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A PRIMER ON UNCONVENTIONAL MONETARY POLICY

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ABSTRACT

A primer on unconventional monetary policy

Due to the severity of the financial market crisis most central banks reached the limits of their traditional monetary policy instruments and relied to a very large extent on instruments of unconventional monetary policy. In our paper we develop a simple theoretical framework for the money supply process which is able to analyze the need for such measures as well as their implications for the banking system. The paper starts with a presentation of a price-theoretic model for the money supply under "normal conditions". It then shows how the different shocks of the financial market crisis have affected the market for bank loans and how a central can compensate such shocks. The need for unconventional measures derives from the size of these shocks and the zero lower bound of the central bank's policy rate. Under such conditions the central bank can only stabilize the loan market by providing direct loans to the non-bank sector. A by-product of this approach is a net creditor position of the banking system vis-à-vis the central bank which can lead to high excess reserves and a "decoupling" of the policy rate and the level of reserves. The paper also discusses the impact of bank losses and the role of maturity transformation on the banks' loan supply.

JEL Classification: E51, E58 and G21
Keywords: bank regulation, maturity transformation, money multiplier, money supply process and unconventional monetary policy

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1 Theory of the money supply: the terra incognita of monetary theory

For decades economists have paid very little attention to the theory of the money supply process. As a consequence, the extremely simplistic multiplier approach has been able to survive not only in textbooks but also in theoretical papers e.g. on the so-called credit channel of monetary policy (Bernanke and Gertler (1995)). The lack of interest in the money supply process becomes also evident in the new Keynesian macro models. For instance, in the ECB's new area wide model (Christoffel et al. (2008)) the central bank sets the nominal interest rate but the interplay between the central bank and the banking system is not explicitly modeled, which is partly due to the fact that the model does not entail a financial sector at all.

With the financial market crisis and the increasing reliance of central banks on unconventional monetary policies this theoretical deficit has become apparent for the first time. Above all observers were surprised that - in contrast to the textbook multiplier approach - a strong increase in the monetary base of many central banks did not lead to corresponding increase in the money supply. And more general it became apparent that besides the "*now defunct theory of the supply*" (Goodhart (2009)) there was no comprehensive framework for an analytical discussion of the innovative approaches of central banking that were applied in the years 2008 and 2009.

What is needed is a simple theoretical framework that allows describing the interaction between the central bank and commercial banks not only in terms of quantities but above all in terms of the interest rate that is controlled by central bank and the loan supply of the banking system. In section 2 we develop such a price-theoretic model for the money supply for conventional monetary policy. In section 3 we use the model to describe the shocks that originated from the financial crisis to the money supply process. In section 4 we first discuss the limitations of the zero bound for interest rate for the central bank's control over the money supply. They are a main justification for unconventional monetary policy in the form of direct central bank loans to the private or the public sector. This also allows distinguishing between quantitative and qualitative easing. Section 5 discusses the impact of capital regulations and rating downgrades. Finally in section 6, the increasing role of long-term refinancing in the ECB's toolbox can be shown as a form of pure qualitative easing.

2 Conventional monetary policy: A simple model for the money supply process

For decades the paradigm of the mechanistic money-multiplier has dominated the conventional textbook approach to the money supply. Its core message is simple: If the central increases the supply of base money by a certain percentage, the banking system will automatically increase the supply of loans and money proportionately. As this approach completely neglects the role of interest rates, it implicitly assumes a disequilibrium on the market for bank loans at given interest rates so that banks are always able to find a sufficient amount of new borrowers at unchanged interest rates.

This mechanistic approach has little in common with the standard practice of central banking: central banks control the loan supply of the banking system by varying the level of their refinancing rates (e.g. Fed Funds Rate, Rate for Main Refinancing Operations). Thus, for an analysis of conventional as well as of unconventional monetary policy one needs a model for the money supply that explicitly takes into account

- the interest rate that banks have to pay for their refinancing loans from the central bank, and
- the interest rate that non-bank borrowers have to pay for their loans from the banking system.

The model which we present in the following was developed by Bofinger, Reischle and Schächter (1999). It is based on the assumption that the supply of money is identical with the supply of loans and accordingly that the demand for money is identical with the demand for loans. This simplifying assumption allows a discussion of the money supply process in terms of the demand for and the supply of loans on the market for loans. With the multiplier relation the demand of the commercial banks for central bank refinancing (demand for monetary base) can be derived from equilibrium amount of loans (=money). Thus, the model describes the interaction between

- the market for loans, which is determined by the demand of the non-bank sector for loans and the loan supply of commercial banks, and
- the market for monetary base, which is determined by the commercial banks' demand for monetary base and the central bank as a monopolistic supplier of base money.

2.1 Loan supply

The profit maximization of a representative bank j reads:

$$\Pi^j = i_C Cr^j_{B/NB} - i_D D^j - i_R \left(Cr^j_{CB/B} - R^j\right) - O^j - V^j \tag{1}$$

The bank extends loans with the amount $Cr^j_{B/NB}$ to the private sector, which yield the interest rate i_C. For refunding the loan amount $Cr^j_{B/NB}$, the bank can use deposits D^j yielding the interest rate i_D or central bank loans $Cr^j_{CB/B}$ with the interest rate i_R. There is a minimum reserve requirement (r) on deposits, so that bank j has to hold reserves R^j with the central bank, which bear the same interest rate as the official policy rate. This is the practice in the Euro area as well as in the United States (Anderson (2008)). To simplify the profit maximization equation, we use the balance sheet of bank j (table 1) and rearrange equation 1 to equation 2 by substituting the central bank loans ($Cr^j_{CB/B}$):

Assets	Liabilities
$Cr^j_{B/NB}$ (Loans to the private sector)	D^j (Deposits of the private sector)
R^j (Minimum reserves)	$Cr^j_{CB/B}$ (Central bank loans)

Table 1: Simplified balance sheet of bank j

$$\Pi^j = Cr^j_{B/NB} \left(i_C - i_R\right) - D^j \left(i_D - i_R\right) - O^j - V^j \tag{2}$$

It shows, that bank profits are determined by an interest rate spread between interest rate for bank loans (i_C) and the interbank rate (i_R). Fixed costs (O^j) and variable costs (V^j) arise from the lending process. Variable costs depend quadraticly on the amount of loans granted to the private sector:

$$V^j = \frac{\beta \left(Cr^j_{B/NB}\right)^2}{Y} \tag{3}$$

Following Cosimano (1988) adjustment costs as described in equation 3 originate from the valuation of loan risks during the maturity by the bank's employees. The bank has to hire new employees if the loan amount rises or has to restructure its loan department at declining loans quantity, which generates cost in amount of V^j. We assume that the default rates moves countercyclically, so default rates are expressed by the overall macroeconomic situation ($\frac{1}{Y}$). Equation (3) also includes adjustment costs β. According to Freixas and Rochet (2008) these costs arise from the evaluation of deposited securities during the loan maturity, executed as well by the bank's employees. Now we plug V^j into the profit maximization equation, differentiate with respect to loans $Cr^j_{B/NB}$ and get the following loan supply:

$$\begin{aligned} \frac{\delta \Pi^j}{\delta Cr^j_{B/NB}} &= i_C - i_R - \frac{2\beta Cr^j_{B/NB}}{Y} \stackrel{!}{=} 0 \\ \Rightarrow Cr^j_{B/NB} &= \frac{(i_C - i_R)\,Y}{2\beta} \end{aligned} \tag{4}$$

In the following, we assume that the lending behavior of bank j is representative for the whole banking system, so we identify the aggregated macroeconomic loan supply for n banks:

$$Cr_{B/NB} = \sum_{j=1}^{n} Cr^j_{B/NB} = \frac{(i_C - i_R)\,nY}{2\beta} \tag{5}$$

