces separate forecasts for all the main autonomous factors. The following table provides, for the second semester of 2002, the accumulated volatility of the main autonomous factors as well as the forecasting errors over three different time horizons. As a fraction of volatility, forecast errors are the smallest for the most volatile series, banknotes and government deposits. This reflects the larger amount of resources devoted to the forecasting of these two key autonomous factors.

Table 3: Autonomous liquidity factors in the euro area, second half of 2002, standard deviations of changes and of forecast errors at three different forecasting horizons, in billion of EUR (source: European Central Bank)

	Absolute size[9]	Forecast horizon		
Horizon:	(end 2002)	One day	Five days	Ten days
Banknotes	377	1.1 / 0.2	4.1 / 1.4	7.8/2.8
Government deposits	50	4.5 / 0.4	10.0 / 2.0	12.0 / 3.4
Net foreign assets	380	0.4 / 0.1	0.8 / 0.4	11.4 / 0.9
Domestic financial assets	120	0.4 / 0.2	0.8 / 0.6	1.3 / 1.0

3.2 Open market operations

Open market operations are monetary policy operations conducted at the initiative of the central bank in order to affect the level of reserves of banks with the central bank, and thereby achieve the operational target of monetary policy. They may consist of reverse operations (i.e. repos or reverse repos) or outright purchases or sales of securities. Today, day-to-day monetary policy implementation is done almost exclusively through repos, while outright holdings of securities

[9] Note that the length of the Eurosystem balance sheet at end 2002 was EUR 832 billion.

are used by some central banks as a means of structural liquidity supply. Section 5 will elaborate in more detail on the choice between repos and outright operations for the structural supply of liquidity to the market.

Both Keynes (1930) and Milton Friedman (1982), as advocates of the reserve position doctrine, argued that open market operations, which they conceived to be outright operations in securities, would be the supreme instrument of monetary policy implementation, if not the only one really needed. Today, with the dominance of reverse operations, the distinction between open market operations and standing facilities has become more blurred, and the idea to operate without standing facilities is no longer considered. Section 6 looks at the details of repo operations using fixed rate tenders and auctions, especially in the context of the ECB.

Table 4 surveys current practice of repo operations for our sample of central banks. The standard frequency of the main refinancing operations in Europe is one to two weeks. The maturity of these operations tends to be one week (columns 1 and 2). In terms of tender procedure, the fixed rate tender seems to dominate in Europe with the exception of the euro are (column 3). Like the ECB, the Fed also uses variable rate tenders (discriminatory auctions). Most central banks conduct more than one type of reverse operations (column 4), and the number of outstanding operations at any moment in time is mostly in the order of 2 to 4 (column 5).

Table 4: Use of reverse open market operations by selected central banks

	1. Frequency of reverse operations	2. Maturity of main operation	3. Tender procedure	4. Other open market operations	5. Average number of operations outstanding
Euro area	weekly	One week	Variable rate tender with minimum bid rate	Longer term refinancing operations: monthly variable rate tenders with pre-announced volume and three months maturity; Fine tuning overnight operations: n in 2004	4
UK (new*)	Weekly	One week	Fixed rate	Overnight operation on last day of the reserve maintenance period	
Sweden	Weekly	One week	Fixed rate tender	Daily fine-tuning operations	2
Denmark	Two weekly operations in parallel: one liquidity absorbing, one providing	Two weeks	Fixed rate tender with full allotment (at lending rate)	-	4
Norway	No standard frequency	Varying, up to 10 days	Variable rate tender	Collection of fixed term deposits (rarely)	Few, sometimes none
Switz.	Daily	Mainly one week (also overnight, two weeks)	Fixed rate tender (rationing if demand > supply)	Fine tuning operations, etc.	5
Belarus	Weekly	Varying (up to one month)	Variable rate tender with max or min bid rates	Issuance of central bank debt instruments to absorb liquidity	N/A
Russia	overnight repo; 3 month repo; 1 or 2 week repo	twice a day; once a month; once a week	Variable rate tender with minimum bid rate	Issuance of Central bank's bonds, deposit auctions and reverse repo at various maturities (to absorb liquidity)	N/A
US	Almost daily	Overnight (192 in 2004) and two weeks	Variable rate	Other maturities up to 28 days	Around 3

* The Bank of England is currently in a process of changing its monetary policy implementation technique (see Bank of England 2004). This and the following tables describe the new framework, as it will be implemented towards the start of 2006.

3.3 Standing facilities

Standing facilities are, in contrast to open market operations, monetary policy operations conducted *at the initiative of the commercial banks*, under the conditions specified by the central banks. Historically, they were only liquidity providing and were either a discount or a lombard (advance) facility. In a discount, the counterparty sells short term paper to the central bank, but receives only a part of the nominal value of the asset, since the nominal value of the paper is "discounted" at the prevailing discount rate. The maturity of a discount hence depends on the maturity of the discounted paper. In a lombard loan, the counterpart in contrast obtains collateralised credit of a standardised maturity, today usually overnight. We will refer to a liquidity providing standing facilities as a "*borrowing facility*", taking the perspective of the central bank's counterparty.[10] Practically all borrowing facilities today are lombard facilities. More recently, some central banks, e.g. the ECB, have introduced a liquidity absorbing facility ("*deposit facility*"). The deposit facility enables counterparties to place their end-of-day surplus liquidity with the central bank on a remunerated account.

The rates of the standing facilities are often fixed by the central bank at a "penalty level", i.e. such that the use of the facilities is normally not attractive relative to market rates. The interest rates on the two facilities then forms the ceiling and the floor of a corridor within which short-term money market rates move. Such a corridor system is applied by the Bank of England, the ECB, and the central banks of Canada, Australia, and New Zealand among others. A symmetric corridor has the important advantage, relative to an asymmetric approach a la Fed, in that it creates a general symmetry of the liquidity management problems of the central banks and the commercial banks. This symmetry allows for instance to ignore higher order moments of autonomous factor shocks (Bindseil 2004).[11]

Systems in which standing facilities are not set at penalty levels were standard until the first half of the 20th century, and are still applied in some cases today. Section 5 discusses some advantages and disadvantages of different approaches.

[10] The ECB calls its liquidity providing facility the *marginal lending facility*. The Fed calls its facility the discount facility, although it is strictly speaking a lombard facility.
[11] An interesting study on how standing facilities may be misused by banks to manipulate the money market is Ewerhart et al (2007).

