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Amplification Effects and Unconventional Monetary Policies

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Abstract. *Global financial crises trigger off amplification effects, which allow relatively small shocks to propagate through the whole financial system. For this reason, the range of Central banks policies is now widening beyond conventional monetary policies and lending of last resort. The aim of this paper is to establish a rule for this practice. The model is based on the formalization of funding conditions in various types of markets. We conduct a comprehensive analysis of the "unconventional monetary policies", and especially quantify government bonds purchases by the Central bank.*

Keywords: unconventional monetary policies; amplification effects; central banking; crisis management.

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Introduction

Since the beginning of the 2000s, global finance has had three distinctive characteristics. The first characteristic is the disintermediation of capital markets, mostly caused by the increasing use of securities to raise capital, rather than banks. It is all the more considerable that the government and firms of a country used to borrow in comparison with households. The second characteristic is that the boundary between intermediary financial institutions and markets is not clear. This is shown by the important weight of market capitalization of banks, and by the fierce competition between traditional stock exchanges and electronic platforms, that are sometimes controlled by banks. The third characteristic is the increasing importance of OTC markets, without price quotes and volume statistics, contrary to organized securities exchanges. This can have a destabilizing effect, considering that only a small part of the trades executed in the OTC markets are handed over to a clearing house.

Consequently, global financial crisis trigger off specific large amplification effects that strengthen the expected financial acceleration effects (Adrian, Shin, 2009). Those amplification effects allow relatively small shocks to a single market to propagate through the financial system, leading to both rapid and deep drops in the value of financial assets and large increases in the costs of external finance to economic agents.

Under these circumstances, there was a wide range of Central Banks (CBs)' responses to the recent financial crisis. These unconventional monetary policies have three main characteristics (Caruana, 2010). In a remarkably short time, the CBs brought down the official interest rate nearly to zero. They provided large amounts of additional CB liquidity to commercial banks, and dramatically expanded the size of their balance sheets by directly purchasing assets, supporting asset prices and achieving a decrease in yields on bonds and long term interest rates.

The aim of this paper is to describe the whole range of unconventional monetary policies. We will focus on quantifying direct government and private bonds purchases in the case of a shock, with a negative link between an increase in the cost and availability of external funding of economic agents. The paper is organized as follows. It begins with a survey of recent literature on central banking. On this basis, in section 2 we propose a model of a CB's decision-making in the case of a shock, triggering amplification effects. In the model, if the decrease in the official interest rate combined with additional refinancing operations in the interbank market does not allow an easing in funding conditions, the CB will purchase government bonds and private securities. As a conclusion, in section 3 the paper finally turns to capital markets' structure reforms with a central idea: if a financial crisis keeps triggering off amplification effects, unconventional monetary policies could become the standard practice of monetary policy.

2. Survey

It is generally agreed that financial innovations improve risk diversification in credit markets, which in turn reduces the likelihood of a crisis (Gai et al., 2008). However, the financial accelerator can be reinforced by amplification effects if the market players' risk perception (and aversion) suddenly sharply increases (Krishnamurthy, 2009, Mishkin, 2009, Martin, Ventura, 2010, Sarkar, Shrader, 2010). Moreover, in the context of "global finance", any market disruption (especially over the counter [OTC]) (Blanchard, 2009) is likely to cause a turmoil on a wide range of asset prices (Adrian, Shin, 2010, Ehrmann et al., 2010), hence a potential market liquidity shortage in the interbank market, especially within the originate-and-distribute business model. The subsequent deleveraging is greater when pro-cyclical accounting standards or regulatory regimes have strengthened the wealth effect in good times (Berger et al., 2008, Chatterjee, 2010, Dell'Ariccia et al., 2008, Geanakoplos, 2010, Tobias, Shin, 2010). First, aggregate liquidity is closely linked to the balance sheet of the banking system (Gatev, Strahan, 2006, Shin, 2008). Secondly, banks liquidity depends on market liquidity and may suddenly vanish, behaving like a binary variable (Franck, Krausz, 2007). Regulators are likely to bail out a large proportion of banks because of both the "too-big-to-fail" and the "too-many-to-fail" effects (Acharya, Yorulmazer, 2007).

