DNB Working Paper
No. 740 / March 2022

Excess liquidity and the usefulness of the money multiplier

Jan Marc Berk and Jan Willem van den End

DeNederlandscheBank
EUROSYSTEEM

Excess liquidity and the usefulness of the money multiplier

Jan Marc Berk and Jan Willem van den End*

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

Working Paper No. 740

De Nederlandsche Bank NV
P.O. Box 98
1000 AB AMSTERDAM
The Netherlands

March 2022

Excess liquidity and the usefulness of the money multiplier

Jan Marc Berk[a,b], Jan Willem van den End[a,c]

[a] De Nederlandsche Bank, the Netherlands

[b] University of Groningen, the Netherlands

[c] Vrije Universiteit, the Netherlands

February 2022

Abstract

Despite being an identity, the money multiplier (MM) is also a useful summary of the financial intermediation process as it can be interpreted as the rate of substitution between inside and outside money. By modelling the supply and demand for inside and outside money, we provide this rate of money substitution with behavioural underpinnings. Our model illustrates how the creation of large outside money balances by central banks induces behavioural changes, creating an environment characterised by a low MM and low market interest rates. The outcomes of switching regressions for the US and the euro area confirm that such a low regime can be distinguished from a conventional MM regime. The low regime reflects a state in which the functioning of the financial system changes fundamentally due to excess supply of reserves. This so-called excess liquidity trap has adverse economic consequences, is persistent, and cannot be solved by monetary policy alone. We argue that government and supervisory measures taken during the pandemic provide an example of supporting policies that are effective in escaping the excess liquidity trap.

JEL classification: E51, E52

Keywords: monetary policy; interest rates; money multipliers

---

* Corresponding author. Email address: w.a.van.den.end@dnb.nl

For useful comments we would like to thank Maurice Bun, Niels Gilbert, Aerdt Houben, Tom Hudepohl, Jan Kakes, Yvo Mudde, Sebastiaan Pool, Sweder van Wijnbergen and participants in various seminars and conferences. Martin Admiraal provided excellent data assistance. Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank or the Eurosystem.

1. Introduction

The money multiplier (henceforth MM) is a concept that could figure prominently in a new edition of the amusing book "Zombie Economics" (Quiggin, 2010). Born as an identity without any causal interpretation, the MM evolved into a key causal ingredient in the money supply framework and monetary policy strategy of the monetarist revolution, following the landmark work by Friedman and Schwartz (1963). Of course, the usefulness of this causality rested on shaky foundations, as the implicitly assumed stability (and exogeneity to monetary policy) of the behaviour of the general public and financial sector proved to be an illusion[1], given innovations in the payments system and the financial sector in general. This implies that not only the relationship between base and broad money is unstable, but also the relationship between broad money and spending. Moreover, the fondness of academia for a MM with causality running from base money (or outside money) to broader monetary aggregates (or inside money) ran counter to monetary policy implementation procedures since decades applied by most major central banks. And central bankers were not shy to communicate (see, for example, Tucker, 2004) that the fiction of the central bank manipulating the amount of base money in such a way as to achieve a certain supply of money that would (ceteris paribus) equilibrate the money market at the interest rate desired for the monetary stance was exactly that – a fiction. In short, the MM is only a bookkeeping identity and is a useless concept for monetary policy purposes.

This uselessness is well-known, see for example Goodhart (2009, 2010), Disyatat (2008) and Stella et. al (2021). So why write a paper on the MM anyway? The reason is also to be found in this earlier literature stressing the uselessness of the MM. A major argument in that literature is the inelasticity of base money with respect to the (policy) interest rate. This inelasticity was shown to hold as long as policy rates were comfortably above their (effective) lower bound. Clearly, the latter situation is not the reality we have been living in since around 2010. Instead, it seems to be the case that multiple amounts of base money are consistent with a single policy interest rate (zero, or effectively so). One could even consider a regime in which – under the condition that liquidity supply exceeds demand for central bank reserves – the amount of base money indeed becomes the policy instrument. So what happens if the policy interest rate loses its potency and the central bank instead employs its balance sheet as the monetary policy instrument? What, if any, are the consequences for causal interpretations of the MM? These questions are the motivation for this paper from a conceptual perspective.

From a policy perspective, the MM is also worth to be revisited. Interpreted as the relative value of inside money in terms of outside money, the MM functions as a metric of the degree to which frictions inhibit the financial sector to allocate liquidity efficiently across sectors and time. These frictions impair monetary transmission, the effectiveness of monetary policy in achieving its objectives and might signal financial stability problems. Consider for example the base money expansion through unconventional

[1] The idea of causality running from base money to broad money was a confluence of this assumed stability and central banks setting binding reserve requirements.

monetary policy measures by central banks such as the ECB and the Fed since the Global Financial Crisis (GFC). These measures have created huge excess reserves in the banking systems of the euro area and the US. For different reasons this outside money creation did not go in tandem with similar increases of inside money, reflected in a low marginal rate of money substitution. As a consequence, the excess liquidity remained trapped in the banks, as reflected in a low MM, i.e. a low rate of substitution between inside and outside money. We argue that the MM is a useful concept to explain this liquidity trap, since it confronts outside and inside money dynamics with behavioural determinants of economic agents, as reflected in demand and supply of money in its various forms. This follows the broad approach of monetary economics as advocated by Tobin (1963). By modelling the behaviour in the market for reserve balances and bank loans we link the excess liquidity trap to the price of broad money, i.e. the market interest rate. Thereby the excess liquidity trap discussed in this paper can be seen as a financial sector variant of the (Keynesian) macro-economic liquidity trap. The latter is associated with a flat yield curve anchored by the policy rate at the lower bound, inducing an infinite demand for liquidity (see Sutch, 2014).

The data clearly show a regime with very low interest rates and excess reserves and hence a low MM. We argue that behaviour of economic agents can reinforce such a tendency and that other agents than the central bank can help to escape from the excess liquidity trap, e.g. by removing frictions for inside money creation. We illustrate this by the a-typical dynamics of inside and outside money in the pandemic. In the pandemic both base money and broader monetary aggregates displayed vigorous growth. This is a-typical in a crisis, because monetary transmission – inter alia depending on banks and financial markets - is then usually strained, leading to lackluster broad money growth. We will discuss the mechanisms behind the a-typical correlation between outside and inside money, by showing that policy measures of governments and supervisors have been a determining factor for keeping monetary dynamics away from the trapped regime.

The rest of this paper is structured as follows. In the next section we define the money multiplier and its components. Section 3 describes the model framework that links inside to outside money. Section 4 describes the development of the MM over four decades in the US and the euro area, which puts the MM dynamics during the pandemic into perspective. In section 5 we estimate the MM regimes by switching regressions. Section 6 discusses policy implications and section 7 concludes.

2. Money concepts

In essence, the money multiplier is an identity that describes the relationship between outside and inside money. Lagos (2010) defines outside money as money that is either of a fiat nature (unbacked) or backed by some asset that is not in zero net supply within the private sector, e.g. gold. This qualifies outside money as coming from outside the private sector. More formally, outside money, also called base money or high powered money (H), is defined as the sum of banknotes circulating in the economy (C) and reserves that banks hold at the central bank (reserve balances, R)[2]:

$$H \equiv C + R \qquad (1)$$

Lagos (2010) defines inside money as an asset representing, or backed by, forms of private credit. So the price of inside money is determined by the interest rate in the private credit market. More precisely, for the asset to qualify as money, the underlying credit should be extended by the money issuing sector – i.e. the banks. They create deposits by lending to or buying assets from non-banks, whose deposit accounts (i.e. the asset of the money holding sector) are credited. The definition of money thus implies that developments in non-bank finance affect the MM if financial transactions are settled by banks, or result from asset purchases by the central bank from non-banks.[3] Thereby the MM captures the primary sources of financialization. It does not reflect financial transactions settled among non-banks, which is a limitation of the MM as indicator of financial intermediation. Hence inside money, or the money stock (M), is defined as the sum of C and bank deposits (D_i) held by non-bank private agents. The subscript i reflects the fact that there are various forms of bank deposits, and that these various forms are the distinguishing feature of the various measures of money supply (M1, M2 or M3):

$$M_i \equiv C + D_i \quad , \quad \text{with } i=1, 2, 3 \qquad (2)$$

In addition, reserves that banks are required to hold at the central bank (required reserves, RR) are distinguished from reserves that banks hold voluntarily at the central bank (excess reserves, ER):

$$R \equiv RR + ER \qquad (3)$$

RR are set by a regulator (either for monetary control or for prudential reasons), and ER are determined by banks on the individual bank level. On the aggregate level, (opportunity) costs of holding ER, which are created by the central bank and end up at the asset side of the banking sector, will adjust in order for banks to absorb ER.[4] In between there can be a flow of transactions, depending on portfolio choices of banks and transactions between non-bank agents with accounts at different banks. ER is made up of an autonomous component (working balances of reserves that banks use to pay the central bank for cash

[2] Vault cash of the banks - an empirically insignificant part of base money - is included in bank reserves, for ease of exposition.

[3] If non-banks trade assets with other non-banks the money supply does not change; it only leads to a shift of a bank deposit from the buyer of the asset to the seller. Neither does inside money change if a non-bank financial institution extends credit to another non-bank agent. This form of credit creates a liability at the financial institution’s balance sheet, which does not qualify as money as it does not offer liquidity services similar to bank deposits.

[4] Tobin (1963) in his classic paper refers to the “hot potato” analogy (p.12). This in contrast to inside money, where an economic mechanism exists for both its creation and extinction.

withdrawals of customers) and a non-autonomous component that is for instance related to banks' preferences to hold reserves as safe and liquid assets. We will specify both components and elaborate on the behavioural factors behind *ER* in the next section. There we will illustrate why the distinction between autonomous (*AR*) and non-autonomous reserves (*NAR*) is useful to describe the post-GFC market situation. So, *R*=*AR*+*NAR* with *AR*= *RR*+*AF* where *AF* stands for working reserve balances. Clearly, *NAR* = *ER* - *AF*.

After some simple manipulation of (1)-(3) we get the following equation:

$$M_i \equiv \frac{1+c}{c+e+r} H \qquad (4)$$

with $c \equiv C/D_i$, $e \equiv ER/D_i$ and $r \equiv RR/D_i$.

Eq. (4), an identity, defines the money multiplier $\frac{1+c}{c+e+r}$, taking *H* to the left-hand side.[5] As an identity, it obviously has to hold at all times and by itself does not imply any causal relationship. Changes in the supply of inside money can be decomposed into three factors: (i) changes in the amount of outside money *H*, holding the parameters *r*, *c*, *e* constant. The latter are governed by the behaviour of the policy maker, the public (money holding sector) and the banks (money issuing sector); (ii) changes in one or more of these behavioural parameters, assuming a constant amount of outside money and (iii) the interaction between (i) and (ii).

Figure 1 illustrates, using monthly data for the euro area and the US during 1981-2021, the decomposition of the (year-on-year) change of inside money (*M*) into movements of base money, the combined behavioural parameters (i.e. the first term on the RHS of eq. (4)) and the interaction between both. The graph illustrates that none of the components of the MM remain constant over time. In addition, it seems to be the case that the movements in outside money and behavioural parameters are inversely related. Finally, these factors were much more stable in the period before the GFC.

[5] From now on, we will drop the subscript for ease of exposition. In our empirical work below, we will use M3 for the euro area and M2 for the US, and the scope of the deposits used is consistent with the statistical definitions of the money stock variable.