Table 5: Use of standing facilities for selected central banks

	1. Borrowing facility	2. Deposit facility	3. At penalty level?	4. Width of the corridor set by standing facilities
Euro area	Yes	Yes	Yes	+/- 100 basis points around the target level for short term rates
UK (new)	Yes	Yes	Yes	Rates on standing facilities will be the MPC's repo rate +/-25 basis points on the final day of the maintenance period, and wider on all other days
Sweden	Yes	Yes	Yes	+/- 75 basis points
Denmark	none	Remuner. of current accounts at discount rate – but only up to ceiling	Light penalty level (only 15 basis points)	If one considers Danmarks Nationalbank's full allotment fixed rate open market operations as standing facilities, one could stipulate a corridor of 15 basis points. However, open market operations are only weekly, so there is no effective upper bound to the overnight rate.
Norway	Yes	Yes	Borrowing facility yes, deposit facility no	200 basis points. Note: access to the deposit facility is automatic in the sense that any deposits on the sight accounts of banks with the central banks are remunerated at the deposit facility rate.
Switzerl.	Yes	No	Yes	Borrowing facility is 200 basis points above the overnight rate (the call money rate)
Belarus	Yes	Yes	Mostly	Mid 2005: 15%, asymmetric around policy rate. Deposit facility=3%, refinancing rate=13%, and lending facility=18%.
Russia	Yes (collat. borrowing at 7 days and overnight)	Yes	Yes	Mid 2005: Overnight borrowing rate at 13%; overnight deposit rate at 0.5%; 1% for one-week deposits. Market rates fluctuate in between.
US	Yes	No	Yes	Borrowing facility 100 basis points above the target level for short term rates

3.4 Reserves of banks with the central bank and reserve requirements

This is arguably the most important single item on the balance, since reserves represent the good for which the short term market interest rate is the price. Most central banks today impose reserve requirements, including the Fed and the ECB. Banks that do not fulfil reserve requirements face penalties; in the case of the ECB, it is equal to the borrowing facility rate plus 250 basis points.

The justification for imposing reserve requirements has evolved considerably (see for instance Goodfriend and Hargraves, 1983, or Bindseil, 2004, Chapter 6). Today, there is consensus that the main purpose of reserve requirements lies in facilitating the control of short-term interest rates. This stabilizing effect works in two ways. First, if reserve requirements are set above the demand for working balances, which fluctuate from day to day, they stabilize the demand for reserves. Second, if reserve requirements are to be held only on average over a reserve maintenance period, they provide a buffer against transitory autonomous factor shocks. For instance the ECB can only achieve a high degree of interest rate stability with a weekly frequency of open market operations because of a combination of relatively high reserve requirements and the fact that these have to be maintained only on average over the one month reserve maintenance period. This being said, reserve requirements are not strictly necessary to control very precisely short term interest rates. Control can also be achieved through daily open market operations or standing facilities to which recourse is systematic and the rate of which is at the level of the operational target (as under the Norwegian and Reichsbank approaches, as they will be called in section 5).

While in the 1990s, many authors predicted the disappearance of reserve requirements, recent years have witnessed some innovations which have raised their popularity, in particular with banks. These innovations go into the direction of taking away the taxation character of reserves. The ECB was, after de Nederlandsche Bank, the second to introduce reserve requirements remunerated at market rates (in 1999). The Fed has added to its reserve requirement a voluntary ("contractual") component. This voluntary component is remunerated at market rates, and can be chosen by the banks (within certain limits) before the start of the maintenance period. At end 2004, the total requirements (including the voluntary component) stood at USD 20 billion (Federal Reserve Bank of New York 2005). The Bank of England, which has long been a strong opponent of traditional reserve requirements, is currently in the process of introducing voluntary reserves with averaging. Under its new scheme, "banks will choose a target level of positive balances (voluntary reserves) that they will be required to hold with the Bank on average over a maintenance period lasting from one MPC meeting to the next. Reserve holdings will be remunerated at the Bank's repo rate (with ceilings on the amount each scheme-member bank can hold)" (Bank of England 2004).

Table 6 provides a survey of features of reserve requirements in those countries of our sample that have some kind of reserve requirement system

Table 6: Main features of reserve requirement systems – missing central bank are those without any reserve requirement system

	1. Reserve base categories; reserve ratio	2. Size of reserve requirements	3. Remuneration	4. Averaging period	5. Level available for averaging
Euro area	2% of deposits and debt securities with maturity up to two years	EUR 140 billion	At rates of Eurosystem's main refinancing operations.	Approximately one month. Exact time depends on meetings of ECB Governing Council	Equivalent to reserve requirements
UK (new)	Banks choose themselves their reserve requirements up to a certain maximum	Targets for reserve balances may total GBP 25 billion (Clews, 2005, p. 215)	Remunerated at BoE repo rate	Between MPC meetings, i.e. one month	Equivalent to level chosen by banks
Switz.	2.5% of liabilities with a maturity of 90 days; 2.5% of 20% of liabilities in the form of savings deposits	CHF 7.5 billion	None	One month, from the 20th to the 19th of the following month	Around CHF 5 billion[12]
Belarus	5% of all deposits from household denominated in BYR; 10% of all deposit from firms denominated in BYR; 10% of all FX deposits	BYR 465 billion (about USD 200 million)	None	One month, starting on 15th calendar day and ending on 14th calendar day.	20% of reserve requirements on liabilities denominated in BYR.
Russia	2% for liabilities to non-residents and 3,5% for all the others	135 billion rubles (about USD 4,5 billion)	None	1 month	20% of total
US	Different marginal levels, max. 10% of transactions deposits	After deduction of vault cash USD 10 billion	None (but at market rates for "clearing balance requirements)	Two weeks starting on a Thursday	Around USD 20 billion (of which EUR 10 billion is clearing balance requirement)

3.5 The demand and supply for reserves

The balance sheet identity (assets = liabilities) allow us to present one balance sheet item as a residual, for example the net recourse to the standing facilities. Letting B and D denote recourse

[12] In Switzerland, banks are allowed to use vault cash to fulfil their reserve requirements. This reduces the need to hold reserves in the form of deposits with the central bank. Currently, vault cash held by banks amounts to 4.5 billion CHF.

to the borrowing and deposit facilities, respectively, we have, over the course of the reserve maintenance period, if we assume that there are no excess reserves:

net use of standing facilities (B-D) = - *open market operations (M)*
+ *required reserves (RR)*
+*net autonomous factors (A).*

We see that there is a net use of the standing facilities whenever open market operations do not equal reserve requirements plus autonomous factors. We say that the banking sector is long (short) reserves in aggregate if, $M - A - RR > 0$ $(M - A - R < 0)$. In a system that penalizes users of the standing facilities, as is the case in the euro area, an efficient interbank market implies that standing facilities are used only when the banking sector is strictly long or short reserves over the monthly reserve maintenance period. In this case, short term rates at the end of the maintenance period are determined by whether or not the banking sector is short or long reserves. If it is long, short term rates are determined by the deposit facility. If it is short, rates are determined by the borrowing facility. Because the autonomous factors are stochastic, this means that short term rates at the end of the maintenance period will also be stochastic. Rates prior to the end of maintenance period will then be given by the relative likelihood of the banking sector being long or short reserves at the end of the period. In the next section, we discuss a model that captures this idea and show how standing facilities and open market operations can be used to steer short term rates.