In such circumstances, it is necessary (e.g. for Eurosystem and US Federal Reserve) to conduct an unconventional monetary policy (Korinek, 2011). On the one hand, this implementation complements the lender of last resort function in order to deal with the financial and banking crisis, with a sharp lowering of official interest rates. On the other hand, it represents a continuation of monetary policy toward asset prices and returns (Caruana, 2010), causing changes in inflation expectations. Traditional standing facilities are associated with a "stigma" effect in the interbank market (Armantier and al., 2009, Le Maux, Scialom, 2010), hence the injection of large amounts of liquidity through the use of new instruments, such as the (anonymous) Term Auction Facility. Furthermore, after the beginning of the subprime phase of the crisis, CBs significantly extended refinancing deadlines for various operations and broadened the range of eligible collateral for repurchase agreements and refinancing operations (e.g. Primary Dealers Credit Facility; Fleming et al., 2009). These measures also aimed to restore interbank confidence and markets liquidity (Noyer, 2009). Nevertheless the risk-bearing capacity of market makers (prime brokers) remains highly limited and major banks stop providing liquidity to OTC markets (Brunnermeier, Pedersen, 2009, Brunnermeier, 2009, BIS, 2009, Monnet, 2010). Thus CBs act as buyers of last resort or market-makers-of-last-resort (Lagos et al., 2009, Bolton et al., 2009). Assets purchases finally aim to get more robust corporate balance sheets and relatively healthy banking sectors.

Despite moral hazard effects (Keister, 2010) and a CBs' balance sheet expansion and deterioration (Buiter, 2009), these coordinated quantitative and credit easing policies made it possible to rein in crisis (Bentoglio, Guidoni, 2009, Besson, Nguyen, 2011). Baumeister and Benati (2010) underline the need to avoid deflation, which is achieved. Fahr et al. (2011) or Sarkar and Shrader (2010) show the effectiveness of the Fed's action. Lenza et al. (2010) or Giannone et al. (2011) find the same result concerning the ECB's policy. However they state that this positive effect is undermined because the relationship between assets purchases and money markets spreads should include the possibly delayed impact on confidence. Market spreads are actually not only a dependent variable; they affect corporate portfolio choices, hence a critical indirect effect of unconventional monetary policies through confidence (Berg, 2010, Gelain, 2010, Guichard et al., 2009, Manganelli, Wolswijk, 2007). Recent researches also focus on the sequencing of these policies (Chiu, Koeppl, 2009) and the zero lower bound on nominal interest rates (Cúrdia, Woodford, 2009). DSGE frameworks based on frictions and the financial accelerator assess the positive impact of CBs policies (Cúrdia, Woodford, 2009, Christiano et al., 2010, 2011, Dellas et al., 2010, Del Negro et al., 2010). Recent developments provide more specific results by introducing a stylized banking sector with its own collateral and borrowing constraints (Gerali et al., 2010, Meh, Moran, 2010), and highlight the impact of market liquidity risk on monetary policy transmission channels (Gambacorta, Marques-Ibanez, 2011). Asset securitization globally increases banks' exposure to risks (Brunnermeier, Sannikov, 2009), hence the importance of the bank capital channel (N'Diaye, 2009), the risk-taking channel[(1)] (Borio, Zhu, 2008), the role of asset prices (Jeanne, Korinek, 2010), and consequently of counter-cyclical macroeconomic responses[(2)].

Those theoretical underpinnings are necessary to reduce market uncertainty and improve coordination and crisis management. In this context, Gertler and Karadi (2009) compute an optimal unconventional response to the disruption of financial intermediation. The aim of their paper is to determine the proper amounts to moderate the downturn when the CB directly lends in private credit markets. As shown by the present sovereign debt crisis, the breakdown of banking activities also worsens public finances and government bonds risk premium (Schuknecht et al., 2010), through recovery plans and recapitalizations schemes. Monetary authorities are all the more inclined to buy government bonds than those usually safe haven securities are in turn purchased by banks ("flight to quality"). We present a simple theoretical model in which the so-called modern CBs (Buiter, Sibert, 2008) quantify the amount of asset purchases in primary and secondary markets, by taking into account the additional issuance of government bonds. The CB's demand for securities faces liquidity shortages in these markets. As in the recent contagious crisis, the shock in the firstly declining market has fundamental causes, and they remain outstanding even though confidence and markets functioning are restored.