Figure 1. Decomposition of inside money M (year-on-year growth rate in decimals)

A. Euro area *B. US*

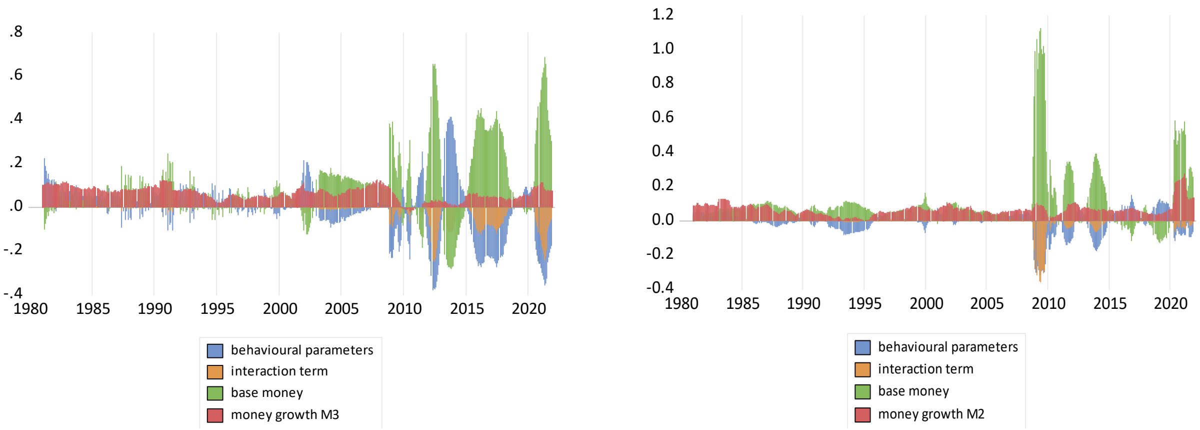
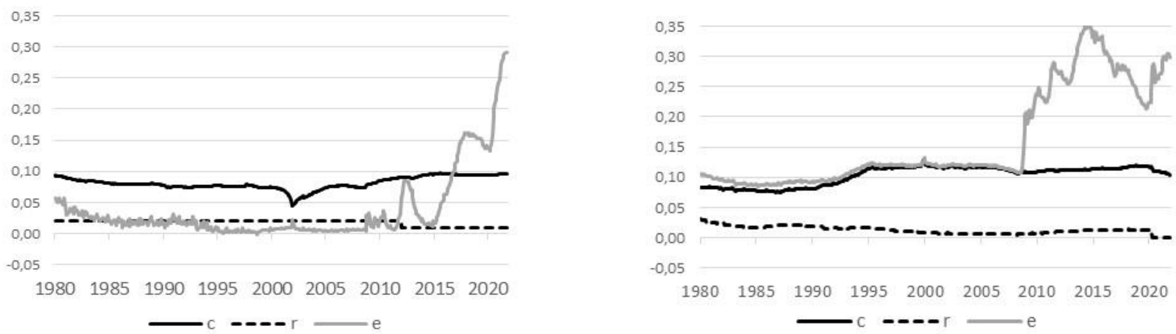


Figure 2 presents the behavioural parameters *c*, *e*, *r*, for the US and the euro area. The parameter levels in both regions a priori differ due to differences in financial regulation (*r*), financial structures and preferences of economic agents (*c*, *e*). Since the GFC, it is primarily the increased holdings of excess reserves by banks (relative to bank deposits) that changed the MM. The excess reserves are determined by the central bank on the aggregate level, based on monetary policy considerations.[6] In particular since the GFC central banks have expanded *ER*, partly as a result of Quantitative Easing (QE).

Figure 2. Money multiplier parameters

A. Euro area *B. US*



Note: c = C/D; r=RR/D. e=ER/D, with D = M3 – repos (euro area); D = M2 (US).

We define the first factor of the abovementioned decomposition as the marginal rate of money substitution (marginal MM) which reads as follows:

$$\Delta M \equiv \frac{1+c}{c+e+r}\Delta H \qquad (5)$$

[6] Interbank transactions or transactions by clients of different banks can shift reserves from one bank to another.

By measuring the change of broad or inside money relative to the change of base or outside money (holding the behavioural parameters constant), this factor represents the elasticity of inside money with respect to outside money. The marginal rate of money substitution is a useful concept to examine the MM, given that the behavioural factors behind movements of inside and outside money usually relate to dynamic interactions between agents' (portfolio) responses and economic conditions, such as low interest rates. The marginal MM more closely reflects such dynamics than the MM defined in eq. (4), since it also captures temporary deviations from longer-term movements in the MM.

3. Model framework

In this section we provide the MM with behavioural underpinnings, by modelling the supply and demand for outside and inside money. We model the behaviour of different sectors in the economy, while indicating when individual bank responses are a distinguishing factor. The model allows for two states: one in a regime where reserves are scarce ("normal MM regime") and one in the regime with excess reserve supply ("low MM regime"). In both regimes the MM is the outcome of a set of behavioural equations, for two markets that determine inside and outside money: the market for reserve balances and the market for bank loans (implictly taking into account the bank deposit market as explained below).

3.1.Market for reserve balances

Demand and supply for outside money, i.e. reserve balances, are settled in the money market (assuming *C* is determined outside the model). In this market, banks' demand for reserves (R_d) and the supply of reserves (R_s) by the central bank come together. Based on existing models of the money market (e.g. Brunner, 1994; Bernanke and Mihov, 1998; Afonso et al., 2020), we derive the supply and demand for reserves as

$$R_d = -\lambda\,(i_R - i_{ER}) + \bar{v}^d + v^d \qquad (6)$$

$$R_s = \bar{v}^s + v^s \qquad (7)$$

Reserve demand first and foremost depends on the opportunity cost for banks of holding them, ie the costs if they borrow from the central banks and hold the liquidity as a central bank deposit. This is represented by the differential between the money market rate (i_R) and the central bank deposit rate (i_{ER}). Two additional demand components that we identify – both not primarily driven by movements in opportunity costs - are fixed, autonomous reserve demand ($\bar{v}^d$) and the demand for excess reserves (v^d). The former includes demand for required reserves (*RR*) and autonomous factors (demand for working balances of reserves (*AF*), related to banknotes in circulation and government balances at the central bank). Excess reserve demand is determined by the preferences of banks (and the yield they implicitly attach) to hold central bank reserves as liquid and safe assets for precautionary reasons or for regulatory reasons. Regulatory reforms implemented after the GFC and structurally higher risk aversion are commonly cited as factors that have boosted demand for safe and liquid assets among economic agents (Grandia et al., 2019). Parameter λ (with $\lambda > 0$) is the elasticity of reserve demand related to the opportunity costs of holding reserves. This parameter depends on the terms and conditions at which the central bank provides reserves when it conducts its monetary policy (Åberg et al., 2021). If the allottment of reserves is more generous for instance by extended refinancing operations, λ is lower. This will be reflected in a flatter demand curve (Figure 3, panel C).

Reserve supply consists of two components: a fixed, autonomous reserve supply ($\bar{v}^s$) and a monetary policy, or supply shock (v^s). The former includes the supply of reserves to accommodate *RR* and reserve demand related to autonomous factors. While the central bank can adjust the reserve requirement for monetary policy purposes, it will always provide sufficient reserves to banks to allow them to satisfy *RR* and to balance demand stemming from autonomous factors (*AF*), since it will not let shocks in those factors influence the market interest rate. This implies that $\bar{v}^s = \bar{v}^d$.

In what we label as the normal reserve regime, the central bank aims to clear the money market at a certain level of the interest rate, that it chooses as the operational target variable of monetary policy. In order to achieve this, it maintains a liquidity shortage to ensure a certain positive reserve demand by banks. The central bank then determines the marginal price of reserve balances (money market rate i_R), which is the outcome - not of the total quantity of reserves in the system but - of the distribution of reserves among banks. Maintaining a scarcity of liquidity implies discouraging banks to hold reserves (over-and-above the autonomous component $\bar{v}^d$) via the opportunity costs for holding them. The central bank then balances the supply and demand for reserves in order to keep the money market rate i_R in line with the policy rate i_P. The latter is set by the central bank based on macroeconomic considerations (and often formalised using a policy rule such as the famous Taylor (1993) interest rate rule, see Woodford (2003) for an extensive discussion) and is not determined by the supply of reserve balances. This separation principle[7] holds in the normal regime.

In our low reserve regime the central bank implements monetary policy not by maintaining an excess demand but an excess supply of liquidity, implying having a level of reserve supply as the operational target. In these so-called floor systems (already used by some central banks prior to the GFC) the central bank structurally supplies an excess of reserves. As in the normal regime, the market for reserve balances will clear via adjustment of the opportunity cost of holding reserves. That is, market rates will decrease

[7] I.e. explicitly distinguishing between the *determination* of the desired policy rate and the *implementation* of this rate using the operational instruments of monetary policy. In the following, we assume (unless stated otherwise) that the desired monetary policy rate remains unchanged, in the face of various shocks. Not all monetary policy rules are interest rate based, see for example the base money monetary policy rules proposed by McCallum (1984, 1985, 1987) in the context of nominal GDP targeting.

until the (negative) opportunity costs will make it attractive for the marginal bank to absorb the reserves.[8] This illustrates that the separation principle does not require a reserve shortage. Put differently, conventional monetary policy (ie aligning align i_R with i_P) can be conducted in conditions of a structural reserve surplus as well as deficit (it does imply using a different central bank interest rate as the main instrument to implement monetary policy).[9] Note that in both the normal and the low regimes it is an interest rate *differential* that is pivotal for the central bank for its policy implementation (management of liquidity); it is quite independent of the *level* of any specific interest rate.

Total reserve supply R_s is represented by the vertical supply curve in Figures 3 and 4, panel C. The balance between ν^d and ν^s determines the MM regimes:

Normal regime (reserve scarcity): $\nu^s < \nu^d$

Low regime (excess reserve supply): $\nu^s \geq \nu^d$

Both regimes: $\bar{\nu}^s = \bar{\nu}^d$

When the money market is in equilibrium it holds that,

$$R_d = R_s$$

$$-\lambda\,(i_R - i_{ER}) + \bar{\nu}^d + \nu^d = \bar{\nu}^s + \nu^s\,,$$ and after rearranging terms, given $\bar{\nu}^s = \bar{\nu}^d$

$$i_R = i_{ER} + \frac{1}{\lambda}(\nu^d - \nu^s) \qquad (8)$$

The distinguishing feature between the two regimes (normal versus low) is the sign of the opportunity cost component $(i_R - i_{ER})$. An imbalance in the reserves market will, in equilibrium, be reflected in the opportunity cost variable. Eq. (8) yields i_R as a function of supply and demand for *ER*, and policy parameter i_{ER}. It implies that in the normal regime equilibrium, when excess reserve demand is higher than supply, a positive opportunity cost is needed to align demand with this lower level of supply, hence $i_R > i_{ER}$ (Figure 3, panel C). In the low regime equilibrium, the central bank satiates the market with excess reserves and equilibrium requires a commensurate negative interest rate spread to ensure that banks absorb these excess reserves[10]. This equilibrium is the point at the flat part of the demand curve

[8] Not all market participants (usually non-banks) have direct recourse to central bank liquidity facilities. Market rates can therefore decline below the central bank deposit rate.

[9] This is of course well-known, see for example the contributions of Goodfriend (2000) and Woodford (2003), p. 26-31. A similar discussion was held (with a similar conclusion) in the context of the question whether a "cashless economy" due to the advent of electronic money would imply the end of central bank control over interest rates, see the contributions in International Finance (2000), 3(2) and Berk (2003).

[10] In this case banks receive a premium for depositing their funds at the central bank vis-a-vis the yield on the market for very short term assets (banks borrow from money market participants without recourse to central bank facilities and deposit the funds at the central bank, paying i_R and receiving the higher i_{ER}). So arbitrage ensures that the

in Figure 4 panel C, where the preferred demand for *ER* is fully accommodated by central bank reserve supply ($\nu^s \geq \nu^d$). As a result, $i_R \leq i_{ER}$. So in the low regime, banks' opportunity cost of holding reserve balances is negative. This implies that reserve demand is determined by the fixed, autonomous component ($\bar{\nu}^d$), which predominantly consists of working balances of reserves, and demand for excess reserves (ν^d), which can be related to the preference to hold safe and liquid assets. In the low regime equilibrium this demand equals reserve supply.