2.2 Loan demand

In contrast to the loan supply we do not derive the demand side of the loan market explicitly. For the sake of simplicity we assume that the demand for loan is identical with the demand for money. We assume a standard demand function for money, where the money demand depends negatively on the interest rate for bank loans (αi_C) reflecting the opportunity costs of money holdings and positively on the income (γY) reflecting the transaction motive:

$$Cr^D = \mu + \gamma Y - \alpha i_C \tag{6}$$

To calculate the equilibrium loan interest rate, we equalize loan supply with loan demand:

$$\begin{aligned} Cr_{B/NB} &= Cr^S = Cr^D = \frac{(i_C - i_R)\,nY}{2\beta} = \mu + \gamma Y - \alpha i_C \\ \Rightarrow i^*_C &= \frac{2\beta\mu + 2\beta\gamma Y + nY}{nY + 2\alpha\beta} \end{aligned} \tag{7}$$

For the equilibrium loan amount we plug i^*_C into the loan demand:

$$\begin{aligned} Cr^* &= \mu + \gamma Y - \alpha \frac{2\beta\mu + 2\beta\gamma Y + i_R nY}{nY + \alpha 2\beta} \\ &= \frac{(nY)\,(\mu + \gamma Y - \alpha i_R)}{nY + 2\alpha\beta} \end{aligned} \tag{8}$$

2.3 Demand for central bank loans

The monetary base is the input factor for the money supply process of the banking system due to the minimum reserve requirement and the monopolistic issue of bank notes by the central bank. Because of these two reasons banks depend on central bank liquidity provided by refinancing loans, so that the central bank can set interest rates on the interbank market. To derive the demand for monetary base one can use the simple multiplier relation, which shows how much monetary base is needed if an additional loan unit is granted.

$$m = \frac{M}{B} = \frac{C+D}{C+R} = \frac{bD+D}{bD+rD} = \frac{1+b}{b+r} \tag{9}$$

After the rearrangement of the multiplier relation, the multiplier consists of the cash holding coefficient b, representing the common paying habits of the economy and of the reserve ratio r banks have to hold on deposits. In normal times without distortions on the interbank markets, the reserve ratio is almost identical with the minimum reserve requirement, because excess reserves do not yield interest so that banks want to avoid interest rate losses.

To calculate the equilibrium demand for monetary base B^* we set the equilibrium loan amount (equation 8) into the multiplier relation (equation 9):

$$\begin{aligned} m &= \frac{M}{B} \\ \Rightarrow B^* &= \frac{(nY)(\mu+\gamma Y-\alpha i_R)}{m(nY+2\alpha\beta)} \end{aligned} \tag{10}$$

2.4 Graphical derivation of the money supply model

The model can be derived graphically in a simple way. The starting point is the market for money, which is identical for the market for loans (left panel, figure 1). According to equation

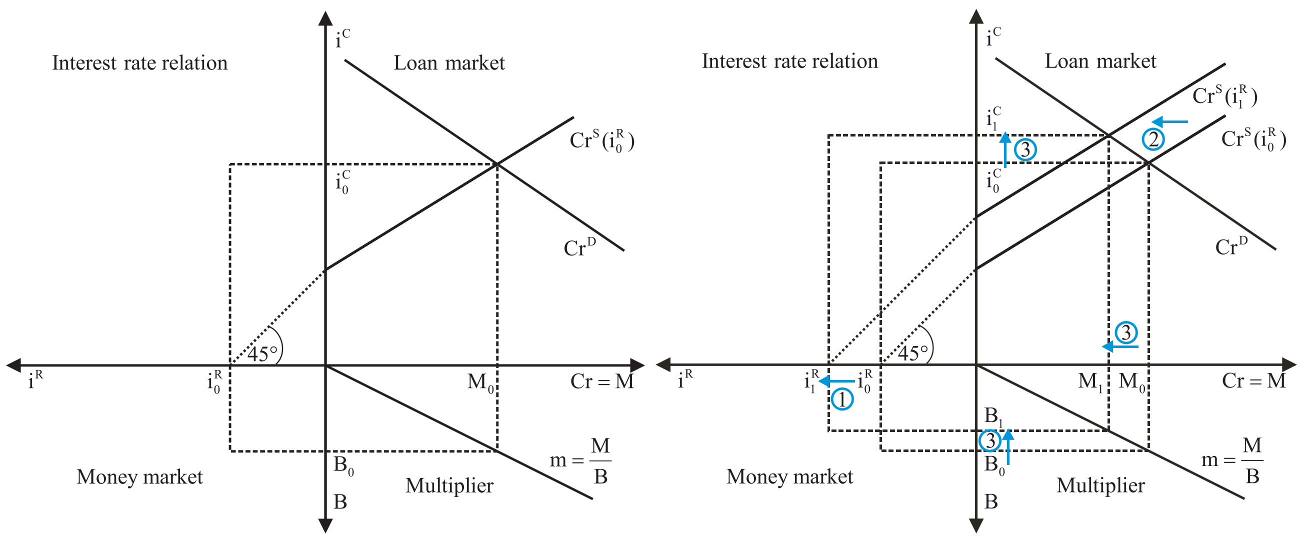


Figure 1: Graphical derivation of the money supply model

2 the loan supply depends on the refinancing interest rate. The intersection of the supply and demand curve gives the equilibrium loan amount M_0 and a corresponding loan interest rate

i_0^C. To calculate the demand for monetary base for a given loan amount, banks use the money multiplier m.

To derive the demand for monetary base and the interest rate relation graphically, we simulate a rise in refinancing interest rate as shown in the right part of figure 1. As a first step central bank increases the refinancing rate from i_0^R to i_1^R, so the loan supply curve shifts to the top left. Due to rising marginal refinancing costs loans are granted only at a higher interest rate i_1^C and therefore the loan amount shrinks to M_1. As a consequence the demand for monetary base calculated via the multiplier m declines to a level of B_1. This allows us to derive a demand curve for monetary base in the money market quadrant. As we have also two realizations of the refinancing and loan interest rate, we are able to construct the relation of i^R to i^C, which we call interest rate relation. As a result, we get the basic version of the money supply model shown in figure 2. Changes in the refinancing rate lead to a shift of the loan supply curve and therefore the loan availability and the costs of a loan are negatively affected.

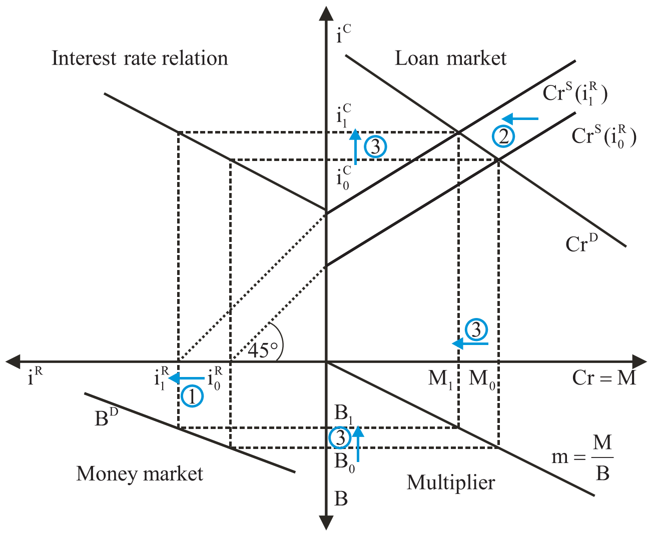


Figure 2: Basic version of the money supply model

2.5 A comparison with the model by Cúrdia and Woodford (2009)

After a long neglect New Keynesian models have now also paid more attention to the money supply process. An interesting approach can be found in a recent paper by Cúrdia and Woodford (2009). Their model is based on three interest rates:

- a market determined return i_t^d for deposits held with intermediaries and or for government debt, which the authors also identify with the central bank's policy rate (e.g. the federal funds rate),
- an interest rate i_t^b for one-period loans from intermediaries,

- an interest rate i_t^m for the remuneration of reserves that the intermediaries hold with the central bank.