3. The model

Let us assume an initial shock in a single market, rather than a bank. This initial trigger leads to a strong deterioration in funding conditions of a wide range of markets. Following Goodhart & Huang (1999), we propose a model of the CB's decision making, based on a set of predetermined desired levels of liquidity in these markets. The initial shock causes a change in liquidity levels, which is partly predictable and partly stochastic. We consider three types of markets: credit markets (including the interbank market), primary and secondary securities markets.

The main problem in modeling is the treatment of the difference between nominal liquidity and its desired level. In central banking models, the loss from getting macro-policy wrong is usually quadratic, since the total damage caused by the deterioration of financial conditions is a non-linear function of the magnitude of the original shock. However, the remarkable expanding size of the CBs' balance sheets shows that the treatment of deviations from the target cannot be symmetrical. Thus, we apply a minimum desired level of liquidity in each market. If this threshold level cannot be achieved by the decrease in the official interest rate, the CB will conduct bonds purchases.

3.1. Markets setup

There is a total of N different assets, each of these corresponding to a different market with index *i*. The government bonds market is associated with 0 index; credit markets with 1 (the interbank market) to n_1 indexes; the other primary and secondary markets, respectively, with n_1+1 to n_2 and n_2+1 to N indexes.

Each type of asset is characterized by funding conditions, which include the cost and availability of capital. The availability of capital, called "liquidity" of the market in the rest of the paper, is measured by the difference between demand and supply of funding. The cost of capital is measured by the risk spread between the nominal return on asset i, r_i, and the official interest rate, r_{cb}. At the beginning of the model, all the markets are in equilibrium. After the shock r_i is affected by variations in both the official interest rate and the spread (depending on the amplification effects of the initial shock). r_i takes the form of interests in the case of credit and bonds markets; for all other markets it is supposed to be fully anticipated. The return on the *i* asset is written as follows:

$$r_i = r_{\mathrm{CB}} + \pi_i,\ i = 0, \dots, N \qquad (1)$$

Credit markets

Credit markets are associated with *1* (the interbank market) to n_1 indexes. Liquidity is measured by the difference between demand (*LDi*), and supply (*LSi*) of credit, which increases with a rise in the interest rate(3). Before the shock, the market is in equilibrium. Then the liquidity indicator (CM_i) can become positive, that is:

$$LS_i = -c \times r_i + d, \; c > 0, d > 0 \quad (2)$$
$$LD_i = -a \times r_i + b, \; a > 0, b > 0, c > a, d > b \quad (3)$$
$$CM_i = LD_i(\mathrm{r}_i) - LS_i(r_i) \quad (4)$$

Apart from the interbank market, credit markets are specific: in case of a liquidity shortage, the CB cannot conduct direct intervention. It can neither provide liquidity as a lender of last resort (as in the interbank market), nor directly purchase assets (as in primary or secondary markets). If lowering official interest rates does not take credit markets back to equilibrium, the liquidity shortage will remain.

Primary markets

Primary stock markets are associated with *0* (government bonds, see below) and n_1+1 to n_2 indexes. In these markets liquidity is measured by subscription (D_i) of securities issues (S_i) with an expected return (r_i).

$$PM_i = S_i(\mathrm{r}_i) - D_i(\mathrm{r}_i), \; with \; \frac{d\,S_i}{d\,\mathrm{r}_i} < 0 \quad (5)$$
$$\frac{d\,D_i}{d\,\mathrm{r}_i} < 0 \; and \; \frac{d^2\,D_i}{d\,\mathrm{r}_i^{\,2}} > \frac{d^2\,S_i}{d\,\mathrm{r}_i^{\,2}}$$

As in credit markets, the supply function is more strongly decreasing than the demand. Whenever the liquidity indicator PM_i is strictly positive and exceeds the CB's threshold, it will purchase assets in the relevant(s) market(s).