The low regime can also be shaped by the creation of excess reserves (ν^s) exogenous to reserve demand, for instance by QE or extended central bank refinancing operations. Such unconventional monetary policy is associated with a structural excess supply of reserves and a binding lower bound on the *level* of interest rates available for implementing monetary policy (in our case the central bank deposit rate i_{ER}). In this low regime, with policy interest rate i_{ER} stuck at $i_{R,0}$ (see Figure 4, panel C), the choice variable of the central bank is the supply of reserves (R_s). R_s is then not just accommodating the demand for base money in order to steer i_R, but acually is a policy instrument, represented by ν^s in eq. (7). In this case the separation principle does not hold anymore. Balance sheet instruments have effectively been used by central banks since the GFC. With the policy rate at the effective lower bound, central banks have applied balance sheet policies such as QE to influence term premia and other risk premia in bond yields. The aim is that, by reducing such premia, the cost of frictions are reduced, the profitability of loan supply increases, stimulating bank lending and inside money growth.

In equilibrium, the market for reserve balances will clear as the (negative) opportunity cost ("opportunity benefit") will ensure that the marginal bank absorbs the additional reserves. This absorption will be realised via changes in bank behaviour, for example induced by a decrease in their profits from financial intermediation. The opportunity benefit of excess reserve holdings can further be increased by tiering, i.e. by exempting a part ($0 < \theta < 1$) of the excess reserve holdings from a remuneration at i_{ER} if this rate would be negative and the central bank instead offers a zero percent interest rate on the tiered part. This would change eq. (6) in the low regime into,

$$R_d = -\lambda\,(i_R - (1-\theta)\,i_{ER}) \;+\; \bar{\nu}^d \;+\; \nu^d \qquad (6a)$$

With the resulting excess reserve supply ($\nu^s > \nu^d$), the MM is lower than in the normal regime when reserves are scarce, ceterus paribus. In this regime, the excess reserves (*ER*) creation by the central bank drives the parameter *e* in the MM eq. (4). The consequences of behavioral adjustments for the MM are described in more detail in the next sections.

money market interest rate aligns with the policy rate or central bank deposit rate (which becomes the de facto policy rate in the low regime).

3.2. Bank loan market

Lending is determined by supply and demand in the bank loan market, as in Figure 3, panel D. The loan supply and demand curves are modelled as

$$L_d = -\gamma\, i_L + \bar{L}_d \quad (9)$$

$$L_s = \varphi\, m + \bar{L}_s \quad (10)$$

$$m = (i_L - i_R) - n \quad (11)$$

$$n = f(\sigma_L, \kappa_b, \tau_m, \nu^s) \quad (12)$$

$$\frac{\partial n}{\partial \sigma_L} > 0; \quad \frac{\partial n}{\partial \kappa_b} < 0; \quad \frac{\partial n}{\partial \tau_m} < 0; \quad \frac{\partial n}{\partial \nu^s} < 0$$

Loan demand is a function of lending rate i_L in eq. (9), with parameter γ the interest rate elasticity coefficient ($\gamma \geq 0$). This coefficient for instance depends on the share of variable rate loans in the economy (determining the interest rate sensitivity of loan demand). $\bar{L}_d$, $\bar{L}_s$ are the loan amounts determined by factors outside the model. Eq (10) states that the supply of loans positively depends on the profitability of loan provision (margin m, with $\varphi \geq 0$). The margin equals the profits that banks gain from intermediation, which depends on the competition in the banking sector amongst other factors.[11] Following eq. (11), profitability equals the margin between the lending rate i_L and the money market rate i_R net of the banks' costs (n) related to financial frictions. Margin $i_L - i_R$ reflects the compensation for banks' maturity transformation (or interest rate risk), which will generally be positive, since loans usually have a longer maturity than money market liabilities. It is assumed that the compensation for credit risk is part of n, the parameter which captures the costs of financial frictions.

Such frictions are usualy micro-founded, being related to asymmetric information, adverse selection and moral hazard (Brunnermeier et al., 2012). They make it harder for a bank to ascertain the creditworthiness of a borrower and give rise to agency costs and default risk, which requires provisions. So n is a function of loan risk σ_L (eq. (12)), which depends on the strength of borrowers' balance sheets. The positive sign of the derivative of n with respect to σ_L reflects that the cost of frictions increases (decreases) if loan risk rises (falls). This refers to the balance sheet channel (Gertler and Gilchrist, 1993).

Banks themselves may also be subject to frictions, for instance due to a lack of liquidity or capital (i.e. banks' own risk). This refers to the bank lending channel of monetary transmission (Bernanke and Gertler, 1995). This channel implies that a bank that is better capitalized and/or more liquid (i.e. higher κ_b) faces less frictions, for instance because the bank has easier market access. This reduces n, as reflected in the negative partial of κ_b in eq. (12). In other words, a bank that becomes more (less)

[11] Put differently, the margin reflects the premium that compensates banks for various risks mainly interest rate risk, credit risk and market risk, which can relate to financial frictions.

financially sound faces lower (higher) costs of frictions. The economic rationale for this is that an increasing financial strength of a bank lowers its funding and capital costs and so increases its capacity to lend (and vice versa). Empirical research confirms that an increasing capital surplus raises banks' loan growth (e.g. Berrospide and Edge, 2010). The reverse also holds. The loss absorption characteristics (size of equity cushion) and length of banks balance sheets (leverage ratio) will be important in determining the extent to which an increase in excess reserve supply will crowd out bank lending or increase it, see Diamond et al. (2021). The former is much more likely to happen when banks are confronted with binding regulatory constraints (ie capital and leverage ratio requirements).

This also links inside and outside money. When the financial sector is well capitalized, the need for outside money is minimal (for example in terms of the liquidity service it provides, see Goodfriend, 2000) and hence has low value relative to inside money (resulting in a high rate of money substitution, i.e. a high MM). Brunnermeier et al. (2012) show that the effects of frictions on financial intermediation and the macro-economy can be amplified by shocks to risk preferences and liquidity. Such shocks are associated with a contraction of inside money. Monetary policy can mitigate such adverse effects by extending outside money supply to banks.

So, the costs of frictions can be reduced by central bank balance sheet policies. Actually the literature has shown that balance sheet policies can affect the economy to the extent that there are frictions in private intermediation (Gertler and Karadi, 2013). Financial frictions show up in risk premia, which can be reduced by QE and/or extended refinancing operations, since by these instruments the central bank removes risks from the market (e.g. duration risk or credit risk) on to its balance sheet. This implies that excess liquidity creation by central banks lowers the costs of frictions, as reflected in the negative derivative of n with respect to v^s in eq. (12).

Financial market conditions (τ_m) also influence n in eq. (12). Parameter τ_m summarizes various financial market channels that can affect banks' intermediation function, such as confidence effects, risk-taking appetite, market liquidity and asset price developments (see for instance Beyer et al., 2017). Worsening market conditions (i.e. lower τ_m) raise banks' cost of intermediation, for instance because financial market operations require higher provisions, while banks' wholesale funding costs increase if market distress increases (and vice versa). This makes n also a compensation for market risk and is reflected in the negative partial of τ_m in eq. (12).

The equilibrium lending rate i_L is then determined as,

$$L_d = L_s$$

$$-\gamma\, i_L + \bar{L}_d = \varphi\,(i_L - i_R - n) + \bar{L}_s\,, \qquad \text{and after rearranging terms,}$$

$$i_L = \frac{(\bar{L}_d - \bar{L}_s) + \varphi(i_R + n)}{\varphi + \gamma} \tag{13}$$

The model allows us to trace the impact of shocks in the bank loan market. We discuss the effects of a conventional monetary policy shock in i_R (by lowering i_{ER}) and an unconventional monetary policy shock in ν^s which affects the costs of frictions *n*. Given the partial equilibrium nature of our model, the ceteris paribus assumption holds in the discussion below.

- A monetary policy rate cut lowers i_R (as determined in eq. (8b)) and thereby reduces lending rate i_L to a lower new equilibrium level. This follows from eq. (11), which - after rearranging terms - determines i_L as a function of i_R (i.e. $i_L = \ i_R + n + m$). Margin *m* increases in the new equilibrium, given the negative sign of the derivative of *m* with respect to i_R (see Annex 2). Only in the unlikely case that credit demand is insensitive to the lending rate i_L (i.e. $\gamma = 0$) margin m would remain constant after a monetary policy shock, since then there is complete pass-through of the policy rate into the lending rate. In all other cases lending L increases by both a positive credit demand (through lower i_L) and supply effect (through higher m) following a monetary loosening through a decline in i_R.
- An unconventional monetary policy shock through an increase of ν^s reduces risk premia in financial markets and thereby lowers the costs of frictions (*n*). This raises margin *m*, given the negative sign of the derivative of *m* with respect to *n* (see Annex 2). As a result, banks respond by expandingcredit supply, which supports the creation of inside money. The lower costs of frictions (*n*) also reduce lending rate i_L, given the positive sign of the derivative of $i_L$with respect to *n* (see Annex 2). This boosts lending also by a positive demand effect.

To summarise, a conventional monetary policy shock through i_R and an unconventional monetary shock through ν^s (influencing frictions), both affect credit supply and demand. In the model, the effects of both shocks on lending rate i_L and margin *m* are equal, due to the linearity assumption of eq. (9)-(11), and illustrated by the expressions for the partial derivatives of i_L and *m* with respect to i_R and *n* (see Annex 2). The relative impact of both monetary policy shocks is determined by parameter λ in eq. (6). A lower value of λ reflects a higher likelihood of a low regime with excess reserve supply, implying that bank credit is more likely affected by changes in n than by changes in i_R (and vice versa if λ is higher).

The link between bank lending (inside money creation) and central bank reserves is illustrated in Figure 3. In panel D an exogenous positive credit demand shock at $t = 1$ shifts the loan demand curve to the right (dotted downward sloping curve). This enables banks to raise the lending margin to m_1, by which credit supply increases to $i_{L,1}$ (following eq. (10)). The increased loan supply creates deposits (inside money *M*), as reflected in the shift to the right along the inside money curve in panel A, leading to an autonomous extra demand for *RR* (shift of reserve demand curve to the right in panel C). The central bank provides additional reserves to banks to meet the demand for *RR* and to keep the money market rate at $i_{R,0}$. This increases the supply of reserves to R_1 (dotted vertical line in panel C).

The central bank reaction follows Goodhart (2009), who states that the demand for credit (L_d and thereby *D* and *M*) determines reserve balances and thereby *H*. The central bank changes reserves supply (through $\bar{v}^s$ in eq. (7)) in order to maintain its desired level of the interest rate. This implies that the money multiplier works in reverse, with *M* determining *H*. Following a positive credit demand shock at t = 1, and the subsequent central bank response to it, *M* (through *L* and *D*) and *H* (through reserves) stabilise at a higher level. Due to the central bank reaction the MM remains unchanged (*M* and *H* rise proportionally as in panel B).