4. A basic model of short term interest rate control and the "liquidity effect"

Models of the relationship between available reserves and interest rates and how this relationship is to be used by the central bank start with Poole (1968). In section 4.1, we will provide a simple microeconomic model following the specification of Woodford (2001). In section 4.2, the even simpler aggregate model will be presented which is also suitable for modeling reserve maintenance periods with more than one day.

4.1 The one day "individual shocks" model of Woodford (2001)

In this model, banks must end each day with nonnegative reserve positions. That is, negative positions must be made up by using the borrowing facility. A bank with positive holdings can use the deposit facility. Within the day, the timeline is as follows: first, the central bank conducts an open market operation which determines the amount of reserves available in the system. It is assumed that the central bank is perfect in forecasting aggregate autonomous factors, and that aggregate liquidity conditions are precisely known to the market. Secondly, a fully efficient interbank market session takes place in which the overnight interest rate is determined. Finally, end of day clearance takes place, in which banks are subject to individual surprise cash-flows, such that they may be pushed into having to use either the borrowing or the deposit facility offered by the central bank.

Let s_j be the reserves bank *j* chooses to hold (through dealing in the interbank market) at the beginning of the day. The bank is subsequently subject to a shock in its holdings of ε_j, taking its end of day holdings to r_j. The shocks are independently distributed across banks with $E[\varepsilon_j \mid s_j] = 0$, $Var[\varepsilon_j \mid s_j] = \sigma_j^2$. For each *j*, ε_j / σ_j has cumulative density function *F*, with a mean of zero, variance of 1, and $F(0) = 0.5$. Let i, i_B, and i_D denote the market rate, the rate of the borrowing facility, and the rate of the deposit facility, respectively. A risk-neutral bank will choose s_j to minimize expected costs C of refinancing, i.e. it will minimize

$$C(s_j) = is_j - i_B E_j[\min(s_j + \varepsilon_j, 0)] - i_D E_j[\max(s_j + \varepsilon_j, 0)] \tag{1}$$

The first order condition is

$$(i_D - i)(1 - F(-s_j / \sigma_j)) + (i_B - i)F(-s_j / \sigma_j) = 0 \tag{2}$$

This implies desired overnight balances of

$$s_j = -\sigma_j F^{-1}\left(\frac{i - i_D}{i_B - i_D}\right) \tag{3}$$

The market clearing overnight rate is the one that ensures that demand and supply of reserves match. Thus, we must have

$$\sum_j s_j = R \tag{4}$$

where R is the aggregate reserves of banks with the central bank set at the beginning of the day. Substitution of (3) into (4) yields the solution:

$$i = i_D + F\left(\frac{-R}{\sum_j \sigma_j}\right)(i_B - i_D) \tag{5}$$

Thus by choosing R, for example through open market operations at the beginning of the day, the central bank can achieve any market interest rate within the corridor set by the two standing facilities. If $R = 0$, the market rate would be in the middle of the corridor [since $F(0) = 1/2$]. This would correspond to, e.g., the case of the ECB and the central banks of Australia, New Zealand, and Canada. If R is very large, then banks will tend to load off excess liquidity with probability close to one through the deposit facility at day-end, and the market price for overnight money should thus be close to i_D. If instead R has a large negative value, banks will be forced into the borrowing facility with high likelihood, and the interbank market will clear at a rate close to i_B.

Incorporating a positive level or (daily) reserve requirements into this model is straightforward; just substitute *R* by *R-RR* (*RR* being reserve requirements) in equation (5).

4.2 A model with aggregate shocks an averaging

In this model, the relationship between aggregate reserves and the interbank interest rate is not driven by liquidity shocks at the level of individual banks, but by an aggregate shock on autonomous factors. The central bank has an unbiased forecast *E(A)*, with $A = E(A) + \varepsilon$. Let F be the cumulative distribution function of ε. We first assume that there is no averaging and that required reserves each day are zero. At the beginning of the day, the central bank conducts an open market operation of *M.* Along the same lines as in the previous model, we have

$$i = i_D + F\left(-(M - E(A))\right)(i_B - i_D) \tag{6}$$

This can also be written:

$$i = i_D\left[1 - F\left(-(M - E(A))\right)\right] + i_B F\left(-(M - E(A))\right) = i_D\left[P("long")\right] + i_B[P("short")] \tag{7}$$

In words, the overnight rate is a weighted average of the two standing facility rates, the weights being equal to the respective probabilities that the market is on aggregate “long” or “short” of funds at the end of the day. If *M = E(A)* and F(0)=0.5, the interbank rate will be in the middle of the corridor.

We now introduce reserve requirements and averaging. As recourse to standing facilities at the end of the reserve maintenance period is then a matter of average reserves over the maintenance period being above or below required reserves, one simply needs to re-interpret all quantities as averages over this period. Thus let $\overline{M}, \overline{A}$ be the averages over the reserve maintenance period of daily outstanding open market operations and autonomous factors, respectively. Thus, on any day t of the reserve maintenance period, we can write:

$$i_t = i_D + (i_B - i_D)F_{t,\overline{M}-\overline{A}}(RR(t)) \tag{8}$$

where $F_{t,(\overline{M}-\overline{A})}$ is the conditional cumulative distribution function of $\overline{M} - \overline{A}$ as perceived by banks at the time of the money market session of day t, and *RR(t)* is the remaining average reserve requirement to be fulfilled from day *t* to the end of the reserve maintenance period for the banking sector as a whole. Note that now both $\overline{M}$ and $\overline{A}$ are random variables, since the open market operations after day t but before the end of the reserve maintenance period are not yet known.

Consider as an illustration the following example from Bindseil (2004). First assume a three day reserve maintenance period with an open market operation (with three days maturity) only on the first day, as displayed in figure (1):

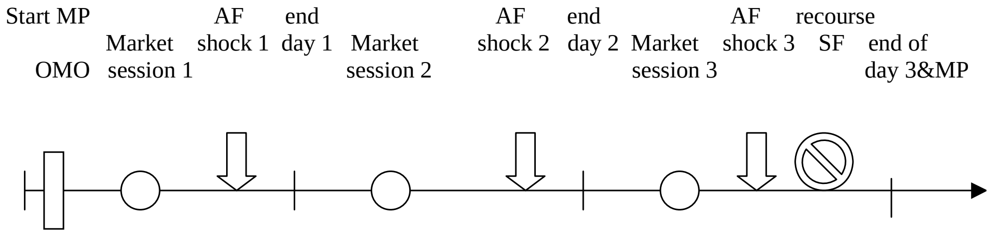

Figure 1: A three days maintenance period with one open market operation

For the sake of simplicity of notation, assume that $i_B = 1; i_D = 0$. For the same reason, also assume that reserve requirements are zero, but that there are no limits to averaging. Banks can thus overdraft their account with the central bank, but have to fulfill zero reserve requirements on average over the three days period. Denote the random aggregate autonomous factors on each of the three days by $\tilde{\eta}_1, \tilde{\eta}_2, \tilde{\eta}_3$, with realizations written without the tilde. Suppose these are iid $N(0, \sigma_\eta)$. Assume that the central bank operates a neutral liquidity policy so that M is zero as well. Then the market interest rate on day 1 is

$$i_1 = P(-(\tilde{\eta}_1 + \tilde{\eta}_2 + \tilde{\eta}_3))/3 < 0) = \Phi\left(0 \Big/ \sqrt{\sigma_\eta^2 / 3}\right) = 1/2 \qquad (9)$$

where $\Phi()$ is the standard normal cumulative distribution function. The market rate on day 1 will always be in the middle of the corridor as liquidity conditions are neutral. This changes on day 2, as market players observe the realisation of autonomous factors on day 1 (for instance the ECB publishes its relevant previous day's balance sheet figures at 9:30 a.m.). The market interest rate on day 2 will thus be

$$i_2 = P(-(\eta_1 + \tilde{\eta}_2 + \tilde{\eta}_3))/3 < 0) = \Phi\left(\eta_1 \Big/ \sqrt{\sigma_\eta^2 / 2}\right) \qquad (10)$$

