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The Impact of a Liquidity Shock on the Economy and the Banking Sector through a Fire-Sale Mechanism[1]

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Abstract

The paper analyses the impact of a systemic liquidity shock on the banking sector and the economy using a New Keynesian model with banks. The literature on dynamic stochastic general equilibrium models with the explicit banking sector is still in an early stage. The paper contributes to this literature by studying the liquidity shock transmission through a fire-sale mechanism that lowers banks' assets and triggers deposit withdrawals. The shock is transmitted to the economy as banks contract their lending supply, significantly reducing investment. The model includes financial frictions on how banks allocate financial resources to the economy (principal-agent frictions). The results show that the fire-sale mechanism is one of the most significant channels for shock transmission and amplification for the banking sector. The implications of the fire-sale shock are more severe for the banking sector than a negative shock on capital quality or productivity.

Keywords: fire-sale mechanism, banks' liquidity, DSGE.

JEL Classification: E51, F34, G21.

1. Introduction

Fire-sale is an important amplification mechanism for a systemic liquidity shock that could make a crisis worse (Diamond, Rajan, 2011). During a financial crisis, financial institutions might be unable to rollover their liabilities (mainly deposits in the case of commercial banks). Banks might be forced to sell part of their portfolios due to lack of liquidity, but at a substantial discount (fire-sale price). Due to the specific conditions during a liquidity crisis, the assets sold at the fire-sale price are usually of good quality. The Global Financial Crisis (GFC) provides a good example of such a crisis (Bernanke, 2010; Shleifer, Vishny, 2011).

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This paper studies the liquidity shock transmission through a fire-sale mechanism that lowers banks' assets and triggers deposit withdrawals in a DSGE framework. The shock impacts the economy as banks contract their lending supply, significantly reducing investments. This paper uses a New Keynesian DSGE model with the banking sector based on Gertler et al. (2020). The model includes financial friction in how banks allocate resources to the economy (principal-agent frictions). The literature on DSGE models on financial crises is still being developed, with significant improvements seen after the GFC (Christiano et al., 2018). The DSGE models provide a good framework for policy analysis despite its limitations.

This paper contributes to the literature on banks' liquidity risk and banking crises models (Gertler, Karadi, 2011; Gertler, Kiyotaki, 2015; Gertler et al., 2020) by disentangling the shock of banks' returns on loans into two distinct shocks: on capital quality and asset prices. The hypothesis that I test is that the main driver of banks' rapid deterioration of the financial stance following a shock is the fire-sale mechanism. In this paper, the capital quality shock is applied directly to the return on capital, while a different shock (named fire-sale shock) on asset prices, as opposed to Gertler et al. (2020), where the capital quality shock is on the banks' loan return. I calibrate the parameters using the data for the Romanian economy for the period 2006-2020 and the existing literature. The simulations show that the main transmission channel of a shock on banks' earnings from loans is through the fire-sale mechanism. This shock is more severe for the banking sector than a negative shock on capital quality or productivity. The impact is even higher if we include another financial friction on the inefficiency of direct household lending. In this model, when banks exit the credit market, the households step in to finance the economy but at a higher cost for selecting and monitoring projects funded. The results of this model extension are not presented in the paper due to lack of space.

The paper is organized as follows. Section 2 describes the DSGE model emphasizing the banking sector and the fire-sale mechanism. Section 3 presents the calibration of the model. Section 4 discusses the results of the simulations based on the baseline model. Section 5 concludes.

2. Model Main Features

The model is based on a New Keynesian DSGE model for a closed economy with price stickiness and a banking sector developed by Gertler et al. (2020). The model includes a self-fulfilling run framework similar to Cole and Kehoe (2000) and principal-agent friction similar to Gertler and Karadi (2011) and Gertler and Kiyotaki (2015). I study the impact of a fire sale mechanism after a liquidity shock on the banking sector and the economy.