3.3. Inside money creation

As defined in section 2, inside money (*M*) is partly made up by bank deposits held by non-bank private agents. We subscribe to Schumpeter's famous statement "that it is much more realistic to say that banks create credit, i.e. that they create deposits in their act of lending, than to say that they lend the deposits that have been entrusted to them" (Schumpeter, 1954, p. 1114) by postulating that deposits are created by bank lending. The statement that loan origination creates deposits implies that the money supply is endogenous, a function of the loan generation process determined by the supply and demand for credit as modelled in the previous section.[12]

Following from that, inside money is created by bank loans (*L*) extended to non-bank agents and by assets (*F*) purchased by banks from non-banks. In a closed economy (abstracting from money creation and destruction from abroad) this defines inside money creation as,

$$M = C + D = \bar{C} + \bar{D} + \beta_t (L + F) \tag{14}$$

It states that inside money (*M*) rises in proportion β_t to bank loans and bank asset purchases (*t* denoting the time dimension), as plotted by the inside money curve in Figure 3 panel A (assuming C and $\bar{D}$ are determined outside the model). $\bar{D}$ is the deposit amount determined by factors other than bank lending, such as government transfers to households or firms who keep these funds in a bank deposit. Deposit creation can also originate from a QE transaction, in case the central bank purchases assets (*F*) from (domestic) non-bank agents. Such a transaction is settled by banks, who credit the deposits (*D*) of the non-bank agents in return for the assets, which banks then pass to the central bank in return for central bank reserves. So inside money *M* is created by central bank purchases of assets *F* from non-banks, settled by banks. This makes *F* a function of monetary policy, in particular of the reserve supply shock (v^s) specified in eq. (7). Our approach differs from Acharya and Rajan (2022), who assume that banks

[12]The relationship (direction of causality) between loans and deposits is of course a variant of the core issue in monetary economics, ie the relationship between money and credit. A history of the academic work on this topic can be found in Schumpeter (1954), see also McLeay et al., (2014) and Goodhart and Jensen (2015) for a recent exposition of its macro-economic dimensions and Werner (2016) for the equivalent in the field of finance and banking.

pro-actively issue deposits to finance the increase of central bank reserves on their asset side. We further analyse this channel in the next section.

It is instructive to distinguish between the creation and the (re)distribution of deposits. At the moment of origination (say $t = 0$) of a loan or the purchase of an asset by the marginal bank the deposit account of the money holding sector will always be credited. This implies $\beta_{t=0} = 1$. Eq. (14) can then also be written as deposit supply equation,

$$D_{s,t=0} = \beta_{t=0}(L + F) + \bar{D} \qquad (15)$$

which determines the supply of deposits D_s at the moment of loan origination or asset purchases ($t = 0$) as a function of bank lending *L* and asset purchases *F*. It implies that the extension of loans or purchases of assets by banks from non-bank private agents create deposits. Vice versa, the deposit supply decreases if loans are redeemed or banks sell assets to non-banks.

In contrast to the situation at the moment of origination (where the abovementioned statement of Schumpeter refers to), the process of deposit (re)distribution is governed by portfolio decisions by non-bank deposit holders and banks. These decisions will change the relation between *L*, *F* and *D*, *M* (and hence β) over time. Depositors can substitute deposits *D* for assets that do not count as inside money (such as bonds issued by banks or the central government[13], or banknotes (*C*). Such portfolio decisions of depositors are driven by the risk (σ_D) and return (i_D) of deposits relative to those of alternative bank liabilities, government bonds or banknotes. So the deposit demand can be expressed as,

$$D_d = f(y,\ i_D - i_P\ ,\ i_F,\ \sigma_D) \qquad (16)$$

$$\frac{\partial D_d}{\partial y} > 0; \quad \frac{\partial D_d}{\partial i_D} > 0; \quad \frac{\partial D_d}{\partial i_F} < 0; \quad \frac{\partial D_d}{\partial \sigma_D} < 0$$

This determines deposit demand, in line with Goodhart (2010), as a function of output *y*, the spread between the deposit rate and the central bank policy rate, the returns on alternative assets and deposit risk σ_D. The latter is part of banks' own risk (κ_b), i.e. the financial soundness of a bank. While κ_b determines the portfolio allocation across bank (like deposits) and non-bank liabilities (e.g. government bonds), σ_D also determines the allocation across bank liabilities. This implies that σ_D also determines the allocation across inside money (ic. bank deposits) and bank liabilities that do not count as money (like long-term bank bonds). Changes in output *y* (which determine income and wealth of non-bank

[13] If banks or the central government issue a bond, the liquidity proceeds they receive do not count as inside money, since banks and central governments are non-money holding sectors. Therefore the substitution of *D* for bank or governments bonds reduces inside money *M*. However, if non-bank private agents trade assets amongst each other, *M* does not change, because the trade only leads to a shift of a bank deposit from the buyer of the asset to the seller.

agents) and in the relative asset returns drive portfolio adjustments by non-bank agents so that their deposit demand meets their budget constraint.

The relative risk and return (σ_D and i_D) are endogenous to the funding strategy of banks, who might decide to offer an deposit spread $(i_D - i_P)$ to ensure that customers supply a sufficient amount of deposits, instead of substituting to alternative savings vehicles like bonds (the positive partial of i_D reflects that an increasing deposit rate attracts deposits).[14] Vice versa, a bank could substitute deposits for alternative funding sources if the risk and return of such sources fit with banks' liability management. Such a substitution of funding sources consequently changes a banks' liquidity risk profile and thereby σ_D (the negative partial of σ_D reflects that deposit demand declines if the risk profile of deposits increases).

Banks' asset management determines the composition of *L*, *F* and *ER* on their individual balance sheets. In addition to regulatory parameters, governing both the length and loss absorption characteristics of bank balance sheets, determining factors are the risk and return (interest rates) of assets, relative to the central bank deposit rate (i.e. interest rate i_{ER} on excess reserves), following Tobin's (1969) portfolio approach. For instance, if the yield on high quality liquid assets like government bonds would drop below i_{ER} then banks will substitute bonds (*F*) for central bank reserves (*ER*). This asset swap is then purely driven by banks' portfolio behavior.

So portfolio adjustments by banks and non-banks determine *D*.[15] It implies that over time *t*, the level of *D* may differ from $D_{s,t=0}$ and so parameter β_t may differ from $\beta_{t=0}$ (in which case $\beta_t \neq 1$). Since β_t represents the coefficient of the inside money curve in Figure 3 panel A, its inverse $(1/\beta_t)$ is the loan-to-deposit ratio. This ratio is another driver of the asset and liability management of banks. With regard to the MM, a change of *D* implies a change of parameters *c*, *r* and *e* (which are scaled by *D*) and so the MM changes by the behaviour of bank and non-bank agents.

3.4 Impact of QE on MM

The impact of QE on the MM depends, firstly, on the identity of the seller of the assets purchased by the central bank. If the central bank purchases assets *F* from (domestic) *non-bank* agents the MM will change.[16] This QE transaction is settled by banks, who credit the deposits (*D*) of the non-bank agents and pass the asset purchased by QE to the central bank in return for reserves. So banks create inside money *M* via *D* and the central bank simultaneously creates outside money (shift of R_s to the right in

[14] So the interest on deposits is an instrument that banks use to compete for funding to finance loans, and in this respect is connected to the description of the bank loan market in the previous section.

[15] Loan origination creates deposits, but the composition of the asset side of the banks' balance sheet is the result of portfolio choices.

[16] The monetary aggregate remains unchanged when the ultimate seller is a non-domestic resident, unless the latter re-invests proceeds domestically.

panel C). The rise of D and ER on parameters e, r, c most likely has a downward effect on the MM.[17] This is the first round effect of QE. As a second round effect, the reserve expansion lengthens banks' balance sheet and raises banks' leverage. Diamond et al. (2021) show that this "reserve channel of QE" crowds out bank loans by a significant amount. This implies that the capacity to create inside money (D) by lending diminishes, also putting downward pressure on the future level of the MM.

A second determinant of the impact of QE on the MM is the behaviour of the seller of the assets purchased by the central bank. The increase of bank deposits through QE improves the liquidity of *non-bank* agents, i.e. deposit holders. When banks reduce the deposit rate i_D, depositors are induced to rebalance their asset portfolio to higher yielding assets, for instance bank bonds.[18] This would lead to a substitution of inside money (bank deposits) to assets (F) that are not part of M. Such portfolio adjustments reduce parameter β and flatten the inside money curve (dotted upper part of the curve in panel A). So the liability management of banks and search for yield by non-banks reduce the MM. Since the portfolio rebalancing to bonds will also lower bond yields, it reinforces a regime with a low MM and low market interest rate. Portfolio rebalancing in this regime by non-bank agents may inflate asset prices and induce imbalances in financial markets.

If the assets are purchased from *banks*, inside money M does not change, since QE only swaps F (e.g. bonds) for ER on the asset side of the balance sheet of banks and both do not count as inside money. ER increases and thereby outside money H (shift of R_s to the right in panel C from $R_{s,0}$ to $R_{s,1}$). By the change of ER and thereby parameter e, the MM falls (reflected in the flat upper dotted part of the MM curve or rate of money substitution in panel B). The swap of F for ER makes banks more liquid (raising κ_b) without lengthening their balance sheet, by which potential liquidity frictions in the bank lending channel diminish. Hence, costs n decrease and margin m increases. As a result, banks respond by extending more loans. which will be matched by higher demand since the lending rate i_L will likely decline (see Annex 2). This raises M and mitigates the initial decline of the MM caused by the increase of ER. Balance sheet policy by the central bank then has the intended effect.

Financial frictions related to higher risk of loans (higher σ_L) or deteriorating market conditions (lower τ_m) can constrain loan supply if banks' profitability (margin m) falls due to higher costs of frictions (Δn in Figure 4 panel D) that are not fully passed-through in a higher lending rate. This leads to a shift of the loan supply curve along the demand curve to $L_{s,1}$ and an increase of i_L. In the face of frictions, the central bank may try to unclog the bank lending channel by further expanding excess reserves (ie. increasing ν^s which lowers n in eq. (12) and shifts the reserve supply curve to R_2 in Figure 4 panel C). This can mitigate frictions related to market liquidity risk (reflected in τ_m in eq. (12)), but cannot resolve all frictions, in particular frictions related to a lack of capital (κ_b) or poor loan quality (σ_L). In the latter

[17] This effect depends on the initial values of ER and D.
[18] So, the recent phenomenon of banks offering negative deposit rates implies a lower β.

case, banks may favour holding (on to) safe central bank reserves over supplying loans. The additional reserves then end up at bank's balance sheets without an increase in loan supply (illustrated by the dotted lower flat part of the inside money curve in panel A). Loan demand falls as well due to the increase of i_L. The MM declines as a result, given the increase of parameter e (*ER* increases relative to *D* and so *H* increases relative to *M* as reflected in the flat lower part of the MM curve, reflecting the rate of money substitution). The decline of the MM thus indicates that the excess reserve supply gets trapped at bank's balance sheets without solving underlying bottlenecks in financial intermediation. Actions by other agents, such as the government and supervisor, are needed to resolve such more structural frictions.

Banks may also prefer alternative safe assets such as government bonds, in particular if bond yields are higher than i_{ER}. In that situation an increase of *ER* stimulates the demand for bonds, exerting a downward effect on bond yields. This is particularly the case when the increase in ER is initiated through refinancing operations (as central bank lending is secured and thereby reduces the availability of bonds in the market). These dynamics reinforce a regime with a low market interest rate and a low MM (proceeds of bond issuances in the hands of governments are not part of inside money *M*), reflected in a shift along the dotted lower flat part of the curves in panels A and B. It indicates that bank behaviour and market conditions change in response to a low regime with excess liquidity.

Besides frictions, changes in relative returns of assets also affect the preference of banks for *ER*. For instance, portfolio rebalancing by non-bank agents from deposits to other assets such as bonds will lower market interest rates, including loan rates which tend to move in tandem with market interest rates, due to competitive pressure. This reduces the margin between the lending rate and the return on other assets versus the central bank deposit rate and thereby raises the preference of banks for excess reserves (which are remunerated at i_{ER}) relative to loans L[19]. This is a similar mechanism as the reversal rate of Brunnermeier and Koby (2018), being the lowest level of the policy interest rate at which further monetary easing is no longer supportive to lending due to a declining interest rate margin. So in the low regime, reserve demand of banks (ν^d) adjusts to the excess reserve supply induced by QE (ν^s), influencing e and the MM. Banks' preferences can reinforce the tendency towards an excess liquidity trap, with an increasing amount of reserves sitting idle on banks' balance sheets.