The interest rate on day 3 will be:

$$i_3 = P(-(\eta_1 + \eta_2 + \tilde{\eta}_3))/3 < 0) = \Phi\left((\eta_1 + \eta_2) \Big/ \sqrt{\sigma_\eta^2}\right) \qquad (11)$$

The variance of the overnight rate increases day by day in the course of this reserve maintenance period, well in line with empirical evidence.

Consider now the case in which the central bank conducts one operation with one-day maturity on each day of the maintenance period, before the respective market session. Assume the allotment policy $M_1 = 0; M_2 = \eta_1, M_3 = \eta_2$, i.e. the central bank neutralises the autonomous factor shocks. It is easy to verify that this open market operation strategy allows a perfect stabilisation of interest rates within the reserve maintenance period, since in each market session, expectations with regard to the liquidity conditions prevailing at the end of the reserve maintenance period tend to be balanced.

The same result could also be achieved for the policy $M_1 = 0; M_2 = 0, M_3 = \eta_1 + \eta_2$, as long as the market is aware that this is what the central bank does. In this case, the market trusts that the central bank delays the correction of the first day's autonomous factor shock. If the market is not aware of the central bank's neutral policy, the market will have biased expectations after observing the shock on day 1, leading to an interbank rate that deviates from ½ on date 2. This example illustrates two key points. First, there may be open market policies that are distinct in terms of the distribution of liquidity supply across the reserve maintenance period, but that are equivalent in terms of the implied interest rate path, if they lead to the same accumulated liquidity supply. Second, it is important that the market has a clear picture of the central bank's strategy of liquidity supply across different open market operations within the reserve maintenance period in order that the volatilities of interbank rates are minimized.

It can be easily verified in these examples that, as implied by an unlimited averaging facility, the martingale property of short term interest rates holds, i.e. $i_1 = E(i_2 | I_1) = E(i_3 | I_1)$ and $i_2 = E(i_3 | I_2)$, where I_t is the information set of banks at date t. The intuition behind the martingale property is as follows. Assume for instance that $i_1 > E(i_2 | I_1)$. This would mean that any risk neutral bank should lower its total refinancing costs in the reserve maintenance period by lending on day 1 and by borrowing in the interbank market on day 2. On day 1, it would under-fulfill its reserve requirement, but it would rebalance it on the next day. As all banks would attempt to do this, however, all banks would try to lend in the interbank market at the high rate of day 1 and all banks would try to borrow at the low rate on day 2. This however cannot be an equilibrium.

4.3 Empirical studies

The empirical literature on overnight interest rates has spotted various more or less important deviations from the martingale hypothesis, and tried to find explanation for them. Ho and Saunders (1985) focus on the possible risk aversion of banks. Campbell (1987) assumes that liquidity benefits of reserves vary across the days of the reserve maintenance period, for instance due to differing payment system activity. Transaction costs are introduced by e.g. Kopecky and Tucker (1993), Hamilton (1996), Clouse and Dow (1999) and Bartolini, Bertola and Prati (2001). Limits to interbank trading have been mentioned by Spindt and Hoffmeister (1988) and Hamilton (1996). Effects of payment systems are analyzed by Furfine (2000). Window dressing by banks is studied by Allen and Saunders (1992) for the US, and Bindseil, Würtz and Weller (2002). Bartolini, Bertola, and Prati (2002) focus on volatility effects of operating procedures, confirming the increased end-of-day volatility also suggested in the simple model above. Gaspar, Perez-Quiros, and Rodriguez-Mendizábal (2004) show that the end of day no-overdraft constraint alone is sufficient for a break-down of the martingale hypothesis and a tendency of short term rates to increase in the course of the reserve maintenance period. Further empirical models of short term interest rates in the euro area are Hartmann, Manna and Manzanares (2001), Angelini (2002) and Würtz (2003). Other estimates of the liquidity effect are Hayashi (2001) for Japan and Thornton (2001) for the US.

The empirical evidence seems to confirm that a variety of factors beyond liquidity conditions and standing facility rates impact on actual overnight rates. However, the simple models developed in this Section provide a good understanding of how monetary policy implementation works and how the short term rate can be controlled.

5. Implications of monetary policy implementation for financial markets

There are many ways for a central bank to steer short term rates and to provide liquidity. These place different requirements on the central and commercial banks with respect to forecasting and managing liquidity conditions, dealing in securities, and managing collateral, and therefore have different implications for financial markets. In this section, we discuss some of these issues in the context of a simple example which focuses on standing facilities and open market operations.

We consider four different implementation techniques, as illustrated in Table 7. The techniques differ in their emphasis on standing facilities, the use of repo operations, or outright holdings of securities. Each of the four approaches is named for a central bank with a similar actual monetary policy implementation technique. For simplicity, in our example we ignore reserve requirements and assume that central bank liabilities consist EUR 100 billion of banknotes.

Table 7: Central bank assets under four different implementation approaches, in billions of euro (liability: EUR 100 billion of banknotes)

	“Reichsbank”	“Norwegian”	“US Fed”	“Eurosystem”
Net recourse to borrowing facility	100	10	0*	0
Repo operations	0	0	10	100
Outright holdings of securities	0	90	90	0

* Under the US Fed approach, there would actually be a very small expected net recourse to the borrowing facility

a) The Reichsbank approach:
All central bank funds are provided through recourse to a borrowing facility, the rate of which is set at the level of the target rate. The structural recourse to the borrowing facility pegs the short term market rates (see Reichsbank, 1900, and Reichsbank, 1925). This approach was practiced by the German Reichsbank from 1876 until at least 1914. While we assume that the borrowing facility is collateral based, the Reichsbank’s actual borrowing facility was a genuine discount facility in which eligible short term paper was sold to the Reichsbank at the initiative of counterparties.

b) The Norwegian approach
Under this approach, banks always need to take recourse to one standing facility, in our case to the borrowing facility (in contrast to the actual recourse to some kind of deposit facility in Norway, Indonesia, China, etc.). Deterministic recourse to the borrowing facility pegs the short term interbank rate. However, in contrast to the Reichsbank approach, the recourse to the standing facility only covers a smaller part of the central bank assets, the rest of assets being outright holdings. Therefore the central bank has more freedom to determine the composition of its assets.

c) The US Fed approach
Recourse to the borrowing facility is stochastic, and the short term interest rate target is set below the borrowing facility rate (in practice, the difference is 100 bp). There is no deposit facility. Most of the funds are provided through outright purchases. The Fed holds Treasury securities in proportion with their market capitalization, implying a portfolio duration of around 5 years. Fine tuning of liquidity is done via repos.

d) The ECB approach
Net recourse to the borrowing facility is stochastic. There is both a borrowing and a deposit

facility, which are 100 bp above and below the target rate, respectively. Both the structural liquidity supply and day-to-day liquidity management takes place through repos against a wide range of eligible collateral.