In contrast to our paper, the authors do not derive the demand for reserves in a systematical way. As already mentioned, under normal conditions banks exactly hold the amount of reserves that is required due to statutory reasons. Holding excess reserves is costly as e.g. in the case of the ECB they are only remunerated if they are held in the deposit facility and the rate for this facility is typically below the policy or refinancing rate at which banks obtain liquidity. As a result, until the outbreak of the crisis the amount of excess reserves remained negligibly small. Thus, under normal conditions the interest rate for the remuneration of statutory reserves is identical with policy rate, and the rate for the remuneration of excess reserves is almost irrelevant.

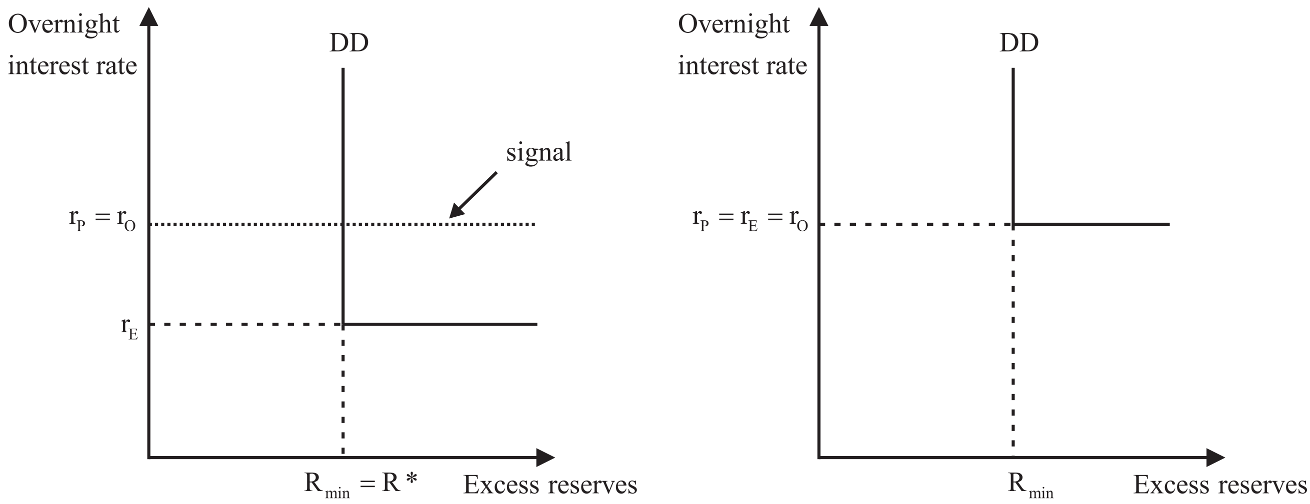
However, in the model of Woodford and Cúrcio the interest rate i_t^m paid on reserves plays a central role. The authors assume that by varying i_t^m the central bank can change the level of the policy rate i_t^d. This approach is difficult to reconcile with the practice of central banks under normal conditions where the policy rate is set directly by the supply of refinancing facilities at the policy rate and where statutory reserves are also remunerated at this rate. One could argue that i_t^m is the rate for the deposit facility, but it would have never come to the ECB's mind using it for a control of the policy rate. In fact this would be impossible.

Woodford and Cúrcio also argue that the quantity of reserves can be targeted independently of the policy rate. However, our model shows that under normal conditions it is not possible to control the quantity of reserves independently of the policy rate. From equation 10 one can see that there is a one-to-one relationship between the amount of monetary base and the policy rate.

Finally, Woodford and Cúrcio introduce a satiation level for reserves. Our model shows that this level is reached for a policy rate of zero which is identical with a maximum loan supply of the banking system.

2.6 "Decoupling principle": A comparison with the model by Borio and Disyatat (2009)

Borio and Disyatat have also presented an interesting theoretical framework for the discussion of unconventional monetary policies. A main element in their analysis is the so-called "decoupling principle" according to which "the same amount of bank reserves can coexist with very different levels of interest rates; conversely, the same interest rate can coexist with different amounts of reserves" (p. 3). The authors explain this principle with two charts (figure 3). The left chart corresponds with the precrisis situation where the remuneration of excess reserves was lower than the policy rate. In the framework of our model R_{min} is equivalent to the demand of the banking system for reserves. Under "normal conditions" it is unlikely that this demand will exceed R_{min}, as it implies that banks obtain refinancing loans at the policy rate r_O which they invest as excess reserves at the rate r_E. As "normal conditions" are characterized by a net debtor position of the banking system vis-à-vis the central bank, the banking system is always able to use an excess supply of reserves for a reduction of its liabilities vis-à-vis the central bank. In other words, under "normal conditions" the central bank is not able to expand the amount of reserves over the amount of R_{min} without changing its refinancing rate. Thus, in the chart by Borio and Disyatat on the left, the demand for reserves is reduced to a point with the coordinates (R_{min};r_P). A "decoupling" is impossible. However, we will see in section 4 that under "unconventional conditions" which can be characterized by a net creditor position of the banking system vis-à-vis the central bank a "decoupling" becomes possible, where the rate on excess reserves can be targeted independently of the level of reserves. The chart on the right



(a) Scheme 1

(b) Scheme 2

Figure 3: Reserve remuneration[1]

R_{min} = minimum reserve requirement due to statutory regulation; R^* = Reserve amount in the equilibrium; r_P =policy rate; r_O =overnight rate; r_E = rate on excess reserves (=deposit facility)

side of figure 3 assumes that the rate for excess reserves is identical with the rate for refinancing loans. As already mentioned, this is not the case under normal conditions. However, as a pure theoretical case, a decoupling would be possible but without a unique equilibrium since could always invest excess reserves at the same rate that they have to pay for their refinancing loans.

[1]see Borio and Disyatat (2009), Figure 1

3 A framework for an analysis of shocks caused by the financial market crisis

The financial market crisis has severely affected the money supply process. With our simple model the most important shocks can be easily analyzed.

- A *money supply shock*: The deterioration of the credit quality can be identified with an increase of the loan default parameter (β) which pivots the loan supply curve to the left.
- A *multiplier shock*: With the breakdown of the interbank market banks have built up high precautionary holdings of reserves in addition to statutory reserves even if this implies costs as excess reserves are remunerated at a rate, which is below the policy rate. As a result of this shock the multiplier curve and the demand curve for monetary base pivot to the left.
- A *loan demand (money demand) shock*: Due the expectation of reduced credit facilities ("credit crunch") the non-bank sector tries to increase its holdings of money. In our model this is identical with a higher loan demand and an upward shift of the loan demand curve.