[19] This is captured in eq. (10); if i_L falls relative to i_R (or i_{ER} in the low regime) less loans will be extended relative to reserve holdings.

Figure 3. Money multiplier diagram (credit demand shock in normal regime)

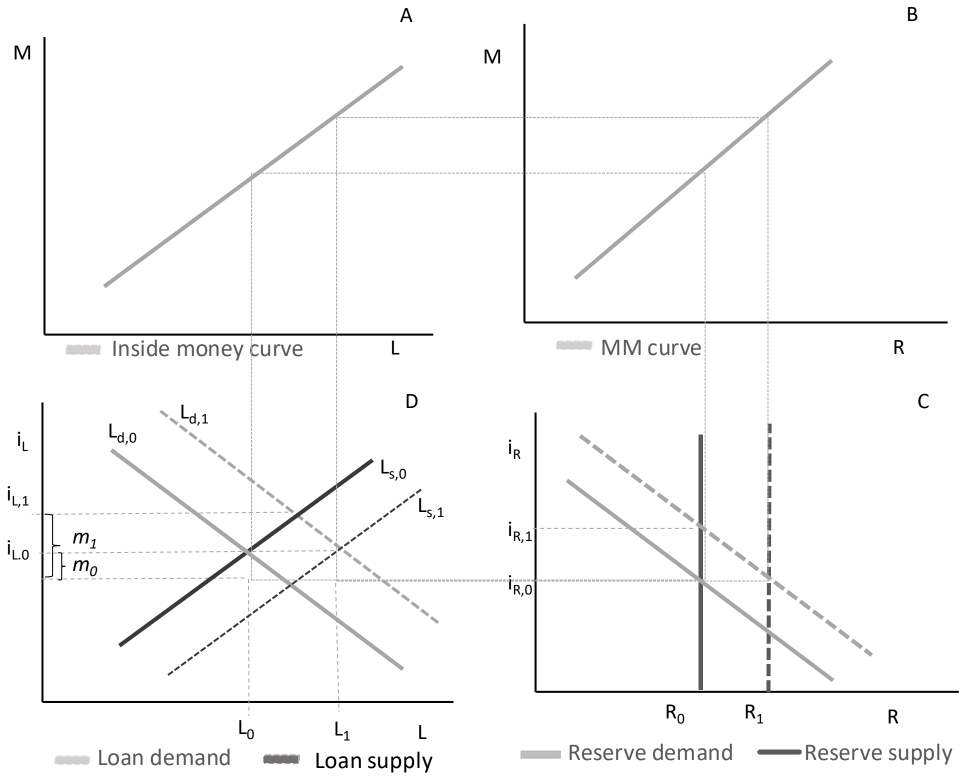
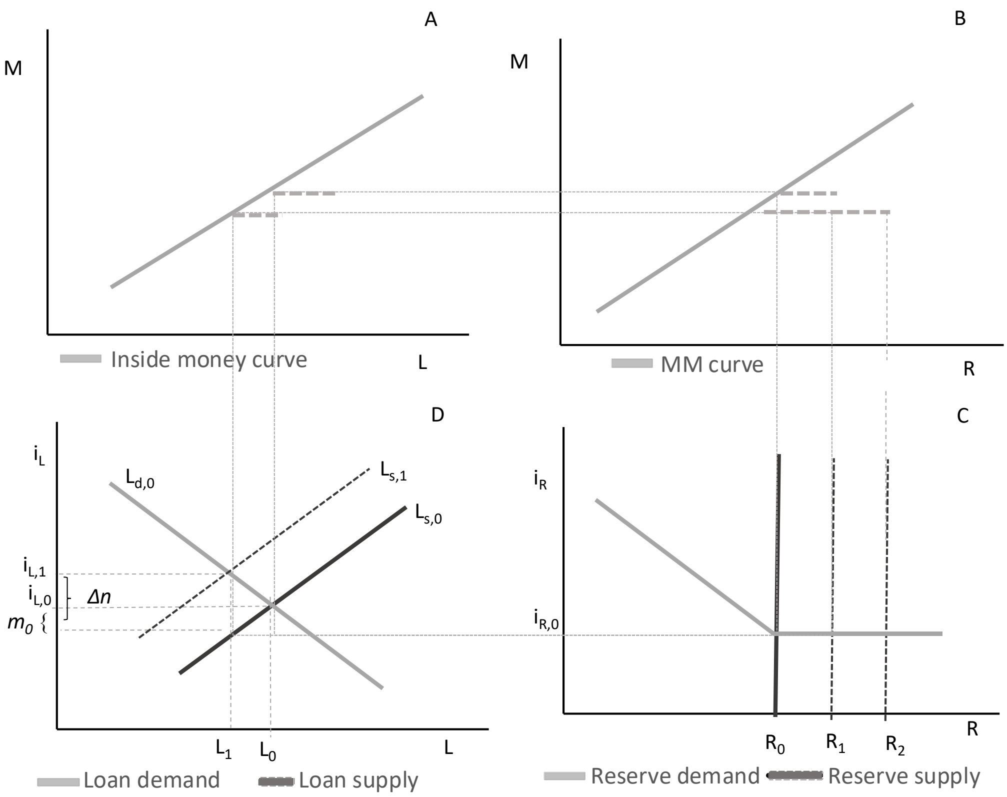


Figure 4. Money multiplier diagram (QE in low regime)



4. Money multiplier dynamics

4.1. Evolution across time

This section describes the evolution of both the MM (i.e. rate of substitution between inside and outside money) and the marginal MM for the US and the euro area in the 1980-2021 sample period (monthly data 1980m1 - 2021m11). Van den End (2014) documents that the MM tends to be lower at low (market) interest rate levels. Such a state is associated with a liquidity trap, where an increase of base money goes in tandem with higher reserve holdings by banks instead of an increase of bank lending. It changes the usual positive correlation between H and M. In other words, the usual money multplier relationship breaks down. In the previous section we related this to an increased preference for safe assets by banks (accommodated by central bank reserve supply) and financial frictions in the banking sector which affect loan supply through the lending margin, costs and profitability. This suggests that the MM is time-varying, regime dependent and driven by behaviour of economic agents. It illustrates that the low MM is an endogenous outcome of the dynamics between the variables in our model.

We examine the evolution of the MM by plotting monthly data of short-term interest rates against the MM in Figure 7. It clearly points at two regimes: one "low regime" with a very low multiplier and very low interest rate and a "normal regime" with a higher MM and interest rates (Figure 7, panels A and C). While the graphs do not capture causality between interest rates and the multiplier, they show that a low interest rate is associated with excess reserves, which reduce the MM. This regime emerges from 2008 onward, when central banks reduced policy rates to very low levels and started to use their balance sheet as a policy tool, thereby offering excess reserves to banks at favourable conditions. The Fed cut the policy rate earlier and more rapidly than the ECB, and the Fed introduced QE already in 2008, several years before the ECB started to purchase assets. This explains why the low regime can more clearly be distinguished in the US than in the euro area. Van den End (2019) explains regime switches in the financial system related to excess liquidity by the behavior of interacting agents, similar to the dynamics in complex systems (see also section 6).

The low regime indicates that the creation of excess reserves (outside money) did not go in tandem with a proportional rise of bank loans and thus creation of inside money. It suggests that the central bank policy of outside money (reserves) creation has been the dominant driver for the fall of the MM since the GFC, illustrating the breakdown of the (fictitious) MM assumption that an increase of H leads to an increase of M. The breakdown of the MM since the GFC indicates that financial frictions, which cannot be solved by extended liquidity supply only, impede inside money creation. Eq. (9)-(12) show that frictions determine lending costs n, bank lending rate i_L and margin m and thereby credit demand and supply.

As explained in section 3.3, a cost shock (increase of *n* due to frictions, like loan default risk) reduces credit supply due to the decline of the margin m. Credit demand falls as well because i_L increases as a consequence of a rise in costs *n*. The data in Figure 8 empirically corroborate that the increased difference between i_L and i_R in the euro area and the US at the beginning of the GFC was related to higher costs of frictions being passed-through in a higher lending rate.[20] The resulting decline of credit demand (in line with eq. (9)) is confirmed by the decline of bank lending for several years in a row following the GFC. It reflects a prolonged deleveraging by highly indebted corporate and household borrowers, illustrating that the higher lending rate weighted on inside money creation through credit demand. If the increased difference between i_L and i_R would have been driven by higher bank profitability (*m*), loan supply would be boosted in line with eq. (10). However, the downturn in lending during the GFC more likely indicates that the higher costs of frictions (*n*) reduced banks' margin *m* (in line with the partials in Annex 2), so that lending was affected by both a negative credit supply and demand effect.

As another indicator for financial frictions we use the VIX index in Figure 9. The VIX is a measure of volatility implied by equity options and reflects market sentiment, risk aversion and financial stability risk (Bekaert and Hoerova, 2014). Such financial market frictions are captured by parameter τ_m in eq. (12), with a rise in VIX proxying for a lower τ_m. Figure 9 shows that the low MM regime is more frequently associated with spikes in the VIX than the normal regime, particularly in the US. This is another indication that financial frictions are associated with a low level of the MM. One channel for this link is that high risk aversion stirs bank demand for safe assets, of which central bank reserves, at the expense of loans. So bank behaviour - driven by risk aversion and financial frictions - is another force behind the low MM regime.

4.2. Marginal multiplier in the pandemic

The distinction between the normal and low MM regime is also visible in the marginal MM, or the marginal rate of money substitution (eq. (5)), which captures the dynamics in the MM. Figure 7, panels B and D show that the marginal MM for the US and the euro area is distributed around 1. However, in the low regime the marginal MM is lower than 1, implying that changes in inside money are smaller than changes in outside money. This is another way of showing that the MM breaks down at low market interest rate levels. The marginal MM was at its lowest levels in the GFC in the US and in the 2012 debt crisis in the euro area, indicating that financial frictions affected the creation of inside money in those periods.

In the pandemic, the marginal MM in the US was higher than in 2008-2009 and rather dispersed in the euro area (Figure 7, panels B and D), despite the increased prevalence of financial frictions, indicated

[20] Until October 2008 the lending rate and (to a lesser extent) the money market rate had increased in the euro area (in the US until August 2008). This might have had a (lagged) negative effect on loan demand.

by the uptick in the VIX index in 2020 (Figure 9). It reflects a combined strong growth of both inside and outside money, which is a-typical in a crisis. Figure 10 shows that both components of the marginal MM increased strongly in 2020-2021, while in the GFC and in the euro debt crisis (in the euro area) inside money growth fell to even negative rates. The robust inside money growth in the pandemic owes to policy responses by central banks, supervisors and governments. Outside money increased rapidly as a result of the large-scale refinancing of banks and asset purchases by the ECB and the Fed in 2020-2021 (reflected in an increase of *ER* by monetary policy shock ν^s, as in eq. (7)). This reduced the money market rate i_R, as well as the costs of financial market frictions (τ_m) in the early stages of the Covid crisis. Bank lending frictions were mitigated by public guarantees on bank loans and income support to households and firms, which kept non-performing loans low (i.e. a lower σ_L, implying lower lending costs *n*). Moreover, supervisors provided banks capital relief by allowing them to operate below certain capital thresholds (ECB, 2020), which reduced banks' capital costs (reflected in a higher κ_b).[21] It makes the pandemic a good example of the effectiveness of measures by other agents than the central bank to mitigate frictions for financial intermediation.