Secondary markets

Secondary markets are associated with n_2+1 to *N* indexes. The supply and demand of assets are functions of return as described in the case of credit markets (5). The liquidity indicator takes the value of the excess supply of assets (SM_i). This value is initially 0 for all secondary markets (organized securities exchanges *vs*. OTC markets, simple *vs*. complex assets markets). After the shock, it must remain within the limit of the CB's threshold as seen above.

Primary market of government debt

This market is associated with the *i=0* index. The supply function S_0 depends on the structural deficit $\bar{S}$ and the other markets' liquidity indicators.

$$S_0 = \bar{S} + \alpha \sum_{i=1}^{i=n_1} (LD_i - LS_i) + \beta \sum_{i=n_1+1}^{i=n_2} (S_i - D_i) + \gamma \sum_{i=n_2+1}^{i=N} (S_i - D_i),$$
$$\alpha, \beta, \gamma \in [0, 1] \qquad (6)$$

When the crisis occurs, the supply function is increased by the cost of the recovery policy (in case of an excess demand of funds in credit markets and primary markets) and of the financial sector support policy (in case of an excess demand of funds in secondary markets). α, β, and γ depend on government priorities.

Demand for government bonds D_0 takes a similar form. It depends on the "risk-free" part of the portfolios and regulatory compliance $\bar{D}$, the magnitude of the deficit λS_0, and the value of liquidity indicators in other markets.

$$D_0 = \bar{D} - \lambda \times S_0 + \zeta \sum_{i=1}^{i=n_1} (LD_i - LS_i) + \eta \sum_{i=n_1}^{i=n_2} (S_i - D_i) + \theta \sum_{i=n_2}^{i=n} (S_i - D_i),$$
$$\lambda, \zeta, \eta, \theta \geq 0 \qquad (7)$$

When the crisis occurs, demand for government bonds is increased because of the "flight to quality" effects entailed by the illiquidity of one or more other markets. Unlike the supply function, for which the coefficients are positive and less than 1, those of the demand function are positive without upper bound. The transfer of investors on government bonds is actually not reduced only to illiquid markets.

Replacing the supply function with its value we get:

$$D_0 = (\bar{D} - \lambda \times \bar{S}) + (\zeta - \lambda \times \alpha) \sum_{i=1}^{i=n_1} (LD_i - LS_i) + (\eta - \lambda \times \beta) \sum_{i=n_1}^{i=n_2} (S_i - D_i)$$
$$+ (\theta - \lambda \times \gamma) \sum_{i=n_2}^{i=n} (S_i - D_i)$$

So the potential liquidity shortage in government bonds market can be written as:

$$S_0 - D_0 = (1 + \lambda)\bar{S} - \bar{D} + (\alpha(1 + \lambda) - \zeta) \sum_{i=1}^{i=n_1} (LD_i - LS_i) +$$
$$+ (\beta(1 + \lambda) - \eta) \sum_{i=n_1}^{i=n_2} (S_i - D_i)$$
$$+ (\gamma(1 + \lambda) - \theta) \sum_{i=n_2}^{i=n} (S_i - D_i) \qquad (8)$$

Recovery policies worsen deficit and increase bonds' supply. The "flight to quality" effects increases bonds demand. The government bonds market is illiquid when the recovery policies adverse effects, outweigh the favorable "flight to quality" effects.

3.2. Timing of the model

Set-up

Let us consider the following three-period model. At $t = 0$, all the markets are in equilibrium, except for the government bonds debt market: there is an excess demand for assets in this market.

At $t = 1$, a shock may occur in one of the secondary markets ($i \in [n_2 + 1, N]$). The market that is suffering the shock is denoted $i = \hat{\imath}$. In this market, the shock triggers both a liquidity shortage and an increase in the risk spread. At this stage of the model, amplification effects generated by the shock affect only the interbank market $(i = 1)$. The CB will provide liquidity to fill the market liquidity shortage but keep the official rate unchanged.

At $t = 2$, funding conditions (cost and availability of capital) in the $\hat{\imath}$ market are unchanged. In the other markets, there can be two cases: either the interbank market is weakly affected at $t = 1$ and the liquidity provision will restore its funding conditions, or amplification effects become widespread and there will be worsening funding conditions in all markets. In this second case, the CB will continue its liquidity provision in the interbank market and begin to implement the unconventional monetary policy. This policy has three characteristics: 1/ the official interest rate is brought down almost to zero; 2/ the CB purchases government bonds if required; and 3/ it purchases private assets in the (remaining) illiquid secondary markets. We will discuss in particular this second case in the model.