Table 8 summarizes these four techniques with respect to how they provide liquidity -- through outright holdings or collateralized loans, or repos – and how they control short term rates – through standing facilities or open market operations. Below, we discuss the impact of these choices on financial markets.

Table 8:Two key dimensions of choices for designing a monetary policy implementation approach

		Technique to control short term interest rates	
		Systematic recourse to SF*	Combination of OMOs** and stochastic recourse to SFs
Structural liquidity provision	Collateral based	Reichsbank	Eurosystem
	Outright holdings based	Norway	US Fed

* SF = Standing facilities; ** OMO = Open market operations

5.2 Efficiency of liquidity management for banks and for the central bank

For a commercial bank, liquidity management is costly in that it requires forecasting its liquidity in- and outflows and trading in the money market. This might require analysts, traders, back office staff, management, etc. These costs do not feature in the models in Section~4, but can be important in practice. Banks face a tradeoff between investing resources into analysis and trading on the one side, and the costs of sub-optimal end of day liquidity positions on the other side. From this perspective, it is desirable to have an operational framework that minimizes the costs of liquidity management.

For the central bank similar cost issues arise. Forecasting the autonomous liquidity factors and conducting operations require staff for analysis, trading, and settlement. In contrast, recourse to standing facilities would appear to involve less costs for the central bank as it is undertaken by the counterparties. One could view the central bank as facing a potential tradeoff between the precision of interest rate control, on the one hand, and administrative costs, including forecasting autonomous factors, on the other.

For the liquidity management of the central bank, approaches based on the systematic use of standing facilities (the two approaches on the left-hand side of table 8) appear more efficient.
The Reichsbank approach in particular would seem to minimize costs as it requires minimal efforts on behalf of the central bank to forecast liquidity developments. The story seems to be similar for commercial banks.

Costs of liquidity management might also be different in collateral versus outright holding based frameworks (the vertical dimension in table 8). Collateral based operations (operated as standing facilities or repo auctions) with a wide range of counterparties facilitate channelling liquidity directly to the counterparties in need of it. With outright operations based approaches, the liquidity has to be redistributed by the banking system itself, which would increase transaction costs. On the other hand, regularly turning over a substantial amount of the stock of liquidity might involve costs that would be avoided under the outright operations based approach.

5.3 Market neutrality in terms of relative prices of financial assets

Choices with regard to the monetary policy implementation technique should avoid having distorting effects on the relative prices of financial assets. This mainly refers to the vertical dimension in table 8, i.e. outright versus collateral based approaches.

Due to the scale of central bank assets, outright purchase or sale operations can potentially influence relative asset prices. For instance, the Fed currently holds around USD 700 billion, all in Government securities. If the Fed decided to exchange some of its holdings to agency or mortgage backed securities, for example, this might well drive down the spreads of these securities relative to government securities. Since the central bank probably cannot hold the full "market portfolio", any outright portfolio will to some extent impact market prices and will thus require difficult choices by the central bank.

It is often said that one of the main advantages of reverse collateral based operations is that they do not distort securities prices, because the underlying assets' ownership is not affected. This appears plausible, particularly if the list of eligible collateral is wide and haircuts are set fairly. But it is possible that there is a premium on securities that are eligible as collateral, since use in central bank operations as collateral is for many banks one of the reasons to hold securities. If a security is made ineligible, then some banks may want to substitute it with eligible ones, which may put pressure on prices.

In subsection 5.5 we will identify some cases where eligibility of collateral seems to have influenced issuance and even legislative activities in the euro area. There is currently a debate in the euro area in the context of the high deficits or debt ratios of some euro area Governments, such as those of Greece, Italy and Portugal. According to some critics, e.g. J. Fels of Morgan Stanley (Financial Times of 1 April 2005) and Buiter and Sibert (2005), the ECB, by accepting Government bonds from these countries on similar terms as Government bonds of euro area countries with a better fiscal position, would narrow down spreads between these different Government debt instruments and reduce incentives for Governments to improve their fiscal situation.[13]

In conclusion, a market neutral operational framework for monetary policy implementation may

[13] The treatment of different Government bonds by the Eurosystem is actually not the same in so far as the Eurosystem applies daily marking-to-market, such that a higher credit risk perceived by market participants and reflected in prices implies that a higher nominal amount of collateral needs to be provided. As a solution to the problem they perceive, Buiter and Sibert (2005: 25-28) suggest inter alia that the Eurosystem should issue sufficient debt to establish a new risk free benchmark against which the credit risk in all public instruments would be priced. However, the (one year) probability of default of a AAA rated Government issuer (like the German Government, which currently provides the euro benchmark yield curve) is generally considered to be below one basis point (such a default has never occurred in history). In addition, the German government presently has an outstanding debt of around EUR 800 billion (approximately the length of the current Eurosystem balance sheet), which implies an exceptional liquidity. To match this liquidity would probably require similar issuance volumes by the Eurosystem. Buiter and Sibert propose to balance the debt issuance through "outright purchases of other eligible debt instruments", meaning that the Eurosystem would eventually hold significantly more credit risk than presently (where its balance sheet is much shorter and mainly based on collateralised operations), and would most likely distort financial market prices significantly more than now.

be hard to achieve. Collateral based systems arguably retain the advantage that they spare the central bank the need to decide which assets to purchase.

5.4 Market neutrality with regard to the yield curve

Another dimension of market neutrality is the effect on the yield curve. Here, a collateral based system appears to ensure market neutrality to a higher extent than an outright holdings based system, since the ownership of assets, and therefore returns and risks, remains with the banks. This is particularly so when the central bank does not restrict the maturity of instruments submitted by banks as collateral, while it obviously would have to choose when buying assets outright.