According to eq. (9)-(13) and the partials in Annex 2, lower costs *n* imply a higher margin *m*, as well as a lower lending rate i_L (in the model the decline of i_R also reduces i_L). Both support inside money creation. The data indeed show an accelerating growth of loans to firms and households in 2020 in the US and the euro area, which decelerated in 2021 (Figure 8). However, contrary to the model, the lending rate did not really change following the decline of i_R (leading to some widening of the spread between i_R and i_L). This suggests that loan growth was primarily driven by credit supply, supported by the increase of margin *m* (in line with eq. (10)). Note that credit demand was supported by factors determined outside the model (captured by $\bar{L}_d$ in eq. (9)), such as the increased demand by non-financial corporations for working capital and liquidity buffers following the lockdowns.

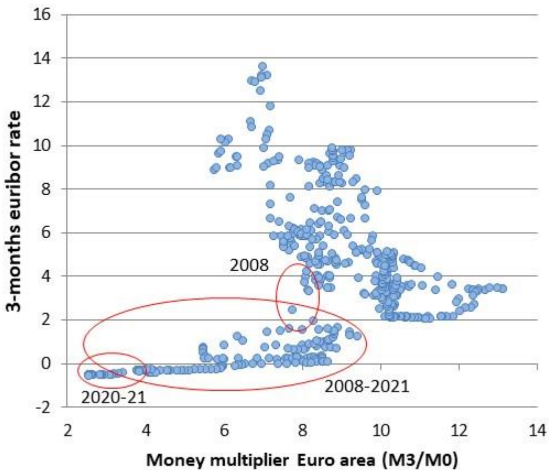
The response of deposit holders also explains the a-typical MM dynamics in the pandemic. In 2020-2021 both precautionary and forced savings by households increased rapidly, as reflected in the expansion of bank deposits in Figure 8. This partly reflects deposit creation by bank lending, but may also reflect a substitution of bank liabilities that do not count as money for deposits *D*. Unlike in the GFC, the stability of banks was not at stake in the pandemic and so the risk of deposits (σ_D) remained low. Since σ_D determines deposit holdings in eq. (16), banks' deposit base remained unaffected. This marks the crucial difference between the GFC - which was a banking crisis and thus did not provide incentives to increase deposits in the banking system - and the pandemic, which was a crisis outside the banking system and thus did incentivize private agents to increase their savings at banks.

[21] A case in point is the exemption of excess reserves (which have swollen due to QE, see section 3.4) from the leverage ratio calculation.

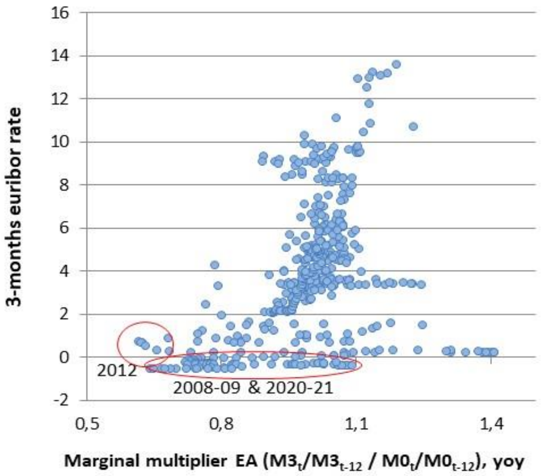
Another part of the increase of *D* is explained by the income support provided by governments to households and firms in the pandemic (*y* in eq. (16)). The central government is not part of the money holding sector and a transfer of funds from central governments to households and firms thus implies an increase of inside money in the form of bank deposits, driven by factors other than bank lending. Hence, the behaviour of deposit holders, interacting with government support measures, was another reason for inside money growth shoring up the (marginal) MM in the pandemic. It is a good example of a policy measure that boosts inside money without creating an excess liquidity trap, since the liquidity ends up in the hands of the money holding sectors.

Figure 7. Money multiplier and interest rate, 1980m1-2021m11

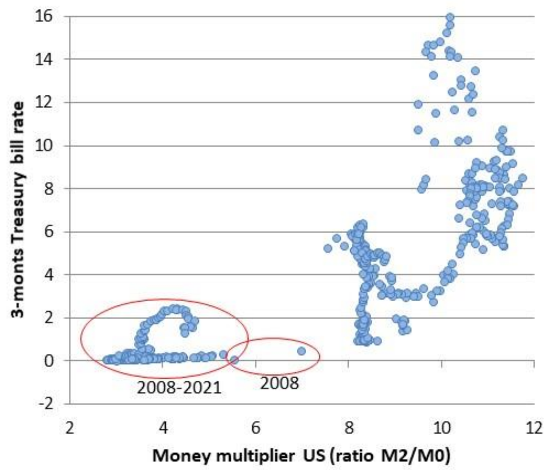
A. Euro area, money multiplier



B. Euro area, marginal money multiplier



C. US, money multiplier



D. US, marginal money multiplier

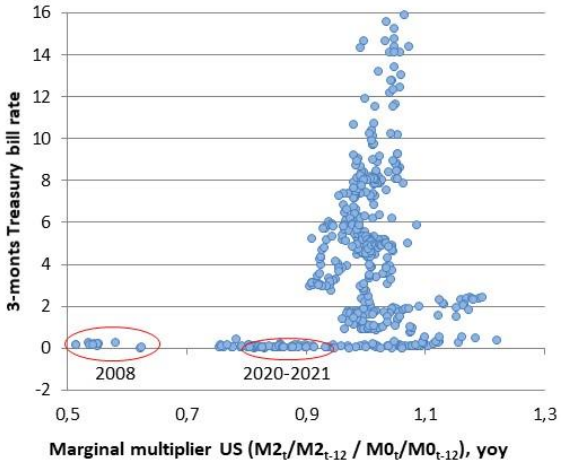
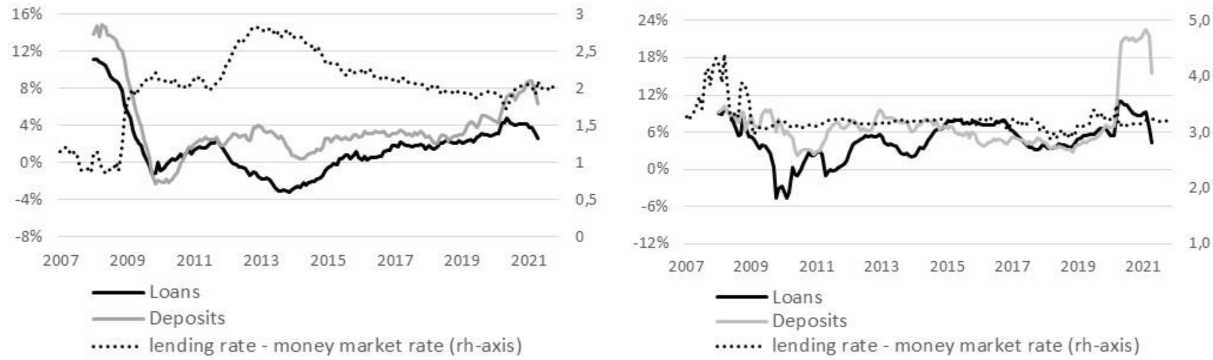


Figure 8. Bank lending and deposit taking to private non-financial sector (year-on-year growth rate; difference between bank loan rate and money market rate in percentage points)

A. Euro area *B. US*



Sources: ECB, FRB StLouis

Figure 9. Money multiplier and VIX index, 1990m1-2021m11

A. Euro area *B. US*

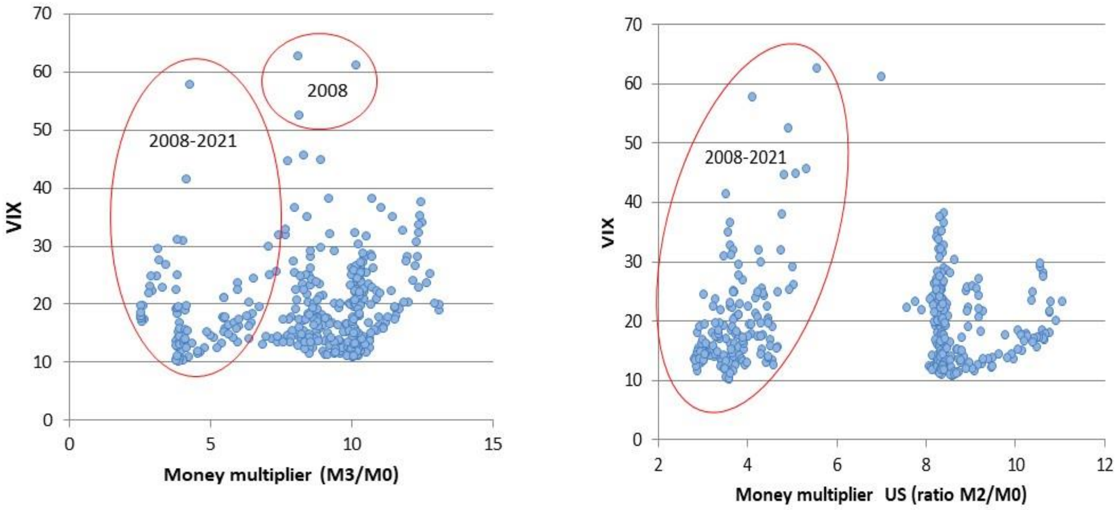
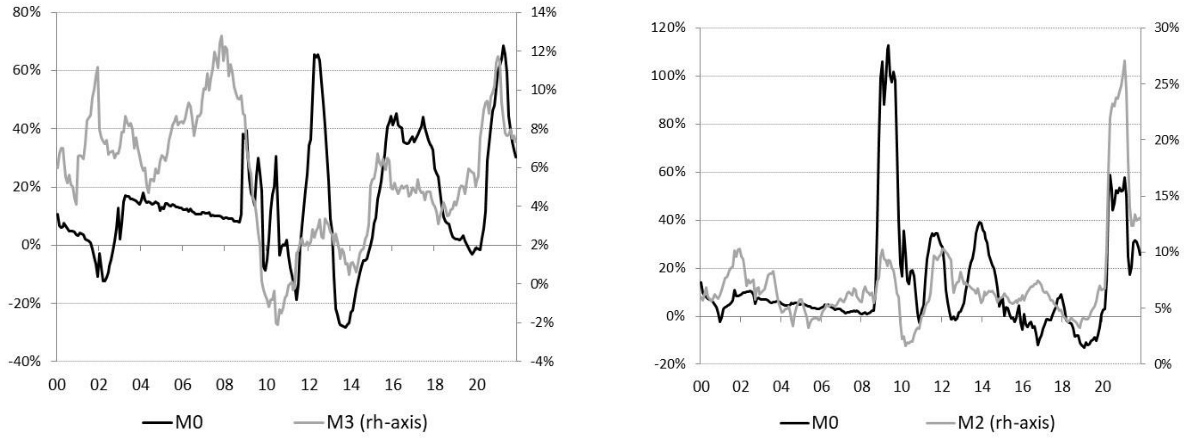


Figure 10. Inside and outside money growth (annual percentage change), 2000m1-2021m11

A. Euro area *B. US*



5. Estimation of regimes

The stylized facts presented above suggest a regime switch in the MM. We now seek to find an econometric corroboration of this, and link the regimes to (endogenous) movements in the MM parameters, governed by the behavioural changes analysed in section 3.