Initial state (t0)

At the beginning all the liquidity indicators comply with the CB's threshold levels. $\overline{CM_i}$, $\overline{PM_i}$ and $\overline{SM_i}$ are respectively associated with the threshold levels in credit markets, primary markets, and secondary markets:

$$\begin{cases} S_{0\ t_0} - D_{0\ t_0} < 0, & \overline{PM_0} < 0 \\ LD_{1\ t_0} - LS_{1\ t_0} = 0, & \overline{CM_1} = 0 \\ LD_{i\ t_0} - LS_{i\ t_0} = 0, & \overline{CM_i} > 0,\ i = 2, \dots, n_1 \\ S_{i\ t_0} - D_{i\ t_0} = 0, & \overline{PM_i} > 0,\ i = n_1 + 1, \dots, n_2 \\ S_{i\ t_0} - D_{i\ t_0} = 0, & \overline{SM_i} > 0,\ i = n_2 + 1, \dots, N \end{cases} \qquad (9)$$

Contrary to the other markets that are in equilibrium, government bonds ($i = 0$) are over-subscribed. The CB's threshold levels are positive, except for the government bonds market and the interbank market. In the government bonds market, there must be a positive excess demand, and the interbank market must not be rationed.

3.3. The shock (t_1)

Initial shock and spill-over in the interbank market

The shock occurs at t_1 in one of the secondary markets - this market is denoted $i = \hat{\imath}$. In this market, the shock affects both spreads and liquidity:

$$\begin{cases} \pi_{\hat{\imath}\ t_1} > \pi_{\hat{\imath}\ t_0} \\ SM_{\hat{\imath}\ t_1} > SM_{\hat{\imath}\ t_0} \end{cases}$$

Amplification effects generated by the initial shock affect only the interbank market, as follows:

$$\begin{cases} \pi_{1\ t_1} > \pi_{1\ t_0} \\ CM_{1\ t_1} > CM_{1\ t_0} \end{cases}$$

The rise in the spread depends on the rise in the spread in the $\hat{\imath}$ market (that was affected by the initial shock) and the size j of this market. It also depends on a multiplicative term composed of a parameter p and of a random term ϵ:

$$\pi_{1\ t_1} = \pi_{1\ t_0} + \Delta\pi_1$$
$$\Delta\pi_1 = \Delta\pi_{\hat{\imath}}\, j\,(p + \epsilon),\ p > 0 \qquad (10)$$

By using **Error! Reference source not found.**] we get the initial value of the interest rate $r_1 t_0$ in the interbank market:

$$LD_{1\ t_0} - LS_{1\ t_0} = 0 \quad \Rightarrow \quad r_1 t_0 = \frac{b-d}{a-c} \qquad (11)$$

Next, we substitute this value in equation (1). Since the official CB's interest rate is unchanged at t_1, the rise in the interbank market interest rate is solely caused by the variation in the spread. The interbank market interest rate is the following:

$$r_1 t_1 = \frac{b-d}{a-c} + \Delta\pi_{\hat{\imath}}\, j\,(p + \epsilon) \qquad (12)$$

Thus, rationing in the interbank credit market is given by the following equation:

$$LD_{1\ t_1} - LS_{1\ t_1} = -(a-c)\,\Delta\pi_{\hat{\imath}}\, j\,(p + \epsilon) \qquad (13)$$

Amplification effects in the interbank market and liquidity provision

In order to capture the level of information asymmetry g in the market that is affected by the original shock and to describe the resulting amplification effects, the random term in equation (10) is formulated as a product of two variables:

$$E(\epsilon) = \varepsilon \times f(g), \qquad 0 \leq g \leq 1$$
$$\mathrm{f}(0) = 1, \ \frac{\mathrm{df}}{\mathrm{dg}} > 0, \ \frac{\mathrm{d}^2\mathrm{f}}{\mathrm{dg}^2} > 0 \tag{14}$$

The value of g depends on the market that is affected by the original shock. $g = 0$ if the market is an organized securities exchange listing simple assets. g will be relatively low in the case of an organized securities exchange listing complex assets, and relatively high in the case of an OTC derivatives market using a clearing house. Finally, in the case of an OTC derivatives market without central clearing, $g = 1$. So $E(\in) = \varepsilon$ in the case of an organized securities exchange listing simple assets and $E(\in) > \varepsilon$ otherwise. Furthermore, since it is all the more difficult for market operators to identify disequilibria than the markets are complex and unorganized, we assume f(g) to be a convex function.