3.1 A loan supply shock

The economic crises which rapidly followed the financial market crisis severely deteriorated the

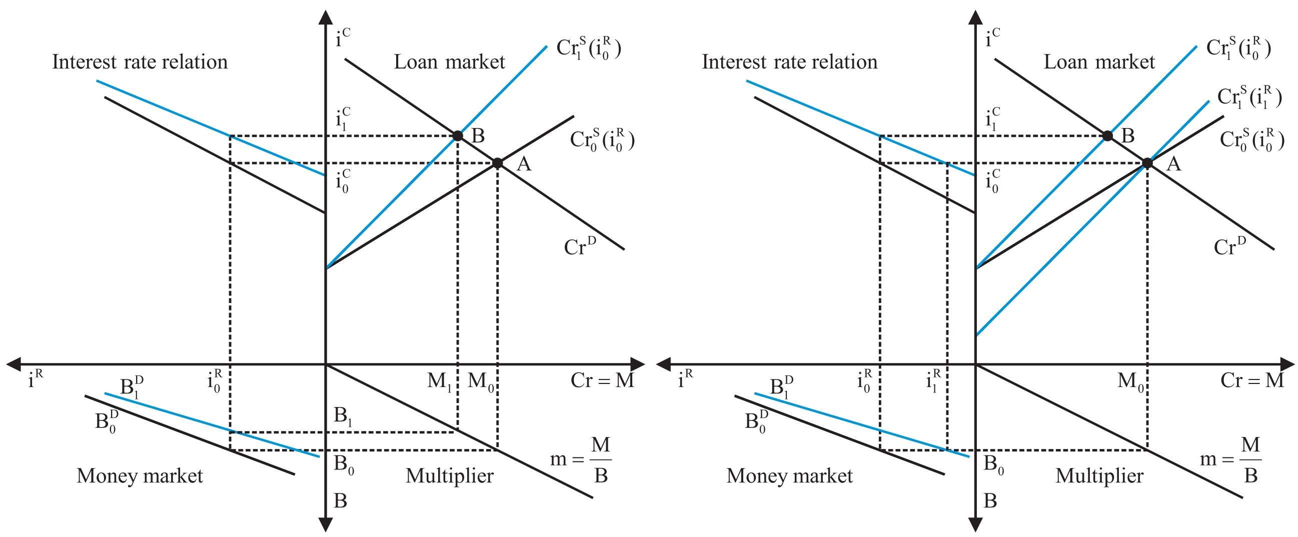


Figure 4: Loan supply shock

credit quality of many borrowers. In our model this can be identified with an increase of the default parameter (β) which leads to a counter-clockwise rotation of the loan supply curve (left part of figure 4). The loan interest rate rises to i_1^C, while the amount of loans is reduced to M_1

(point B). Due to a reduced amount of loans (=money) at an unchanged refinancing rate (i_0^R) the demand for monetary base also pivots counter-clockwise.
In principle the central bank can perfectly compensate this shock by reducing its policy rate from i_0^R to i_1^R (right part of figure 4).

3.2 A multiplier shock

The crisis has led to a very high degree of uncertainty on financial markets. This has especially affected the money markets. Under normal conditions they can be compared to a system of communicating tubes where a liquidity deficit of some banks is efficiently compensated by interbank loans from banks with a liquidity surplus. This explains the very low level of excess reserves in good times. Especially after the Lehman shock interbank lending has been reduced dramatically as banks with excess liquidity preferred to hold it in the form of excess reserves, above all the deposit facility, instead of lending it to other banks. In our model, this can be identified with an increase of the reserve ratio (r) which for this purpose can be split up in

$$r = r^{\text{statutory}} + r^{\text{excess}} \tag{11}$$

As a consequence the multiplier declines, the multiplier relation and the demand for monetary base pivot clockwise (figure 5).
The crisis and its impact on the stability on banks have also led to higher cash holdings of the non-bank sector. In the model this shock is identical with an increase of b which has the same effect on the multiplier as an increase of r.

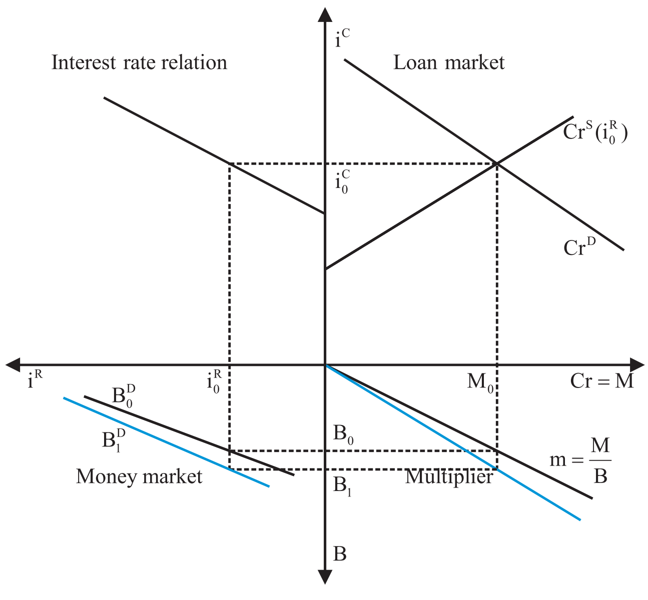


Figure 5: Multiplier shock

The reaction of the central bank to this shock is different to the money supply shock shown in the previous section. It can compensate it perfectly at an unchanged refinancing rate simply by providing more monetary base at the unchanged rate. This analysis provides an important explanation for the "puzzle" that in the years 2009/10 bank loans have not increased although central banks have strongly expanded the monetary base. A similar result is shown in a paper by Keister and McAndrews (2009).

3.3 A loan demand shock

The uncertainty about the future availability of bank loans has caused many borrowers to make use of existing loan facilities. In our model this can be identified with an increase in the demand for loans. Thus, the loan demand curve shifts upwards (left part, figure 6). The equilibrium loan amount increases from M_0 (A) to M_1 (B), and the loan interest rate goes up to i_1^C. As a consequence the demand for monetary base shifts downwards.
Again the central bank is able to compensate the shock, but it is now confronted with a trade-off. If the central bank wants to stabilize the amount of loans it has to increase its refinancing rate from i_0^R to i_2^R so that the supply for loans shifts upwards (right part of figure 6). If the central bank wants to stabilize the loan interest rate, it has to decrease its refinancing rate from i_0^R to i_1^R that the supply curve shifts downwards (left part of figure 6).

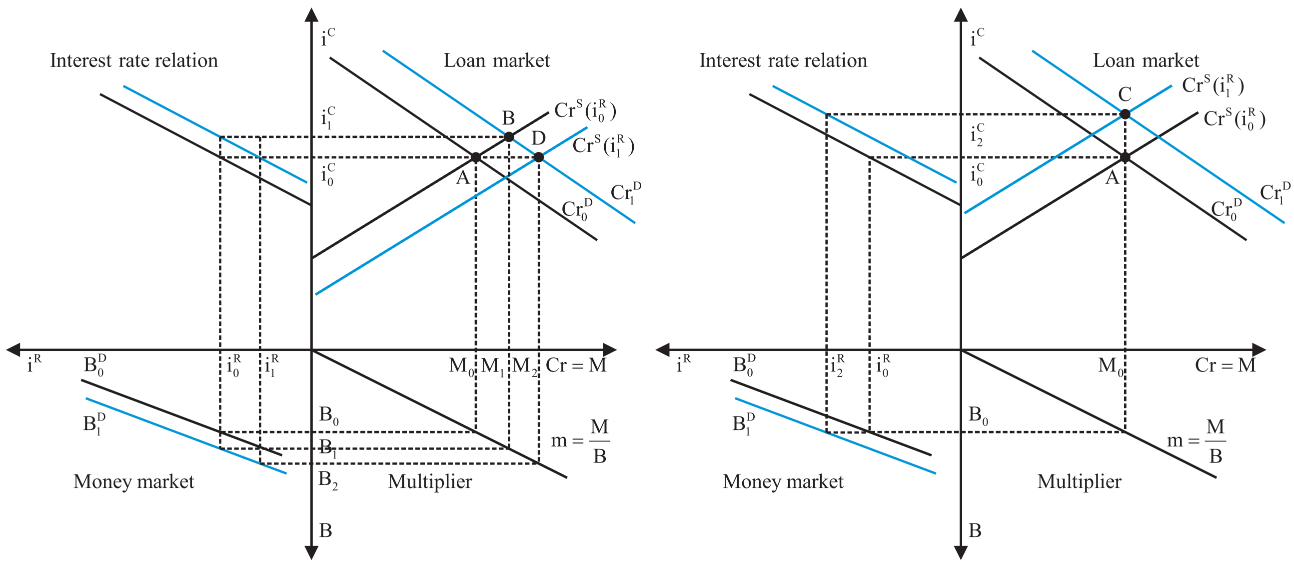


Figure 6: Loan demand shock

3.4 A combination of shocks

If one combines all three shocks it is possible to construct a scenario with a very expansionary monetary policy characterized by a strong reduction of the refinancing rate and a very high monetary base which goes hand in hand with a more or less constant equilibrium amount of loans and a decline in the loan interest rate which is much less than the decline in the policy rate. Such a scenario mirrors very well the present situation in the euro area, which is characterized by very low refinancing rate, a strong increase in refinancing loans and the monetary base, a stagnant money stock and loan supply as well as a strong decline in the multiplier of the money stock M3.