The economy is financed mainly by the banking sector ($S_{B,t}$) and partially by households' through direct lending ($S_{H,t}$):

$$S_t = S_{B,t} + S_{H,t} \tag{1}$$

Similar to Gertler et al. (2020), a shock can occur on the quality of capital between the beginning and the end of a period:

$$K_{t+1} = \xi_{KQ,t+1} S_t \tag{2}$$

where $K_{t+1}$is the capital stock in the economy at the end of period t + 1 and S_t is the capital stock at the beginning of period t + 1 and $\xi_{KQ,t+1}$is the capital quality shock.

2.1 Banking Sector Features

In the model, banks raise deposits from households at interest rate R_t and grant credit to companies at interest rate $R_{B,t}$. The assets against which banks lend to companies are $S_{B,t}$ at price Q_t. The bank's balance sheet constraint is:

$$Q_t S_{B,t} = D_t + N_t \tag{3}$$

Under normal conditions, a bank can survive each period with a probability (σ_B), while $(1 - \sigma_B)f$ new bankers enter the market with an initial net worth of e. Banks accumulate net worth after the initial endowment, $(1 - \sigma_B)fe$, by earning profit through lending at a higher interest rate than the interest rate paid on deposits. The net worth of the banking sector is described by:

$$N_t = \sigma_B \left[R_{B,t} Q_{t-1} S_{B,t-1} - R_t D_{t-1} \right] + (1 - \sigma_B) fe \tag{4}$$

The bankers maximize the expected value of banks' net worth until the bank exit the market. The bankers choose the projects the bank will finance. Still, they can also decide to redirect a part of their assets (θ) to other purposes (like risky investments that turn into nonperforming assets or paying extra bonuses or dividends to the bankers) - principal-agent financial friction, similar to Gertler et al. (2020).

2.2 Fire-Sale Mechanism

A bank commits to pay depositors the return R_t^* . Under specific conditions (for example, after a liquidity shock), a bank might not have enough funds to pay the deposits. Therefore, the return on deposits can be described as:

$$R_{t+1} = \begin{cases} R_{t+1}^* & \text{with probability } 1 - p_t \\ x_{t+1} R_{t+1}^* & \text{with probability } p_t \end{cases} \tag{5}$$

where x_{t+1} is the recovery rate of deposits at market prices:

$$x_{t+1} = \frac{\left[\xi_{KQ,t+1} Z_{t+1} + (1 - \delta) \xi_{FS,t+1} Q_{t+1} \right] S_{B,t}}{R_t^* D_t} < 1 \tag{6}$$

and $\xi_{KQ,t+1}$is the capital quality shock that affects the real return on capital and $\xi_{FS,t+1}$is the fire-sale shock. After a fire-sale event, the asset prices drop quickly and reduce the return on loans. A solvent bank that suffers such a shock might become insolvent if the drop in the bank's profit is severe enough. Gertler et al. (2020) tests the fire sale mechanism by applying a single shock on the banks' return from lending.

The banks' franchise value also drops; the impact is amplified by the banks' leverage (Φ_t). Written as the Tobin rate (Ψ_t), the banks' franchise value is (see the Appendix for more details):

$$\Psi_t = E_t \left\{\Omega_{t+1}\left(\frac{\left[\xi_{KQ,t+1}Z_{t+1} + (1-\delta)\xi_{FS,t+1}Q_{t+1}\right]}{Q_t} - R_{t+1}\right)\right\}\Phi_t + E_t\{\Omega_{t+1}R_{t+1}\} \tag{7}$$

Under normal circumstances, the banks with higher leverage will earn more profit and have higher franchise value. However, the impact will be higher for levered banks when a shock occurs.

3. Model Parameters

I calibrate the parameters according to the existing literature and the Romanian economy for 2006-2020. The data sources are the National Bank of Romania and the National Institute of Statistics. The values used are presented in Table 1.