So the random part ε of the spread shock (10) and the liquidity shock (credit rationing, as described in equation (13) is amplified depending on the market that is affected by the original shock, that is:

$$\Delta\,\pi_1 = \Delta\,\pi_{\hat{t}}\, j \left(p \ + \varepsilon\, f(g)\right) \tag{15}$$

$$LD_{1\ t_1} - LS_{1\ t_1} = -\,(a-c)\,\Delta\,\pi_{\hat{t}}\, j \left(p + \varepsilon\, f(g)\right) \tag{16}$$

The CB will respond with providing an amount X of liquidity:

$$LD_{1\ t_1} - LS_{1\ t_1} > \overline{CM_1} \ \ \Rightarrow X = LD_{1\ t_1} - LS_{1\ t_1} \tag{17}$$

3.4. The widespread capital markets crisis (t_2)

Interbank market

In the market that is affected by the original shock, funding conditions are unchanged. In the other markets, the evolution of funding conditions depends on the magnitude of the shock at t_1 in the interbank market. $\overline{\Delta\,\pi_1}$ is the upper bound of the spread shock that the CB is able to contain. On the one hand, if $\Delta\,\pi_1 \leq \overline{\Delta\,\pi_1}$, the liquidity provision will restore funding conditions in the interbank market and this will break off amplification effects. The other capital markets will not be affected.

On the other hand, if $\Delta\pi_1 > \overline{\Delta\pi_1}$, the liquidity provision is not sufficient to break off amplification effects. This case will be solely described in the remainder of the model. As a response to the increase in spreads and the decrease in liquidity in all capital markets, the CB will bring down the official interest rate to its lowest bound $\underline{r_{CB}}$, implementing a first unconventional monetary policy measure. Following (10) the spread and the interest rate in the interbank market are now respectively:

$$\pi_{1\ t_2} = \pi_{1\ t_0} + \Delta\pi_{\hat{\imath}}\, j\,(\Delta r_{CB} + p + \epsilon),\ \text{avec}\ \Delta r_{CB} = \underline{r_{CB}} - r_{CB\,t_0} \tag{18}$$

$$r_{1\ t_2} = r_{1 t_1} + \Delta r_{CB} + \Delta\pi_1 = r_{1\ t_1} + \Delta r_{CB}\,(1 + \Delta\pi_{\hat{\imath}}\, j) \tag{19}$$

The above equation (18) expresses the fact that the ability of the CB to contain the crisis by lowering the official interest rate depends on the magnitude of the amplification effect, as measured by $(p + \epsilon)$.

Credit rationing in the interbank market at t_1 can be written as:

$$LD_{1\ t_2} - LS_{1\ t_2} = -(a-c)\left[\Delta r_{CB} + \Delta\pi_{\hat{\imath}}\, j\left(\Delta r_{CB} + \left(p + \varepsilon f(g)\right)\right)\right] \tag{20}$$

Thus, credit rationing depends negatively on the sensitivity of credit demand with respect to interest rates a, and positively on the sensitivity of credit supply c. The CB will continue its liquidity provision and totally fill this liquidity shortage, substituting for the interbank market, in the same way as at t_1.