Leaving longer term rates to be set in the market is arguably the efficient thing to do. However, many central banks have tried at some time in their history to directly influence longer term interest rates through monetary policy implementation. But, as summarised in Bindseil (2004) (section 5.3), the results have been disappointing. Nevertheless, considerations of direct yield curve control re-emerged recently not only in deflationary Japan, but also in the US after the stock market downturn in 2000. According to some observers, the Fed tried to "talk down" longer term interest rates by suggesting that there was deflation risk in the US as well. In a speech delivered in November 2002, Governor Ben Bernanke even suggested the active use of open market operations for that purpose, and explained that he would "personally prefer the Fed to begin announcing explicit ceilings for yields on longer-maturity treasury debt (say bonds maturing within the next two years). The Fed could enforce these interest-rate ceilings by committing to make unlimited purchases of securities up to two years from maturity at prices consistent with the targeted yields." However, no such concrete measures have been taken by the Fed.

5.5 Contribute to liquid and resilient money markets

The central bank is normally the largest and most important player in the money market. It therefore also set standards which eventually influence the conventions and practice of money and collateral markets. This can have influence on the liquidity of the markets and their resilience to financial shocks. A liquid and resilient money market would be one in which (i) banks have active trading relation with each other, such as to know and trust each other to a relatively high degree; (ii) ample collateral is available in the system (and efficient methods of collateral settlement), such that even in case that no relationship of mutual knowledge and trust is there to build upon, banks will be able to exchange funds.

Technique of liquidity supply and interbank money market activity

It has sometimes been argued that parts of the interbank market trading volumes are of a speculative nature, and would thus vanish if rate volatility would move close to zero. However, in the euro area or US markets for overnight funds, there is little volatility except towards the very end of the reserve maintenance period. Nevertheless, trading volumes do not tend to increase towards the end of the reserve maintenance period. This is consistent with the view that interbank activity is primarily driven by liquidity management. Hartmann and Valla (2007) provide a more detailed discussion of these issues, and of money markets in general.

Central bankers often argue that with a deterministic aggregate recourse to one standing facility, and, accordingly, overnight rates always at or very close to the relevant standing facility rate, banks would have less incentives to try to trade funds in the interbank market. Can one quantify this impact on the size of the overnight market? Take a very simplistic example with 10 banks, half of them being short by EUR 5 million and 5 being long EUR 4 million, such that a total recourse of EUR 5 million to the borrowing facility will have to occur. Under the *ECB's symmetric corridor* approach and daily operations, the central bank would target through its open market operations a zero recourse, and would thus add EUR 5 million to the system. If this liquidity ends up equally with the banks which were previously short, then 5 are short by EUR 4 million and 5 are long by EUR 4 million. In the absence of forecast errors and efficient markets, recourse to standing facilities will be zero and the interbank lending volume will be EUR 20 million. Now assume that under the *Norwegian approach*, the initial situation is the intended one, i.e. a net recourse to the borrowing facility of EUR 5 million is what the central bank aims at to peg the market rate at the level of the borrowing facility rate. The trades needed to minimize refinancing costs to the banking system are now again lending of EUR 20 million from the surplus banks to the deficit banks (the rate traded should be marginally below the borrowing facility rate – if collateral is not scarce or credit risk is not an issue). Thus, the interbank lending volume would be identical to the symmetric corridor approach. In other words, the interbank overnight market would not collapse, and it would not even shrink, at least not in this example.

What about moving further from the Norwegian to the Reichsbank approach, in which recourse to the borrowing facility would be much higher? Under the Reichsbank approach, we would find the banks in our example in completely different situations. For example, we could have five banks being short by EUR 14 million and five short by EUR 5 million. Each bank has 9 million less, reflecting that the EUR 90 million which were provided under the Norwegian approach through open market operations have to be covered under the Reichsbank approach through recourse to the borrowing facility. Now, all interbank money market activity will be substituted by recourse to the borrowing facility, whereby some banks will borrow EUR 14 million and the others EUR 5 million. Thus, we see that how monetary policy is implemented will impact on interbank activity. A small or nonexistent interbank market could be achieved by adopting the Reichsbank approach. An active interbank market could be achieved through either of the other approaches listed in table 8.

Impact on debt issuance and collateral standards

To the extent that the specification of monetary policy implementation techniques, including in particular the choice of securities for outright holdings and the list of eligible collateral, is not entirely market neutral (see section 5.3), it will have some impact on issuance activity and therefore at least indirectly also on the securities available in the interbank market for repos. Consider the following examples taken from the collateral-based case of the ECB.

(1) Covered bonds like Pfandbriefe can be defined as full recourse debt instruments secured (covered) by collateral pools, namely mortgage assets and/or claims against public sector entities. They constitute "on balance sheet securitization" (ECB 2004b) and are typically AAA rated (Association of German Mortgage Banks 2004). While being originally a German specificity, covered bonds were, from the start of the euro in 1999 on, made eligible all over the euro area as collateral for Eurosystem monetary policy operations. This also contributed to increase their attractiveness sufficiently to have banking systems and legislators work hard on quickly establishing conventions and laws supporting Pfandbrief all over Europe. So-called Jumbo-Pfandbriefe (which are Pfandbriefe with an issuance volume of at least EUR 1 billion) are also used to a growing extent in interbank repo markets. At the end of 2003, a total of EUR 1 trillion of covered bonds was outstanding in the euro area.

(2) Asset backed securities (ABSs). Since 1999, ABSs were also eligible collateral for Eurosystem operations. The amount of outstanding ABSs has developed exceptionally in Europe

since then, with issue volumes reaching EUR 268 billion in 2003 (of which 80% are AAA rated – see ECB, 2004b)[14]. While other factors (Basle II, technological advancements) have certainly also played a major role, anecdotal evidence suggests that eligibility for Eurosystem operations gave a further push to the growth of the market. Even if ABSs are normally not used in interbank repo operations, the securitisation they imply means an increased liquidity per se, as something that could not be traded beforehand (all sorts of non-standardized claims) is made easily tradable, somehow standardised, and credit rated. This could contribute to the liquidity and resilience of financial markets.

(3) Loans of banks to corporates: The ECB decided in 2004 that loans of banks to corporates would become eligible collateral euro area wide (they were eligible only in four countries beforehand). This might to some extent reduce incentives for banks to create Pfandbrief style assets or ABSs with loans they will then be able to submit directly to the Eurosystem. The standards of credit assessment for loans submitted to the Eurosystem as collateral may gain some recognition in the market and help to make the market for loans more liquid.

5.6 Optimal duration of central bank assets, risk allocation and the central bank's risk-return preferences

In a collateral based system, the central bank is constrained to hold assets with limited duration, and it also takes little credit and spread risk (credit risk materialises only in case that both the counterparty and the collateral issuer default simultaneously; spread risk is addressed through haircuts). In other words, a collateral based system is one in which the central bank overall takes very little risks. As far as non-diversifiable risks are concerned, this implies that it leaves correspondingly more risks in the hands of the market.