4 The case for unconventional monetary policy

In our simple model the central bank is in principle able to compensate all shocks perfectly so that it can always control the loan interest rate or the equilibrium amount of loans. However, in the case of very strong shocks the central bank's ability to stabilize the system can be constrained by the zero lower bound of interest rates. Such a situation can occur either with a loan supply or a loan demand shock or a combination of both. For the following we use the example of a loan supply shock.

4.1 The zero lower bound of interest rates

In the left part of figure 7 the equilibrium amount of loans at the starting point is M_0 which corresponds with a monetary base B_0 and a refinancing rate i_0^R. Due to the shock the loan supply curve pivots counter-clockwise so that the equilibrium shifts from A to B. As a result the demand for monetary base also pivots counter-clockwise. As the left part of figure 7 shows, the original monetary base B_0 which is required to reach the original loan equilibrium would require a negative refinancing rate. At the zero lower bound - which defines the satiation level - the monetary base is B_2 which shifts the loan supply downwards but only to point C which is characterized by a higher loan interest rate and a lower loan equilibrium than the original equilibrium A.

If the central bank nevertheless tries to compensate the shock fully it has to become active as direct lender on the loan market. By providing loans to private or public borrowers it can circumvent the banking system and shift the loan supply curve directly. With such an unconventional monetary policy the loan supply is composed of the commercial banks' loan supply ($Cr_{B/NB}$) and the central bank's direct loans ($Cr_{CB/NB}$). We assume that the central bank's loan supply is motivated by macroeconomic considerations only so that it is not necessary to derive it from a microeconomic optimization process.

$$\begin{aligned} Cr^S &= Cr_{B/NB} + Cr_{CB/NB} \\ &= \frac{nY}{2\beta}(i_C - i_R) + Cr_{CB/NB} \end{aligned} \tag{12}$$

With the introduction of a direct loan supply by the central bank, it is possible to shift the loan supply to the right so that original equilibrium A can be reached (right part of figure 7).

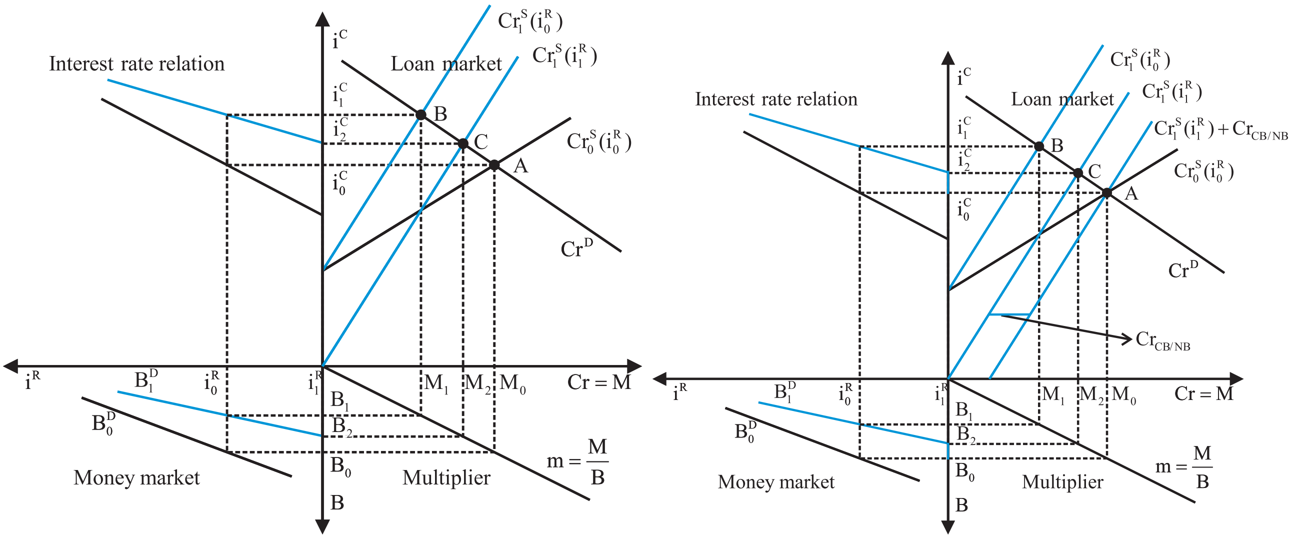


Figure 7: Outcome of a large money supply shock with use of conventional (left) and unconventional instruments (right)

4.2 Qualitative and quantitative easing

This direct lending of the central bank can also be analyzed in terms of the balance sheets of the central bank, the commercial banks and the non-bank sector. We assume that the non-bank sector holds a fixed ratio of cash to its total money holdings, in our numerical example 20 % which implies a deposit ratio of 80 %. We assume that commercial banks have to hold for their deposits a 2 % minimum reserve with the central bank.

Commercial Banks

Assets		Liabilities	
$Cr_{B/NB}$	(100,00 €)	D	(80,00 €)
R	(1,60 €)	$Cr_{CB/B}$	(21,60 €)
			101,60 €

Central Bank

Assets		Liabilities	
$Cr_{CB/B}$	(21,60 €)	R	(1,60 €)
$Cr_{CB/NB}$	(0,00 €)	C	(20,00 €)
			21,60 €

Private Sector

Assets		Liabilities	
C	(20,00 €)	$Cr_{B/NB}$	(100,00 €)
D	(80,00 €)	$Cr_{CB/NB}$	(0,00 €)
			100,00 €

Table 2: Starting situation

Table 2 describes the starting situation in equilibrium A where the central bank has not yet provided loans to the non-bank sector. Equilibrium B (table 3) is characterized by a decline in bank loans from 100 to 90 units which due to a lower demand for monetary base also implies a reduction of the central bank's balance sheet from 20 to 19.44 units.

Commercial Banks

Assets		Liabilities	
$Cr_{B/NB}$	(90,00 €)	D	(72,00 €)
R	(1,44 €)	$Cr_{CB/B}$	(19,44 €)
			91,44 €

Central Bank

Assets		Liabilities	
$Cr_{CB/B}$	(19,44 €)	R	(1,44 €)
$Cr_{CB/NB}$	(0,00 €)	C	(18,00 €)
			19,44 €

Private Sector

Assets		Liabilities	
C	(18,00 €)	$Cr_{B/NB}$	(90,00 €)
D	(72,00 €)	$Cr_{CB/NB}$	(0,00 €)
			90,00 €

Table 3: Loan supply shrinks to 90

In order to reach the original amount of loans the direct lending of the central bank to the non-bank sector has to increase by 10 units. Thus, the balance sheet of the non-bank sector reaches its original size and structure. The balance sheet total of the banking system diminishes by 10 units due to restrictive lending, while in the central bank's balance sheet loans to the banking sector are partly substituted by loans to the private sector. Therefore the risk structure is changed. This unconventional policy instrument is in the literature defined as "altering the composition of central bank balance sheet" (Bernanke et al. (2004)) or in a more concise way as "*qualitative easing*" (Buiter (2009)).