The other markets (credit and other assets)

All the other markets are now also affected by propagation effects. The excess funding demand in these markets is a positive function of private credit rationing in the interbank market:

$$\begin{cases} LD_{i\ t_2} - LS_{i\ t_2} = \zeta \times j_i\left(LD_{1\ t_2} - LS_{1\ t_2}\right),\ i = 2,\dots,n_1 \\ S_{i\ t_2} - D_{i\ t_2} = \eta \times j_i\left(LD_{1\ t_2} - LS_{1\ t_2}\right),\ i = n_1+1,\dots,n_2 \\ S_{i\ t_2} - D_{i\ t_2} = \theta \times j_i\left(LD_{1\ t_2} - LS_{1\ t_2}\right),\ i = n_2+1,\dots,N \end{cases} \tag{21}$$

In addition to private credit rationing in the interbank market, the excess funding demand in each of these markets is a positive function of the size of the market j_i, and a of coefficient (ζ in credit markets, η in primary markets and θ in secondary markets). Those coefficients represent the rate of transfer from each of the three types of markets to the government debt market (7) in the case of a disequilibrium. The more financing conditions in a type of markets are dependent on the interbank market, the larger the transfer to public debt will be, as a result of a "flight to quality" behavior.

Government bonds purchases

Following from equations (6), (7) and (21), the CB sets the amount of government debt that it has to purchase in order to fulfill the liquidity condition (defined in equation (9)).

$$S_{0\ t} - D_{0\ t} = (1+\lambda)\bar{S} - \bar{D} + \left(LD_{1\ t_2} - LS_{1\ t_2}\right) \times$$
$$\times \left[\zeta(\alpha(1+\lambda)-\zeta)\sum_{i=2}^{n_1} j_i + \eta(\beta(1+\lambda)-\eta)\sum_{i=n_1+1}^{n_2} j_i + \theta(\gamma(1+\lambda)-\theta)\sum_{i=n_2+1}^{N} j_i\right] =$$
$$= (1+\lambda)\bar{S} - \bar{D} - (a-c)\begin{bmatrix}\Delta r_{BC} \\ + \Delta \pi_{\hat{\imath}}\, j\left(\Delta r_{BC} + \left(p + \varepsilon f(g)\right)\right)\end{bmatrix} \times$$
$$\times \left[\zeta(\alpha(1+\lambda)-\zeta)\sum_{i=2}^{n_1} j_i + \eta(\beta(1+\lambda)-\eta)\sum_{i=n_1+1}^{n_2} j_i + \theta(\gamma(1+\lambda)-\theta)\sum_{i=n_2+1}^{N} j_i\right]$$

(22)

If the excess supply of assets, as expressed by the difference below, is not negative and less than its threshold level $\overline{PM_0}$, the CB will purchase the following amount of government debt:

$$Y = \begin{cases} 0, & \left(S_{0\ t_2} - D_{0\ t_2}\right) \le \overline{PM_0} \\ (S_{0\ t_2} - D_{0\ t_2}) - \overline{PM_0}, & \left(S_{0\ t_2} - D_{0\ t_2}\right) > \overline{PM_0} \end{cases} \tag{23}$$

Private assets purchases

In the other securities markets, the same principle applies. The only difference is that, in those markets, the CB's threshold level of the liquidity indicator is strictly positive, which means that a positive excess funding demand is tolerated. In each of these markets if the liquidity indicator is greater than its threshold level the CB will purchase assets with an amount Z_i. For example in primary markets:

$$Z_i = \begin{cases} 0, & \left(S_{i\ t_2} - D_{i\ t_2}\right) \le \overline{PM_i} \\ (S_{i\ t_2} - D_{i\ t_2}) - \overline{PM_i}, & \left(S_{i\ t_2} - D_{i\ t_2}\right) > \overline{PM_i} \end{cases} \tag{24}$$

So at t_2 the CB's monetary policy includes both a conventional measure, namely liquidity provision, and two types of unconventional measures, namely the large decrease in the official interest rate and government bonds/private securities purchases.