5.1. Regime switching model

We first estimate the likelihood of the MM regimes and the values of the MM parameters in the regimes. The Markov model that we estimate is an autoregressive switching model with two different regimes, each of which is associated with a regime specific intercept and time trend,

$$y_t = \mu(s_t) + \delta t(s_t) + \rho y_{t-n} + \varepsilon_t \qquad (17)$$

$$s_t = 1,2$$

Parameter s_t is the regime indicator function that ensures that the constant term μ and the coefficient of trend t can take several possible values (depending on the number of regimes, $Q = 1,..n$), indicating either a new regime before or after the structural break. Variable y_t is in state or regime q in period t when $s_t = q$ (s_t being the mean of the state variable).The dynamics of the regime indicator are described by a two-state Markov chain with (time invariant) transition probability $p_{ij,}$

$$p_{ij} = p\ (s_t = j \mid s_{t-1} = i) \text{ for any } i, j = 1, 2.$$

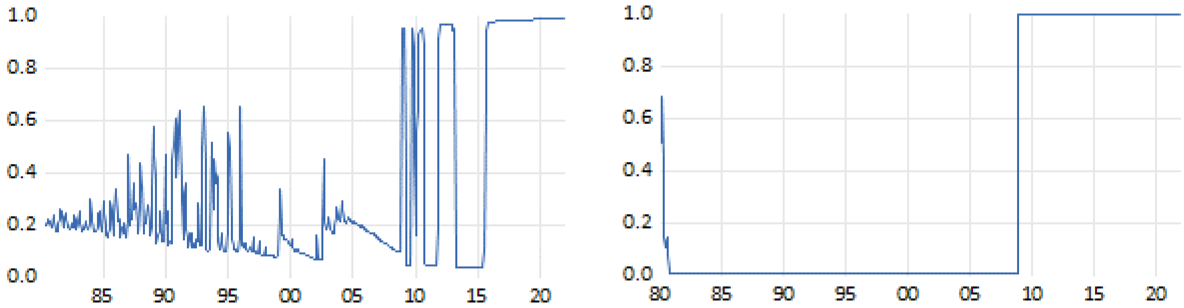
We apply this model to the MM, where variable y_t denotes the ratio $\frac{M}{H}$. This makes the MM the state variable that indicates to what extent a regime switch, from one state to another one, occurs. In complexity theory such critical transitions are related to changes in external conditions (e.g. an increase of excess liquidity by central bank balance sheet policy) or to changes in the state of the system itself (Van den End, 2019). The latter can be related to changes in market functioning driven by behavioural changes of interacting agents. A regime switch occurs if there is a significant shift in the mean difference between the ratios in both regimes. Hence, the mean MM and the time trend are subject to regime switching. The model is estimated for the euro area and the US, using monthly observations in the sample period 1980m1-2021m11. Our choice of autoregressive terms is based on information criteria for model fit (Schwarz information criterion and Akaike information criterion), statistical significance and ensuring stationarity. This leads to the inclusion of AR(3), AR(4) terms for the euro area and the US. Robustness tests indicate that the hypothesis of more than two regimes is rejected, both for the US and the euro area. The model is stationary as the roots lie within the unit circle.

The estimation outcomes in Table A in Annex 1 show that the two regimes are validated by the data, given the high probabilities of staying in the regimes and the significance of the constant term $u(s_t)$ across the regimes. Figure 11 shows the probability of (staying in) the low MM regime (p_{11}, with p_{11} = 1- p_{12}). They point at a regime shift in the euro area and the US at the time of the GFC in 2008, when central banks started to conduct balance sheet policies. While the outcomes only provide a rough indication of a regime change in the MM, they correspond to the graphical analysis in the previous section, where we identify the low MM regime in the 2008-2021 subperiod of the sample. Like in the graphical analysis, the regime probabilities in Figure 11 show that the low regime can more clearly be distinguished in the US than in the euro area.

Another insight is that the regime switch looks like a critical transition from one state to another. The new state seems to be quite persistent as Figure 11 shows. Van den End (2019) explains such transitions in the context of complex systems. Beyond a tipping point the system can switch to another regime after a shock, driven by behavioural responses of interacting agents. The new regime can be persistent. Applied to the MM, the tipping point for the regime switch is dated at the start of the GFC, when central banks started to use balance sheet policy. The subsequent low regime reflects a state in which the functioning of the financial system changed fundamentally due to excess supply of reserves. These changed the market conditions which determine the behaviour of banks and non-bank agents. The estimated regime probabilities in Figure 11 show that the low MM regime has been persistent since the GFC.

Figure 11. Probability of staying in the low MM regime (p_{11}), 1980m1-2021m11

A. Euro area *B. US*



5.2. Extension with MM parameters

We extend the regime switching model with additional regressors, i.e. the MM parameters *c*, *r* and *e*.

$$y_t = \mu(s_t) + \eta_k X_t(s_t) + \rho y_{t-n} + \varepsilon_t \quad (18)$$

where η_k is a vector of coefficients that are regime dependent and X_t is a vector of regressors k, including c, r and e (in this model no trend is included since the regressors in vector X_t already have a trend component, as shown in Figure 2). These parameters are the explanatory variables of the MM after rewriting eq. (1) in section 2 as (abstracting from the constant, autoregressive and residual terms),

$$\frac{M}{H} = \eta_c c(s_t) + \eta_e e(s_t) + \eta_r r(s_t) \tag{19}$$

We assume there are two regimes (Q = 1,2), and variable y_t is in state or regime $q=1$ or $q=2$ in period t when $s_t = q$ (s_t being the state variable). The regime dependence of η_k implies that the MM parameters c, r and e differ across both regimes. The regime transition probability is determined by the constant term μ as in eq. (17). The first regime is associated with the low MM regime. Eq.(18) is estimated including an AR(3) term for variable y_t.[22]

Most of the coefficients have the expected (negative) sign and are statistically significant at the 1 percent confidence level (see Table B in Annex 1). Only the coefficient of r is not significant in the euro area in the low regime. In this regime banks held most reserves as excess reserves (e) rather than required reserves, meaning that parameter r was less meaningful for inside money creation (besides the fact that r is also determined by D). In the US the reserve requirements were reduced to zero percent in March 2020, which eliminated reserve requirements for all depository institutions. Both in the US and the euro area the estimated coefficient of e is significantly negative, indicating that an increasing amount of excess reserves is associated with a lower MM. The negative sign of the coefficients of e is in line with the theoretical framework described in section 3 and points to the downward effect of higher reserve balances on the MM. Moreover, the coefficient estimated in the normal regime is significantly different from the coefficient in the low regime, both for the euro area and the US. The same results for the coefficient of variable e are found when eq. (18) is estimated with the marginal money multiplier as dependent variable (Table C in Annex 1).

6. Discussion and policy implications

As discussed in section 3, the MM relates outside money to inside money. It can be interpreted as the rate of substitution between inside and outside money, or the value of inside money relative to outside money. In that respect the MM can be seen as a summary statistic of the importance of rigidities in the financial sector for the functioning of the real economy. In the normal (low) MM regime, the value of

[22] For the US the model is estimated with a regime specific error variance for stationarity reasons.

outside money vis-à-vis inside money is low (high) indicating a low (high) the degree of rigidities in the financial sector inhibiting an efficient allocation of liquidity between sectors and across time.[23]

The low MM-regime identified by the switching regressions of the previous section can be interpreted as an unwanted by-product of central bank balance sheet policy aimed at lowering market rates in the face of the effective lower bound restriction on policy rates. This by-product comes in the form of an excess of outside money trapped on the balance sheet of the banking sector as the ultimate holder of central bank reserves. Our analysis presented in section 3 provides the behavioural underpinnings illustrating how this trap comes about: portfolio adjustments by both bank and non-bank agents not only contribute to the (intended) decline of market interest rates, but additionally (and unintentionally) create an environment characterised by risk-return profiles that increases the attractiveness of holding central bank reserves and other safe assets.[24] Such an environment enables the absorption of the additional supply of reserves, but is not conducive to inside money creation. This perspective suggests that the monetary system has ended up in a new equilibrium situation associated with a low MM and low interest rate. The empirical analysis in sections 4 and 5 shows that this regime or state is persistent. Our model for the driving factors behind the MM indicates that the behaviour of economic agents, and its interactions with macro-financial variables specific to each state, can reinforce the transition to this state and its persistence.

Our findings following from the regime switching models used in section 5 are consistent with an interpretation in which the shock of the GFC and subsequent balance sheet policy by central banks triggered a transition to a low MM regime. According to our model, this regime switch and its persistence was reinforced by behavioural feedbacks between low market interest rates and excess liquidity through various channels. One is that a lower money market rate reduces the opportunity costs of excess reserve holdings. Another one is the portfolio channel, through which a low lending rate makes reserve holdings (outside money) more attractive compared to loans (inside money). This can also be linked to the reversal rate channel (Brunnermeier and Koby, 2018), which in our model comes into play at the lower bound of the policy interest rate, when a low market interest rate reduces the margin in the bank lending rate and thereby discourages bank lending. Actually the effective lower bound presents a financial friction which can reinforce the low regime by limiting the capacity of banks to create inside money.

We argue that the low regime is a bad state from an economic perspective. The excess liquidity is not a free lunch, given that it presents a financial risk for the central bank and a cost for the banking sector.

[23] A well-capitalised financial system usually implies low financial frictions, and the value of inside liquidity provision outweighs that of outside money provision (as the broadness of liquidity services provided by inside money exceeds that of outside money). In contrast, in absence of a properly functioning private financial intermediation the central bank is the prime source of liquidity provision, implying that outside money is very valuable. See Brunnermeier et al. (2012).

[24] This is akin to Goodfriend's (2002) description of central bank excess reserves in a floor system of monetary policy implementation as government debt with a floating market interest rate.

Particularly in the regime with a low MM and a low or even negative interest rate these risks and costs are mounting. The excess reserves expose the central bank to maturity risk and provisions are needed to insure against the financial risk implicit in an increasing interest rate. While these provisions indirectly post a cost to the tax payer, the excess reserves pose a cost to the banks given that - at an aggregate level - they hold these assets at a very low or negative return.

Moreover, the new state can be problematic if it goes in tandem with impaired financial intermediation. The new state is endogenous on central bank interventions, which market participants ingrain in their behaviour the longer the interventions persist. This comes with the risk that at some point (of excess liquidity) the financial sector may not be able to function on its own anymore. That would hamper an efficient allocation of funds in the economy that can have welfare costs. An inefficient allocation may also arise in the low interest rate regime if it stimulates portfolio rebalancing by non-bank agents that inflates asset prices and increases financial stability risk. The primary sources of such financial risk-taking are captured by the MM.

The persistence of the low regime suggests that monetary policy by itself is impotent to escape from the liquidity trap. We argued that actions by other agents than the central bank are needed to escape from the trap. They can remove frictions for inside money creation, as illustrated by the effectiveness of government and supervisory measures in supporting the MM in the pandemic. It underlines that a well-balanced policy mix is an important condition to support the rate of substitution between inside and outside money. It also indicates that the transition to a low MM regime is not necessarily permanent. In that respect the MM regimes differ from the regimes shaped by critical transitions in complexity theory, in which a tipping point usually presents a point of no return. Having said this, the persistence of the MM regimes indicates that a return to the old state is hard to realize, taking into account that excess reserves have been there for many years and QE seems notoriously hard to end. Referring back to section 3, we note that a sequencing of central bank actions might add value when transitioning towards a more normal monetary policy (for example due to an increase of inflationary pressures): first move the policy rate set by the central bank (i_{ER}) upwards before actively reducing excess central bank reserve balances.

7. Conclusion

The analysis in this paper illustrates that the MM can be a useful variable for policy makers, as it summarizes information about the functioning of the transmission and the effectiveness of monetary policy and financial stability risks in a rate of money substitution.[25] We furthermore showed how a behavioural perspective on the MM helps to explain the dynamics of inside and outside money, as

[25] When balance sheets of financial institutions come under pressure (indicative of financial stability problems), inside money creation is inhibited and the rate of money substitution drops.

summarized in the marginal rate of money substitution. The dynamics result from demand and supply decisions of different economic agents, who interact and respond to macro-financial conditions. In particular the creation of large outside money balances by central banks shaped a regime with a low MM and low market interest rates.