Commercial Banks

Assets		Liabilities	
$Cr_{B/NB}$	(90,00 €)	D	(80,00 €)
R	(1,60 €)	$Cr_{CB/B}$	(11,60 €)
			91,60 €

Central Bank

Assets		Liabilities	
$Cr_{CB/B}$	(11,60 €)	R	(1,60 €)
$Cr_{CB/NB}$	(10,00 €)	C	(20,00 €)
			21,60 €

Private Sector

Assets		Liabilities	
C	(20,00 €)	$Cr_{B/NB}$	(90,00 €)
D	(80,00 €)	$Cr_{CB/NB}$	(10,00 €)
			100,00 €

Table 4: Qualitative Easing

An increase of the balance sheet is in contrast defined as "*quantitative easing*" (Buiter (2009) or Bernanke et al. (2004)) and represents an other common approach relating to unconventional monetary policy. We illustrate the situation in table 5. In order to stimulate the economy and to achieve an loan amount that is higher than the original equilibrium the central bank increases its lending activity to the amount of 30, so the private sector has access to 120 units of loans. However, on the liabilities side of the banking system refinancing loans from the central bank are substituted by a higher amount of deposits from the non-bank sector.

Commercial Banks

Assets		Liabilities	
$Cr_{B/NB}$	(90,00 €)	D	(96,00 €)
R	(1,92 €)	$Cr_{CB/B}$	(-4,08 €)
			96,00 €

Central Bank

Assets		Liabilities	
$Cr_{CB/B}$	(-4,08 €)	R	(1,92 €)
$Cr_{CB/NB}$	(30,00 €)	C	(24,00 €)
			30,00 €

Private Sector

Assets		Liabilities	
C	(24,00 €)	$Cr_{B/NB}$	(90,00 €)
D	(96,00 €)	$Cr_{CB/NB}$	(30,00 €)
			120,00 €

Table 5: Quantitative Easing

Further it is interesting to see that loans from the central bank to commercial banks become negative ($Cr_{CB/B} = -4,08$). Due to quantitative easing the commercial bank system has become a net creditor to the central bank while under normal conditions it is in a net debtor position. Statutory reserves have to be held further, but $Cr_{CB/B}$ can be interpreted as excess reserves. If we sum up statutory and excess reserves we can see that banking system has become a net creditor for the central bank. They actually invest the remaining liquidity in central bank accounts.

So far we have assumed that bank loans as well as direct central bank loans are only made to the private sector. But under the framework of unconventional policy central banks, above all the Bank of England, have also purchased government bonds in large amounts. In principle, our model can be modified in way that the private sector is replaced by the non-bank sector which includes private and public borrowers.

4.3 "Reserves policy"

In the context of unconventional monetary policy "reserves policy" plays an important role. Borio and Disyatat (2009, p. 8) define "bank reserves policy" as a policy where the "central bank sets a specific target for bank reserves regardless if how this counter-balanced on the asset side of its balance sheet." This approach is based on the assumption that "an expansion of bank reserves endows banks with additional resources to extend loans, adding power to balance sheet policy" (Borio and Disyatat (2009), p. 18).

Under normal conditions our price-theoretic money supply model shows that the decision to make loans depends on the refinancing rate of central banks and that at a rate of zero the limits of conventional policy are reached. A rate of zero is identical with the satiation level and an increase of the supply beyond this level has no effect on lending decisions. This is the main difference between a price-theoretic approach and the simple mechanics of the traditional multiplier approach which assumes that an increase of reserves will automatically lead to an increase in loans.

As we have shown in this section quantitative easing can have the effect that the banking system gets into a net creditor system vis-à-vis the central bank. In this case it is unable to reduce excess reserves. Thus, if a central bank purchases government bonds or private bonds at a large scale, the counterpart is an increasing amount of excess reserves. Such a development can be observed above all in the case of the Federal Reserve and the Bank of England.

Under such conditions a "decoupling" of the policy rate from the level of reserves, which Borio and Disyatat (2009) describe, becomes possible. If the central bank wants to control the money market rate in such an environment the rate for remuneration of excess reserves has to be identical with its policy rate (right part of figure 3)

Our analysis shows that it is misplaced to regard this increase of reserves as an explicit target of an unconventional monetary policy. It is just the other way round. In order to stimulate the economy and to keep long-term interest low central banks have increased the asset side of the balance sheet. As an unavoidable by-product of this policy the liabilities side of the balance sheet also had to be extended which implies increasing excess reserves.

In our view "reserves policy" is above all another word for the central bank financing of high government deficits. This is not only the case in the present situation but also in the "quantitative easing policy" of the Bank of Japan March 2001 through March 2006 which was mainly based on an strong increase of the BOJ's purchases of long-term government bonds (JGBs) from the initial pace of 400 billion yen per month to 1,200 billion per month (at that time an equivalent of 9.6 billion US-Dollar) beginning in October 2002 (Ugai (2007)).

5 Introducing bank regulation into the basic model

In this section we discuss a variation of the loan supply shock, but in contrast to the situation discussed above the shock originates from an external credit rating ("rating shock"). This implies that banks have to hold more equity on their balance sheet, so their marginal costs rise. After an analytical expansion of the basic model, we discuss the consequences of higher capital requirements in the graphical context.

5.1 Analytical description

First, we add equity and supervisory standards as laid down by the Basle II accord to our basic model described in section 2.1. Following the Basle principles banks have to cushion credit risks with equity. The higher credit risks the larger is the equity ratio to the granted loans, so banks have to hold more equity in the balance sheet in comparison to low-risk loans. Therefore, capital requirements fluctuate with the credit rating, which represents the risk class of an investment. In a first step we introduce equity (E^j) into equation 1. Equity yields an interest of i_E so we get the following modified profit equation:

$$\Pi^j = i_C Cr^j_{B/NB} - i_D D^j - i_R \left(Cr^j_{CB/B} - R^j \right) - i_E E^j - O^j - V^j \tag{13}$$

The introduction of equity also requires a change in the bank's balance sheet:

Assets	Liabilities
$Cr^j_{B/NB}$ (Loans to the private sector)	D^j (Deposits of the private sector)
R^j (Minimum reserves)	$Cr^j_{CB/B}$ (Central bank loans)
	E^j (Equity)

Table 6: Simplified balance sheet of bank j supplemented with equity

Setting equity into the profit equation is for instance in line with Aguiar and Drumond (2007). The pool of refinancing options is broadened by the item E^j and furthermore the equity regulation according to Basle II holds:

$$\alpha^E = \frac{E^j}{Cr^j_{B/NB}} \tag{14}$$

Bank j has to cover the loan amount $Cr^j_{B/NB}$ with α^E percentage of equity in its balance sheet. The lowest equity ratio is $\alpha^E = 8\%$, but it can be higher if the credit rating worsens. So the bank has to cover the granted loans with more equity (Everling et al. (2008)).

External investors supply more equity while the bank makes a capital increase. The return on equity must exceed the risk free interest rate i_R, because investors only provide funds to the bank if the markup on the interest rate is large enough. Due to a declining rating of credit assets a gap in the equity requirement occurs, which the bank has to close with an additional capital injection.