Key factor in the quantity of securities purchases

Finally, equations (21), (22), (23) and (24) point to three key factors in the quantity of the CB's assets purchases. First, following from (22) and (23), for a given additional supply of government bonds caused by the cost of the recovery policy, the model highlights that the amount of government bonds purchases Y depends on the initial situation of public finances $\bar{S}$. A large structural deficit implies large bonds purchases in order to achieve the threshold liquidity level in the government bonds market. On the contrary, if $\bar{S}$ is low the CB's involvement is less extensive and its independence is strengthened, hence the need for coordination of fiscal policies in the case of a monetary union. Secondly, the amount of purchases of both types of securities (private securities, as described in (21) and (24), and government bonds as described in (22) and (23)) depends on the initial level of the official interest rate. If it is relatively high, then the interest rate tool is more able to fix the markets' funding conditions. The third key factor in the quantity of securities purchases is the connection between the single markets and the interbank market (ζ, η and θ in (21)). A strong connection allows the amplification effect of the initial shock, originally limited to the interbank market, to spill over and cause a global liquidity shortage. As a result, the CB will have to purchase large amounts of private securities. In brief, equations (21), (22) (23) and (24) say that if there exists a possibility of an amplification effect, there is a stronger rationale for careful and coordinated fiscal policies, rapid shifts from expansionary to contractionary monetary policies after a recession has ended, and close monitoring of liquidity indicators of the markets that are strongly correlated with the interbank market.

Note that the exact timing of monetary policy after a crisis ("the exit strategy") is one of the key factors of the CB's ability to manage the following crisis. Moreover, the model could be extended by the consideration of the relationship between official interest rates and the relative sizes of the different types of markets (credit markets and simple assets markets *vs.* complex and/or OTC markets, generating amplification effects).

Conclusion

Eventually our contribution is twofold. First, we build a simple model of unconventional monetary policies in the context of a global financial crisis that is caused by amplification effects of a shock in a secondary complex assets market, resulting in widespread liquidity shortages. This formalized analysis of the different stages of the crisis and of the CB response aims to bring out the underlying rule for the practice of unconventional monetary policies. The need for a better coordination of market operators in the occurrence of global financial crises actually implies that some kind of rule should be defined. Regardless of the question of disclosure of the CB's threshold levels, uncertainty would be lowered by the existence of such a monetary policy rule quantifying each class of assets purchases that may be conducted.

Secondly, conclusions can be drawn about capital markets organization. The question of the widespread adoption of central clearing is indeed closely linked to crisis management issues. Hence the International Swaps and Derivatives Association creates industry standards for derivatives since clearing requires greater standardization. Clearing is usually associated with a reduction of the risk of default of market operators. We emphasize that collateralization, margin requirements and contributions to the clearing houses guaranty funds also reduce the dimension of amplification effects. Considering, in general, the low degree of standardization of OTC assets market and, in particular, the impossibility to clear customized OTC products, the repetition of this type of crises and the need for unconventional monetary policies is inevitable. Nevertheless, their frequency can be reduced, and the importance of the CB's policy response can be limited.

Notes

(1) This outcome calls into question the principle of separating monetary policy and financial stability. The links between financial stability and monetary policy are questioned from the moment that low interest rates for a long time (or CB's commitment to keep policy rates low for an extended period) tend to provide incentives for banks to take ill-considered risks (Adrian, Shin, 2008, 2009, Altunbas et al., 2009, 2010, Bekaert et al., 2010, Ciccarelli et al., 2010, Eickmeier, Hoffman, 2010, Gambacorta, 2009, 2011, Ioannidou et al., 2008, Jimenez et al., 2009, Taylor, 2009). The trade-off between price stability and financial stability (Rajan, 2005, White, 2006) should affect the conduct of monetary policy (De Walque, Pierrard, 2009, Agur, Demertzis, 2009). However according to Dokko et al. (2009), Dooley (2010), Feldstein (2010) or Pollin (2009), CBs did not play a cucial role in generating the crisis. It is the end of the "Jackson Hole" broad consensus, according to which CBs' main task is to keep inflation low and stable in order to anchor inflation expectations (Fahr et al., 2011, Goodhart, Tsomocos, 2007).

(2) Aglietta (2011), Blinder (2010), Borio (2011), Galati and Moessner (2011) or Tucker (2009) point out the fact that CBs are in the best position to implement a counter-cyclical policy since they are best informed.

(3) This result is obtained with a more strongly decreasing credit supply function than the demand, as a generalization of Stigltiz and Weiss (1981). Even when the interest rate is low, the return to the bank is a decreasing function of the interest rate, because of the induced deteriorating behavior and/or distribution of borrowers. So in each credit market the aggregate credit supply function is monotonic and decreases with the interest rate. There is an excess supply (demand) for funds in times of low (high) interest rates.

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