Can one say anything about the optimal duration of central bank assets? One might argue that if the economy as a whole tends to have longer term refinancing needs, then the central bank should also aim at providing longer term financing to avoid the need of a costly duration transformation by banks. On the other side one could argue that banks want to be flexible in their financing behaviour, and thus like to have short term liabilities towards the central bank, at least if they know that they can always refinance again at the central bank when the current refinancing matures. From the central bank's perspective, one could also view the duration decision as being a mere investment problem: how much interest rate risk does the central bank want to take into its balance sheet, and what expected return does it want? Not being threatened by liquidity problems, and having a long term horizon as an investor, it would seem that the central bank should not be overly risk averse in the short run, and should probably not hold less interest rate risk in its balance sheet than the average investor, and thus end up with a portfolio duration not below around five years (a few of the underlying issues are discussed in Bindseil, Manzanares and Weller 2004). If a central bank concludes that it wants to hold assets with a duration of this order of magnitude, be it for investment or more comprehensive social considerations, it will be forced to hold a part of its assets in outright form, i.e. it cannot do so under a pure collateral based approach.

With regard to the extent a central bank should take credit or spread risk in its balance sheet, one could argue that taking these risks always requires careful analysis, and that the central bank can

[14] According to ECB 2004b: "Off-balance sheet term securitization did not take off in Europe until the late 1990s. It has seen impressive growth rates since then and has now become an established asset class in the European fixed income markets".

never be a competitive player in this field and should therefore leave such risk-taking to others. The opposite argument would be that any investor should take credit risk as part of a CAPM type of diversification, and that with limited analysis, important diversification benefits can be achieved. In practice, many central banks have chosen to not incur any non-necessary credit and spread risk in their monetary policy operations, but to define a part of their assets (be they domestic or foreign) as investment assets, where they go for partial diversification into such risk.

It is difficult to draw a clear conclusions on the desirability of a higher duration of central bank assets and of the benefits from diversification into credit and spread risk. In any case, the outright approach is more flexible in this respect than the collateral based approach, as the latter constrains risks and related return perspectives. If one believes that the central bank should get into these risks, then a pure collateral based approach would not be optimal.

6. Open market operation mechanisms

We have seen that open market operations can be classified by whether they inject or remove liquidity and whether they do so through repos or outright purchases. In this section, we will focus on the mechanisms themselves, taking the type of open market operation as given. There are two broad types of mechanisms that are commonly used, namely, fixed rate tenders and variable rate tenders. Both types have been used by the ECB. These different mechanisms can have different impacts on allocations across banks in the operations and therefore on the money markets. We will focus on the case that the operation injects liquidity through a reverse repo, as is the case for the ECB.

6.1 Fixed rate tenders (FRT)

In a fixed rate tender, the central bank fixes the interest rate of the operation and invites eligible financial institutions to submit bids specifying how much they wish to transact at the announced rate. The most common allocation rule is the pro-rata rule, where bidders receive a pro-rated share of the total amount the central bank wishes to provide. If this amount is larger than the aggregate demand in the tender, bidders receive their demand in full. An alternative is the 100% rule, where bidders receive their demands in full.

Fixed rate tenders with the pro-rata rule was used, for example, by the Bundesbank during the 1980s and 1990s and the Eurosystem from January 1999 to June 2000. The Bank of England also uses fixed rate tenders. The 100% allotment variant was applied, for instance, by the Bundesbank in the 1950s and by the Bank of Finland in the years preceding 1999.

6.2 Variable rate tenders (VRT)

In variable rate tenders, the rates at which operations take place are determined by auction. Here, the bids of the counterparties are interest rate-quantity pairs, specifying the marginal quantity that the bidder demands at the specified interest rate. These bids can be organized into an aggregate demand curve. The rate where aggregate demand equals the quantity the central bank wishes to inject is referred to as the stop-out, or marginal, rate. There are two main types of auctions; uniform and discriminatory. In both types, bids above the stop-out rate are allocated in full; while bids at the stop-out rate are pro-rated. In uniform auctions, all bidders pay the stop-out rate; while in discriminatory auctions, they pay the rate of their accepted bids.

As with fixed rate tenders, the central bank may pre-announce the quantity it wishes to transact or it may decide upon this after observing bids. Since the end of June 2000, the ECB has used discriminatory auctions for all but some fine-tuning operations. There is little supply uncertainty in the ECB's operations. The ECB has a liquidity neutral policy and announces the liquidity neutral amount shortly before its main weekly operations. For its monthly longer term operations, the ECB pre-announces the exact amount it will inject (15, 20, or 25 billion euros). When the size of the operation is non-discretionary, as in the euro area, the stop-out rate is determined by the bids submitted by the counterparties and therefore does not serve a role in signaling information from the central bank to the markets.

The choice of mechanism affects at least two important issues: (i) the rate counterparties must pay for central bank funds; and (ii) the allocation of central bank funds in the tender and therefore the activity and possibly the transactions rates in the interbank markets.

Variable rate tenders are sometimes viewed as having two main advantages relative to fixed rate tenders. (i) Variable rate tenders allow banks to express their relative preferences for central bank funds through the bid price, thus possibly aiding a more efficient allocation. (ii) Variable rate tenders solve the problem of overbidding (see below) which can occur with fixed rate tenders.

Fixed rate tenders are sometimes viewed as advantageous to variable rate tenders because:
(i) Fixed rate tenders send a stronger signal regarding the central bank's monetary policy stance. The idea is that there is an implicit commitment to steer the corresponding short term market rates to levels around the tender rate. (ii) Bidding in fixed rate tenders is simpler than in variable rate tenders and therefore do not put less sophisticated bidders (e.g. smaller banks) at a disadvantage.

6.3 Empirical comparison of fixed rate and variable rate tenders

In this subsection, we will discuss the ECB's experience with fixed rate and variable rate tenders. The ECB used fixed rate tenders for its main refinancing operations from its inception in January 1999 to 20 June 2000. Starting with the operation on 27 June 2000, the ECB has used discriminatory auctions. The reason for the switch has mainly to do with the so-called overbidding problem that arose with the fixed rate tenders; that is, banks demanded substantially more than the liquidity neutral amount that the ECB aimed to inject and that banks needed to fulfill reserve requirements. For example, in the tender held on 30 May 2000, banks received only 0.87% of their demand. This translates into a bid-to-cover of approximately 115, relative to the realized tender size.[15]

Very large and highly variable bid-to-cover ratios are considered to be a problem for two reasons. First, high bid-to-cover ratios mean that banks that have relatively small amounts of collateral might need to demand more in the tender than what they have collateral for. If bidding turns out to be weak, such banks could find themselves short of collateral. Thus, banks with relatively little collateral might be at a disadvantage in the tender. This was viewed as a problem particularly because collateral was said to be unequally distributed across the euro area, with some countries being collateral rich and others being collateral poor. Second, highly variable bid-to-cover ratios make tender allotments less predictable and therefore liquidity management more difficult. Discriminatory auctions were viewed as being able to solve the overbidding problem since banks now could increase the likelihood of awards simply by bidding higher on the interest rate dimension.

[15] Overbidding is studied by Nautz and Oechssler (2003) and Bindseil (2005). See also Ayuso and Repullo (2003), Välimäki (2003), and Ewerhart et al (2005).