Using the stylized balance sheet (Table 6) and equation (14) as an supplemental constraint, we can easily rearrange the profit equation:

$$\begin{aligned} \Pi^j &= i_C Cr^j_{B/NB} - i_D D^j - i_R \left(Cr^j_{B/NB} - D^j - \alpha^E Cr^j_{B/NB} \right) - i_E \alpha^E Cr^j_{B/NB} - O^j - V^j \\ &= \left[i_C - i_R - \alpha^E \left(i_E - i_R \right) \right] Cr^j_{B/NB} - \left[i_D - i_R \right] D^j - O^j - V^j \end{aligned} \tag{15}$$

By inserting equity the interest rate spread between the loan and the refinancing interest rate diminishes by the term $\alpha^E(i_E - i_R)$. Therefore, we can derive the loan supply of the bank j in a similar matter as we did above:

$$\begin{aligned} \frac{\delta \Pi^j}{\delta Cr^j_{B/NB}} &= i_C - i_R - \alpha^E\left(i_E - i_R\right) - \frac{2\beta Cr^j_{B/NB}}{Y} \overset{!}{=} 0 \\ \Rightarrow Cr^j_{B/NB} &= \frac{\left[i_C - \left(1-\alpha^E\right) i_R - \alpha^E i_E\right] Y}{2\beta} \end{aligned} \tag{16}$$

Further, we aggregate the loan supply of the whole banking system:

$$Cr_{B/NB} = \sum_{j=1}^{n} Cr^j_{B/NB} = \frac{\left[i_C - \left(1-\alpha^E\right) i_R - \alpha^E i_E\right] nY}{2\beta} = \frac{nY}{2\beta}\left[i_C - \left(1-\alpha^E\right) i_R - \alpha^E i_E\right] \tag{17}$$

The residual profit is used for paying the fixed costs (O), so the profit equals to zero. Fixed costs are for instance bonus payments to the bank management.
The effect of higher capital requirements is similar to a restrictive monetary policy, because the equity restriction increases the marginal costs of lending. As an analytic proof, we look at the axis intercept of the loan supply $i\ _C|_{Cr=0} = i_R + \alpha^E\left(i_E - i_R\right)$ and realize, that the curve is upward slopping $\alpha^E\left(i_E - i_R\right)$. This implies that higher capital requirements lead to an upward shift of the loan supply as banks have to cover loans with a additional amount of equity, which rises the costs of lending. In addition, equation 17 shows, that α^E% of marginal lending costs are lead back to the equity return and $\left(1-\alpha^E\right)$% to the offical policy rate.

Now we can calculate the new equilibrium on the loan and money market and we get the following loan interest rate:

$$\begin{aligned} Cr_{B/NB} &= Cr^S = Cr^D = \frac{\left(i_C - \left(1-\alpha^E\right) i_R - \alpha^E i_E\right) nY}{2\beta} = \mu + \gamma Y - \alpha i_C \\ \Rightarrow i^*_C &= \frac{2\beta\mu + 2\beta\gamma Y + nY\left[\left(1-\alpha^E\right) i_R - \alpha^E i_E\right]}{nY + 2\alpha\beta} \end{aligned} \tag{18}$$

Plugging the interest rate into the loan demand gives the equilibrium loan amount:

$$\begin{aligned} Cr^* &= \mu + \gamma Y - \alpha \frac{2\beta\mu + 2\beta\gamma Y + nY\left[\left(1-\alpha^E\right) i_R - \alpha^E i_E\right]}{nY + \alpha 2\beta} \\ &= \frac{(nY)\left(\mu + \gamma Y - \alpha\left[\left(1-\alpha^E\right) i_R - \alpha^E i_E\right]\right)}{nY + 2\alpha\beta} \end{aligned} \tag{19}$$

To calculate the corresponding equilibrium monetary base we use the multiplier relation:

$$\begin{aligned} m &= \frac{M}{B} \\ \Rightarrow B^* &= \frac{(nY)\left(\mu+\gamma Y-\alpha\left[\left(1-\alpha^E\right)i_R-\alpha^E i_E\right]\right)}{m\left(nY+2\alpha\beta\right)} \end{aligned} \tag{20}$$

5.2 Graphical description

The reaction of the central bank to a rating shock can be derived as follows: The equity ratio α^E increases when the credit rating worsens, so banks have to hold more equity per granted loans due to the higher risk weight according to the Basle II regulations. As a consequence the loan supply curve in figure 8 shifts to top $(Cr_1^S\left(i_0^R\right))$ and we get a similar outcome that we have seen in the case of a supply shock. The loan amount declines to M_1 while loan interest rates rises (i_1^C). The only possibility to compensate this shock is lowering refinancing interest rates, so loan supply shifts back to the old equilibrium A.

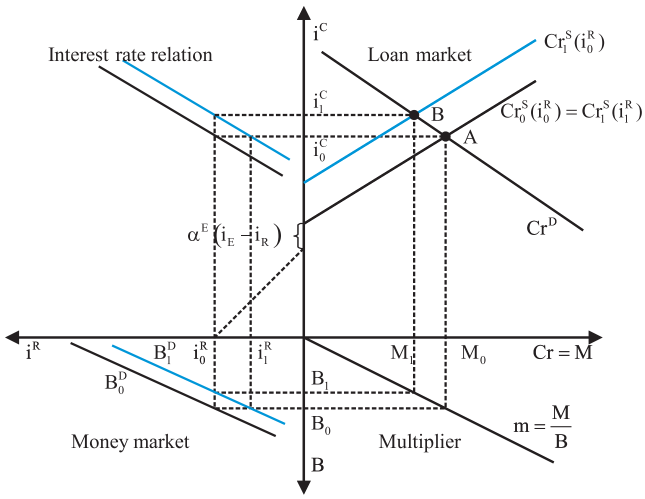


Figure 8: Credit rating shock

5.3 Equity withdrawal

In the next section, we discuss the problem of an abrupt equity withdrawal e.g. because of losses or write-downs in the banks loan portfolio. The starting point is the theoretical framework of section 5.1. A given amount of equity $(\overline{E})$ determines the maximal loan amount:

$$Cr_{B/NB}^{\max} = \frac{\overline{E}}{\alpha^E} \tag{21}$$

As a modification to the last chapter we assume that banks do not have the ability to acquire unlimited equity e.g. because of an economic crisis respectively banks are confronted with a sudden equity drawback. Following equation 21, the loan supply is rationed at a certain point of Cr respectively M and becomes in vertical line, so a credit crunch can occur. Restriction 21

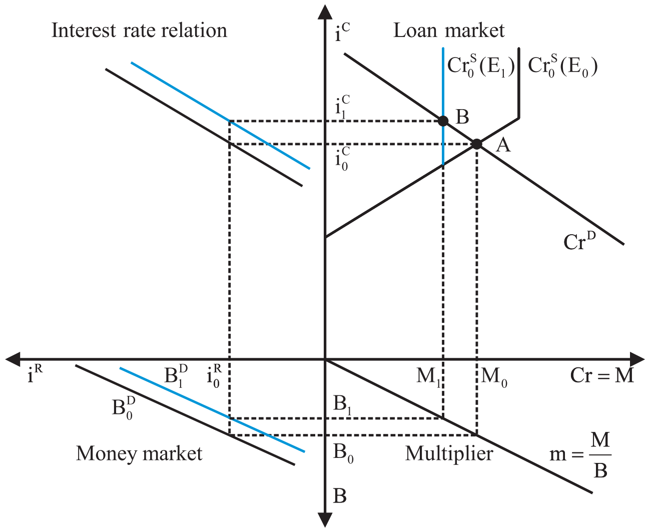


Figure 9: Credit crunch triggered by insufficient equity endowment

does not hold, if the equity of the bank is greater or equal the loan amount times the equity ratio α^E in the equilibrium. In figure 9 we simulate an sudden equity drawback ($E_0 > E_1$), so the vertical loan restriction line shifts to the left. In spite of an unchanged interest rate policy the loan amount shrinks to the level M_1. Even a lower refinancing interest rate does not guarantee, that the old equilibrium is reached. As mentioned above this is due to the reduced equity, so that the loan amount M_1 is the maximum. The economy is experiencing a credit crunch. In such a situation banks charge an interest rate at an excessive level of i_1^C. The solution for that serious problem is only a recapitalization, so the equity injection removes the loan restriction line back to the right. As a conclusion, we see that in such a situation the central bank cannot fully compensate the shock with its conventional targeting mechanisms on the money market and has to fall back to unorthodox instruments.