The outcomes of switching regressions for the US and the euro area confirm that a low regime can be distinguished from a normal MM regime. This implies that the level of the MM is state-contingent. The persistence of the MM regimes also indicates that the MM has been trapped in a new equilibrium situation since the GFC. This state reflects that the central bank and the private financial sector interact differently than before. Behavioural interactions have reinforced that excess liquidity supply remained trapped in the banking sector. While central banks created excess reserves for monetary policy reasons, the subsequent decline of market interest rates reduced the opportunity costs of reserve holdings and safe assets like government bonds. This has made reserve holdings (outside money) relatively more attractive compared to loans (inside money), reinforcing a regime with a low MM and low market interest rate. This has economic consequences, since the new regime is associated with different levels of market interest rates, reserve holdings and bank lending.

The low MM suggests that the financial intermediation process has not been working well since the GFC, as the large outside money creation has not been matched by inside money growth due to frictions and behavioural dynamics. This makes the MM an useful concept to understand the monetary implications of policy measures and shocks to which agents respond. The pandemic is an example where behavioural changes come to the fore in changes of the MM (the marginal rate of money substitution). It indicates that other agents than the central bank can – and might be needed to - help to escape from the excess liquidity trap by removing frictions for inside money creation. Policy measures by such agents likely also run through other channels than the ones we modelled, such as liquidity transfers to the money holding sectors. The dynamics of the MM in the pandemic show that such channels are important to explain the marginal rate of money substitution. Modelling such channels more in depth and using a general equilibrium perspective is left to future research.

References

Acharya, V. and R.G Rajan (2022), Liquidity, liquidity everywhere, not a drop to use - Why flooding banks with central bank reserves may not expand liquidity, CEPR Discussion Paper, DP16907.

Afonso, G., K. Kim, A. Martin, E. Nosal, S. M. Potter and S. Schulhofer-Wohl (2020), Monetary Policy Implementation with an Ample Supply of Reserves, FRB Atlanta Working Paper, 2020-2.

Aberg, P., M. Corsi, V. Grossmann-Wirth, T. Hudepohl, Y. Mudde, T. Rosolin, F. Schobert (2021), Demand for central bank reserves and monetary policy implementation frameworks: the case of the Eurosystem, ECB occasional paper, 282.

Bats, J.V., M. Giuliodori and A. C. F. J. Houben (2020), Monetary policy effects in times of negative interest rates: What do bank stock prices tell us?, DNB working paper, 694.

Bekaert, G. and M. Hoerova (2014), The VIX, the variance premium and stock market volatility, ECB working paper, 1675.

Berk, J.M. (2003), New economy, old central banks?, Economic notes: Review of Banking, Finance and Monetary Economics, 32 (1), 1-35.

Bernanke, B.S. and I. Mihov (1998), Measuring Monetary Policy, The Quarterly Journal of Economics, 113(3), 869-902.

Bernanke. B. S. and M. Gertler (1995), Inside the Black Box: The Credit Channel of Monetary Policy Transmission, Journal of Economic Perspectives, American Economic Association, 9(4), 27-48, Fall.

Berrospide, J. M. and R. M. Edge (2010), The Effects of Bank Capital on Lending: What Do We Know, and What Does It Mean?, International Journal of Central Banking, 6(34), 1-50.

Beyer, A., G. Nicoletti, N. Papadopoulou, P. Papsdorf, G. Rünstler, C. Schwarz, J. Sousa and O. Vergote (2017), The transmission channels of monetary, macro- and microprudential policies and their interrelations, ECB occasional paper, 191.

Borio, C. and P. Disyatat (2009), Unconventional monetary policies: an appraisal, BIS working paper, 292.

Borio, C. and L. Gambacorta (2017), Monetary policy and bank lending in a low interest rate environment: Diminishing effectiveness?, Journal of Macroeconomics, 54(B), 217-231.

Brunner, A.D. (1994), The federal funds rate and the implementation of monetary policy: estimating the Federal Reserve's reaction function, International Finance Discussion paper, 466.

Brunnermeier. M. K., T. M. Eisenbach and Y. Sannikov (2012), Macroeconomics with Financial Frictions: A Survey, NBER working paper, 18102.

Brunnermeier, M.K. and Y. Koby (2018), The Reversal Interest Rate, NBER working paper, 25406.

Diamond, W., Z. Jiang and Y. Ma (2021), The Reserve Supply Channel of Unconventional Monetary Policy, Jacobs Levy Equity Management Center for Quantitative Financial Research Paper.

Disyatat, P. (2008), Monetary policy implementation: Misconceptions and their consequences, BIS working paper, 269.

ECB (2020), ECB Banking Supervision provides further flexibility to banks in reaction to coronavirus, press release, 20 March.

Friedman, M. and Schwartz, A.J. (1963), A Monetary History of the United States, 1867–1960, National Bureau of Economic Research, Princeton, Princeton University Press.

Gertler, M. and S. Gilchrist (1993), The role of credit market imperfections in the monetary transmission mechanism: arguments and evidence, Scandinavian Journal of Economics, 43-64.

Gertler M. and P. Karadi (2013), QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool, International Journal of Central Banking, International Journal of Central Banking, 9(1), 5-53.

Goodhart, C.A.E. (2009), The Continuing Muddles of Monetary Theory: A Steadfast Refusal to Face Facts, Economica, 76, 821-830.

Goodhart, C.A.E. (2010), Money, credit and bank behaviour: need for a new approach, National Institute Economic Review, 214, 74-82.

Goodhart, C.A.E. and M. Jensen (2015), Currency School versus Banking School: an ongoing confrontation, Economic Thought, 4 (2), 20-31.

Goodfriend, M. (2000), Overcoming the zero lower bound on interest rate policy, Journal of Money, Credit and Banking, 32, 1007-1035.

Goodfriend, M. (2002), Interest on reserves and monetary policy, Federal Reserve Bank of New York Economic Policy Review, 8, 77-84.

Grandia, R., P. Hänling, M.L. Russo and P. Aberg (2019), Availability of high-quality liquid assets and monetary policy operations: an analysis for the euro area, ECB occasional paper, 218.

Lagos, R. (2010), Inside and outside money, Monetary economics, in: S.N. Durlauf and L.E. Blume (eds), Monetary Economics, Palgrave Macmillan, London.

McCallum, B.T. (1984), Monetarist rules in the light of recent experiences, American Economic Review, 74, 388-391.

McCallum, B.T. (1985), On consequences and criticisms of monetary targeting, Journal of Money, Credit and Banking, 17, 570-597.

McCallum, B.T. (1987), The case for rules in the conduct of monetary policy: a concrete example, Federal Reserve Bank of Richmond Economic Review September/October 1987, 10-18.

McLeay, M., A. Radia and R. Thomas (2014), Money creation in the modern economy, Bank of England, Quarterly Bulletin 2014Q1.

Quiggin, J. (2010), Zombie economics: how dead ideas still walk among us, Princeton NJ: Princeton University Press.

Schumpeter. J.A. (1954), History of economic analysis, Oxford University Press.

Stella, P., Singh, M and Bhargava, A. (2021), Some alternative monetary facts, IMF working paper, WP/21/6, IMF Washington.

Sutch, R. (2014), The Liquidity Trap, the Great Depression, and Unconventional Policy: Reading Keynes at the Zero Lower Bound, BEHL working paper 2014-05, University of California, Berkeley.

Taylor, J. (1993), Discretion versus policy rules in practice, Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

Tobin, J. (1963), Commercial banks as creators of "money", in: D. Carson (ed), Banking and Monetary Studies, Irwin Homewood, 408-419.

Tobin, J. (1969), A General Equilibrium Approach to Monetary Theory." Journal of Money, Credit and Banking 1(1), 15–29.

Tucker, P (2004), The central bank's balance sheet: where monetary policy meets financial stability, speech to the 15th anniversary of Lombard Street Research, London, July 28.

Van den End, J.W. (2014), The break-down of the money multiplier at the zero lower bound, Applied Economics Letters 21(13), 875-877.

Van den End, J.W. (2019), Applying complexity theory to interest rates: evidence of critical transitions in the euro area, Credit and Capital Markets, 52(1), 1-33.

Van den Heuvel, S. (2006), The Bank Capital Channel of Monetary Policy, Meeting Papers 512, Society for Economic Dynamics.

Werner, R.A. (2016), A lost century in economics: Three theories of banking and the conclusive evidence, International Review of Financial Analysis, 46, 361-379.

Whelan, K. (2020), International money and banking: how central banks set interest rates, School of Economics, UCD, Spring 2020.

Woodford, M. (2003), Interest and prices, Princeton NJ: Princeton University Press.

Annex 1

Table A.

Switching regression outcomes MM

Markov switching regression (2 regimes, switching in mean and trend)
Dependent variable is money multiplier (MM)
sample period 1980m1-2021m11 (monthly observations)
(1) is low regime; (2) is normal regime

	MM euro area		*MM US*	
	Coeff.	sign.	Coeff.	sign.
constant (1)	62.43	***	9.35	**
constant (2)	62.01	***	15.15	***
AR(3)	0.70	***	0.65	**
AR(4)	0.29	***	0.28	
time trend(1)	-0.07	***	-0.01	
time trend(2)	-0.06	***	-0.01	***
P_{11}	0.79		1	
P_{22}	0.92		0.99	
number of obs.	499		503	
AIC	0.86		-0.16	
SIC	0.96		-0.08	

***, **, * denote p-values less than or equal to 1%, 5%, 10%, respectively.

Table B.

Switching regression outcomes MM

Markov switching regression (2 regimes, switching in mean)
Dependent variable is money multiplier (MM)
sample period 1980m1-2021m11 (monthly observations)
(1) is low regime; (2) is normal regime

	MM euro area		*MM US*	
	Coeff.	sign.	Coeff.	sign.
constant (1)	19.82	***	16.01	***
constant (2)	23.33	***	15.91	***
c (1)	-100.62	***	-40.16	***
c(2)	-97.3	***	-35.96	***
r(1)	-10.74		-59.02	***
r(2)	-96.11	***	-65.57	***
e(1)	-16.18	***	-26.39	***
e(2)	-69.63	***	-28.18	***
AR(3)	0.99	***	0.98	***
P_{11}	0.97		0.87	
P_{22}	0.96		0.93	
number of obs.	499		504	
AIC	-1.33		-1.80	
SIC	-1.23		-1.69	

***, **, * denote p-values less than or equal to 1%, 5%, 10%, respectively.

Table C.

Switching regression outcomes marginal MM				
Markov switching regression (2 regimes, switching in mean)				
Dependent variable is marginal money multiplier (MM)				
sample period 1980m1-2021m11 (monthly observations)				
(1) is low regime; (2) is normal regime				
	MM euro area		*MM US*	
	Coeff.	sign.	Coeff.	sign.
constant (1)	1.72	***	0.24	
constant (2)	1.76	***	1.94	***
c (1)	-5.46	***	11.17	*
c(2)	-5.68	**	-1.03	
r(1)	-9.71	**	3.49	
r(2)	-17.57	***	1.71	
e(1)	-2.01	***	-1.82	***
e(2)	-7.87	***	-2.57	***
AR(3)	0.93	***	0.99	***
P_{11}	0.99		0.94	
P_{22}	0.97		0.99	
number of obs.	487		503	
AIC	-3.17		-4.05	
SIC	-3.07		-3.93	

***, **, * denote p-values less than or equal to 1%, 5%, 10%, respectively.

Annex 2

Derivatives of i_L and m with respect to i_R and n, based on eq. (9)-(13).

$$\frac{\partial i_L}{\partial i_R} = \frac{\varphi}{\gamma+\varphi}$$

$$\frac{\partial m}{\partial i_R} = -\frac{\gamma}{\gamma+\varphi}$$

$$\frac{\partial i_L}{\partial n} = \frac{\varphi}{\gamma+\varphi}$$

$$\frac{\partial m}{\partial n} = -\frac{\gamma}{\gamma+\varphi}$$

With parameter restrictions $\gamma, \varphi \geq 0; \lambda > 0$.

De Nederlandsche Bank N.V.
Postbus 98, 1000 AB Amsterdam
020 524 91 11
dnb.nl

EUROSYSTEEM