Table 9 provides some summary statistics under the fixed rate and variable rate regimes.

Table 9: Comparison of Fixed Rate and Variable Rate Tenders Held by the ECB, Jan 1999-June 2001

Panel a: Fixed Rate Tenders. #Obs = 76							
	Minimum bid rate (%)	Bid-to-cover	Swap rate (%)	Swap spread (%)	Volatility of swap rate (bp)	Premium (rel to min bid rate) (bp)	Discount (rel to swap rate) (bp)
Mean	2.95	26.22	3.05	9.20	4.62	0.00	9.20
St. error	0.05	2.92	0.06	1.20	0.17	0.00	1.20
St. dev	0.46	25.47	0.51	10.47	1.46	0.00	10.47
Minimum	2.50	1.00	2.51	-11.25	0.84	0.00	-11.25
Maximum	4.25	114.94	4.34	41.25	10.62	0.00	41.25
Panel b: Discriminatory Auctions (variable rate tender). # Obs = 53							
Mean	4.60	2.06	4.68	8.19	4.29	6.52	1.67
St. error	0.03	0.30	0.02	1.23	0.17	1.05	0.35
St. dev	0.20	2.17	0.18	8.85	1.22	7.55	2.51
Minimum	4.25	1.00	4.31	-5.50	1.18	0.15	-5.65
Maximum	4.75	16.66	4.93	48.25	8.54	45.95	6.76

Swap spread is the swap rate less the minimum bid rate. Premium is the average rate paid less the minimum bid rate. Discount is the swap rate less the average rate paid. Volatility of swap rate is calculated from the modified GARCH(1,1) model in Nyborg, Bindseil, and Strebulaev (2002). All variables are sampled on the tender days (swap rates are taken 15 minutes before the tender), with the exception of the volatility which is sampled the day before (which gives the conditional volatility for the tender day). Bid-to-cover is calculated with respect to the realized tender size.

We see in Table 9 that bid-to-cover ratios indeed fall dramatically with the introduction of discriminatory auctions. Under the fixed rate tender regime the average bid-to-cover ratio is 26.22, while under the discriminatory auction regime it is 2.06. Bid-to-cover ratios are also much less variable, their standard deviation fall from 25.47 under fixed rate tenders to 2.17 under discriminatory auctions.

The table uses the two-week Eonia swap rate to benchmark the auction. This is the rate of the fixed leg for a two week swap, where the floating leg pays the realized overnight rate (the EONIA). The ECB's operations during the sample period are for two-week money. As an alternative to borrowing in the tender, a bank could borrow overnight over two weeks and hedge by entering an Eonia swap, paying the fixed leg. This would mean the bank would obtain the necessary liquidity at the swap rate. Thus the swap rate can be viewed as the appropriate benchmark for the tenders. The swap rate is also more liquid than other two week interbank rates.

The swap spread is the swap rate less the tender rate (in the fixed rate tenders) or the minimum bid rate (in the discriminatory auctions). This variable is the key to the overbidding phenomenon.

We see from Table 9 that the swap spread averages to 9.20 basis points under the FRT period. Thus, banks could obtain funding at on average 9.20 bp cheaper in the tenders than in the interbank market, as we see in the *discount* column. The reason is that the interbank (swap) rate reflects expectations that future tender rates will rise. The tenders therefore provide an easy way for collateral rich banks to make money.

The swap spread does not decline much under the discriminatory auction regime, it averages to 8.19 bp. But the auctions do not provide the same opportunity to make money as the fixed rate tenders. We see that the discount averages to only 1.67 bp, which is well within the typical bid-ask spread of around 3 bp. In the auctions, the huge discounts (or profits to bidders) are competed away. Banks still participate because they need the good on offer, namely central bank funds, in order to satisfy reserve requirements. We can see from the fact that the swap spread and the volatility of the swap spread is more or less the same under the FRT and VRT periods, that the reason for the reduced bid-to-cover ratios and discounts are the change of the mechanism, and not changes in other market conditions.

The experience of the ECB also suggests that allocations in the tenders across banks can be very different under fixed rate and variable rate tenders. In particular, in fixed rate tenders, collateral rich banks would appear to have an advantage. This could potentially be a problem in that it could make squeezing more likely. Squeezing could in theory occur in the money markets since banks have to fulfill reserve requirements. What a bank does not obtain in the tender, it must obtain in the secondary market. An unbalanced tender allocation increases the likelihood of short squeezing since it is becomes more likely that some banks may have market power. Thus the type of mechanism used in the operation can affect the orderliness of the secondary money markets.[16]

Besides overbidding, another problem that can arise is underbidding, whereby banks demand less in aggregate than the liquidity neutral amount; i.e., less than what they need to fulfill reserve requirements. Typically, underbidding occurs when banks expect that within the reserve maintenance period, the minimum bid (or fixed tender) rate will be reduced by the central bank, such as to allow for lower total refinancing costs by "backloading" the reserve fulfillment. Underbidding is costly for banks because it means they must use the ECB's borrowing facility (marginal lending facility) to make up the shortfall, which comes at a penalty of 100 bp relative to the minimum bid rate in the tender. Underbidding also disrupts the planned implementation of monetary policy. If all tenders were consistently underbid, overnight rates would move up to the borrowing facility. If this were expected to be persistent, the whole yield curve also would shift up.

Underbidding has occurred in several instances. In Table 9, a bid-to-cover of 1 means that the quantity allotted to bidders (realized auction size) equals the total demand by bidders. These auctions were underbid relative to the liquidity neutral amount. The reason underbidding happens is that rates are expected to fall. Moreover, in most underbidding cases, the swap rate the morning of the tender is below the minimum bid rate (or tender rate), making the tenders an unattractive source of liquidity. However, after an underbid tender, interbank rates tend to increase, as banks need to go to the borrowing facility.

The ECB has solved the underbidding problem not by changing the mechanism[17], but by matching reserve maintenance periods with meetings of its Governing Council. In particular, there is now only one Governing Council meeting at which interest rates can be changed during a reserve maintenance period, and interest rate changes become effective exactly at the beginning of the period. This means that bidders cannot expect to obtain cheaper funding later in the period. Thus they have no reason to abstain from obtaining funds in the auctions.

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[16] Nyborg and Strebulaev (2001) and (2004) discuss short squeezing in fixed rate tenders and auctions, respectively.

[17] Linzert et al (2007) provide evidence of the smooth working of pure variable rate tenders in the ECB's longer term refinancing operations.

7. Concluding remarks

This paper has provided an overview of monetary policy implementation. We have discussed the three elements of implementation, namely, the operational target, the framework, and liquidity management. The operational target in most economies today is a short term rate. We have discussed a variety of ways how the rate can be controlled, drawing on specific examples from Europe as well as the US, and discussed how monetary policy implementation can distort asset prices through the type of collateral that can be used in transactions with the central bank. Finally, we touched on how the type of mechanism that a central bank uses for its open market operations can affect the allocation of central bank funds across banks and thus the money markets.

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