6 Maturity transformation

The following section deals with the topic of maturity transformation. We assume that banks give multi-periodical loans to the private sector, but have to refinance them every period. As a first step, we rearrange the model with multi-periodical loans which leads to the following version of the profit equation of the representative bank j:

$$\Pi_t^j = \sum_{i=0}^{T} i_{C,t-i} Cr^j_{B/NB,t-i} - i_{D,t} D_t^j - i_{R,t}\left(Cr^j_{CB/B,t} - R_t^j\right) - i_{E,t}E_t^j - O_t^j - V_t^j \tag{22}$$

This also requires a change in the banks' balance sheet, because the balance sheet consists of loans granted in previous periods:

Assets	Liabilities
$\sum_{i=0}^{T} Cr^j_{B/NB,t-i}$ (Loans to the private sector)	D_t^j (Deposits of the private sector)
R_t^j (Minimum reserves)	$Cr^j_{CB/B,t}$ (Central bank loans)
	E_t^j (Equity)

Table 7: Simplified balance sheet of bank j supplemented with multi-periodical loans

As in the previous sections, we rewrite equation (22) using table 7 and the equity constraint (equation 14) in the common form of interest rate spreads:

$$\begin{aligned}\Pi_t^j &= \sum_{i=0}^{T} i_{C,t-i} Cr^j_{B/NB,t-i} - i_{D,t} D_t^j - i_{R,t}\left(\sum_{i=0}^{T}(1-\alpha^E)Cr^j_{B/NB,t-i} - D_t^j\right) \\ &- i_{E,t}\alpha^E \sum_{i=0}^{T} Cr^j_{B/NB,t-i} - O_t^j - V_t^j \\ &= \sum_{i=0}^{T}\left[i_{C,t-i} - \left(1-\alpha^E\right) i_{R,t} - \alpha^E i_{E,t}\right] Cr^j_{B/NB,t-i} - \left[i_{D,t} - i_{R,t}\right] D_t^j - O_t^j - V_t^j\end{aligned} \tag{23}$$

Loans granted in period t have therefore an impact on the bank's profit in the periods following t due to its duration. Thus, the bank is confronted with a multi-periodical problem and is geared to equation 24, which represents the present value (PV_t^j) of future profits, whereas γ is the discount factor:

$$PV_t^j = \sum_{i=0}^{\infty} \gamma^i \Pi^j_{t+i} \tag{24}$$

Maximizing (24) gets an optimal multi-periodical loan supply for bank j, respectively for the whole banking system (equation 26):

$$\frac{\delta PV_t^j}{\delta Cr^j_{B/NB,t}} = \sum_{i=0}^{T} \gamma^i \left[i_{C,t} - E_t i_{R,t+i} - \alpha^E\left(i_{E,t} - E_t i_{R,t+i}\right)\right] - \frac{Cr^j_{B/NB,t} 2\beta}{Y} \overset{!}{=} 0 \tag{25}$$

$$\Rightarrow Cr_{B/NB,t} = \frac{\left(1-\gamma^T\right) nY}{\left(1-\gamma\right) 2\beta}\left[\sum_{i=0}^{T}\left(i_{C,t} - \left(1-\alpha^E\right) E_t i_{R,t+i} - \alpha^E\left(i_{E,t}\right)\right)\right] \tag{26}$$

As a difference to the previous loan supply banks have to build expectations about the future refinancing conditions ($E_t i_{R,t+i}$) and discount the future revenues by the factor γ. Rising interest rate expectations lead to a lower loan supply and have therefore an analogue effect as a rise in interest rate by the central bank. Equation 26 reveals that the central bank can encourage the bank j to extend loan by steering expectations.
The central bank can increase the liquidity supply to banks to guarantee the loan supply by granting liquidity with duration of more than one period. However, we assume that the duration of loan and refinancing are not congruent, because the result would be the same as seen in section 2.1. The duration of the loans are T periods and refinancing liquidity is granted through period m, but $T > m$. The formal expression changes in the following way:

$$\begin{aligned}
\Pi_t^j &= \sum_{i=0}^{T} i_{C,t-i} Cr^j_{B/NB,t-i} - i_{D,t} D_t^j - \sum_{j=0}^{m} i_{R,t-j} \left(\sum_{i=0}^{T} (1-\alpha^E) Cr^j_{B/NB,t-i} - D_t^j \right) \\
&- i_{E,t} \alpha^E \sum_{i=0}^{T} Cr^j_{B/NB,t-i} - O_t^j - V_t^j \\
&= \sum_{i=0}^{T} \left[i_{C,t-i} - \sum_{j=0}^{m} i_{R,t-j} - \alpha^E \left(i_{E,t} - \sum_{j=0}^{m} i_{R,t-m} \right) \right] Cr^j_{B/NB,t-i} - \left[i_{D,t} - \sum_{j=0}^{m} i_{R,t-j} \right] D_t^j - O_t^j - V_t^j
\end{aligned} \tag{27}$$

Therefore, we can derive the optimal loan supply of the whole banking system:

$$Cr_{B/NB,t} = \frac{\left(1-\gamma^T\right) nY}{(1-\gamma)\, 2\beta} \left[\sum_{j=0}^{T} \left(i_{C,t} - \left(1-\alpha^E\right) \left(\sum_{j=0}^{m} i_{R,t+j} + \sum_{j=m}^{T} E_t i_{R,t+j} \right) - \alpha^E i_{E,t} \right) \right] \tag{28}$$

To calculate the quantitative effect of the enhanced long term refinancing supply (Cr_t^{LTL}) we subtract equation (28) with (26):

$$\begin{aligned}
\Delta Cr_t &= Cr_t^{LTL} - Cr_t^{Basic} \\
&= \frac{\sum_{i=0}^{n} \gamma^i \left[\begin{array}{c} i_{C,t} - \sum_{j=m}^{n} E_t i_{R,t+j} - \alpha^E \left(i_{E,t} - \sum_{j=m}^{n} E_t i_{R,t+j} \right) - \\ \left[i_{C,t} - E_t i_{R,t+i} - \alpha^E \left(i_{E,t} - E_t i_{R,t+i} \right) \right] \end{array} \right] nY}{2\beta} \\
&= \frac{\left(1-\gamma^T\right) nY}{(1-\gamma)\, 2\beta} \left(\sum_{i=1}^{m} \left[\left(1-\alpha^E\right) \left(E_t i_{R,t+i} - i_{R,t} \right) \right] \right)
\end{aligned} \tag{29}$$

If the expected refinancing interest rate exceeds the effective realized interest rate, the central bank can effect lending activity by issuing multi-periodical refinancing operation. Therefore the spread $E_t i_{R,t+i} - i_t$ is positive and lending is widened. Due to this fact central banks as the ECB use multi-periodical refinancing operations up to one year to support the lending process and long-term refinancing operations are even the most relevant refinancing resources of the central bank since the beginning of financial crisis. (for an overview of monetary policy actions since August 2008 see European Central Bank (2009)).

7 Conclusion

For an analysis of the shocks which affected financial markets in the last few years and an understanding of the conventional and unconventional responses of central banks a comprehensive model of the money supply is required, which goes far beyond the traditional multiplier approach. We present a simple model in which a central bank targets the banks' loans via the money market by setting its refinancing interest rate. This is in line with the practice in almost all central banks which use a interest rate policy. We show that in principle every occurring shock can compensated by the central bank and therefore a given amount of loans can be maintained. The outcome changes if the economy is hit by a huge shock which would require a negative refinancing rate. This requires a switch to instruments of unconventional policy like the so called "qualitative" or "quantitative easing".

In addition we expand the model by supervisory regulation according to the Basle II accord and introduce loans with different maturity. Term transformation is an important function of the banking system, but this function has been disturbed by the current financial crisis. We demonstrate that the central bank can support the multi-periodical lending process by providing an enhanced long term lending. An example for this approach is the increased provision of long-term loans by the ECB.

The present article therefore contains all relevant instruments, that central bank used since the begin of financial crisis to guarantee the lending process and prevent the unfavorable situation of a "credit crunch".

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