Table 1. Parameters of the baseline model

Parameter	Value	Description
Macroeconomic model		
β	0.987	Discount factor
ς_c	2.000	Risk aversion
ς_h	7.500	Inverse Frisch elasticity
α	0.550	Capital share
δ	0.049	Capital depreciation rate
ε	11	Elasticity of substitution
κ	4	Investment adjustment cost
ϱ	1000	Rotemberg (1982) price adjustment cost
ρ_π	1.500	Monetary policy response to inflation
ρ_y	0.125	Monetary policy response to output
G	0.466	Government expenditure
Banking sector		
θ	0.220	Share assets allocated to other purposes
σ_B	0.847	Probability of survival for a bank
Φ_{SS}	8	Banks' leverage in steady state
$spread_{SS}$	0.005	Banks' spread in steady state
e	0.011	Net worth of new banker
Shocks		
ρ_A	0.750	Persistence of technology shock
ρ_G	0.750	Persistence of government expenditure shock
ρ_{RP}	0.750	Persistence of risk premium shock
ρ_{KQ}	0.750	Persistence of capital quality shock
ρ_{FS}	0.750	Persistence of fire sale shock
σ_{shock}	0.050	Standard deviation of shocks

Source: Christiano et al. (2011), Copaciu et al. (2016), Gertler et al. (2020).

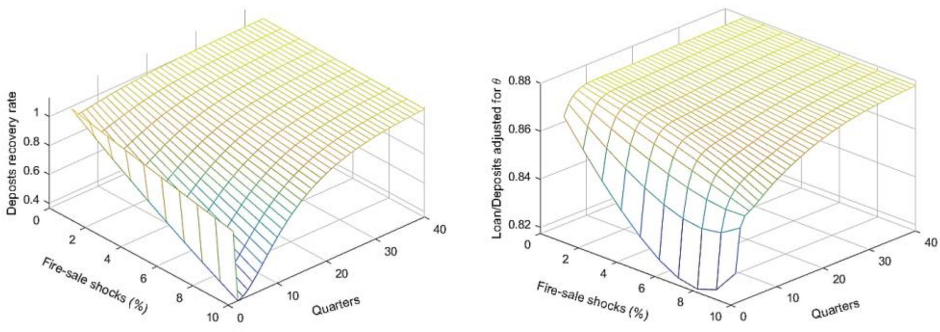
The households' discount factor (β) is set to 0.9866798 which corresponds to the average annual interest rate of 5.4% during the period analysed (or 1.35% quarterly). The capital share (α), the depreciation (δ) and the investment adjustment cost (κ) are set to 55%, 4.9% and 4 based on Copaciu et al. (2016). Inverse Frisch elasticity (ς_h) is set to 7.5 similar to Christiano et al. (2011) and Copaciu et al. (2016). For risk aversion (ς_c), Taylor rule parameters (ρ_π and ρ_y), elasticity of substitution across different input factors (ε), the Rotemberg (1982) price adjustment cost (ϱ) and Government expenditure (G), I follow Gertler et al. (2020). I also follow Gertler et al. (2020) for the banking sector parameters.

I simulate the model using the first-order perturbation method from Dynare v5.0 software. The model was initially based on the codes provided by Gertler et al. (2020). All the figures are created in Matlab using the policy functions estimated by Dynare.

4. Fire-Sale Shock Impact on the Banking Sector and the Economy

The fire-sale shock ($\xi_{FS,t+1}$) lowers the bank's inflows below the minimum level that would allow them to pay their depositors the promised returns. Therefore, the deposits recovery rate (x_{t+1}) drops quickly below 1, and depositors, aware of the bank's financial situation, withdraw their deposits even more. The bank is forced to sell part of its loan portfolio at a discounted price (fire-sale price), thus enforcing the downward spiral of asset prices. The results are presented in Figure 1.

Figure 1. The responses on different fire-sale shocks



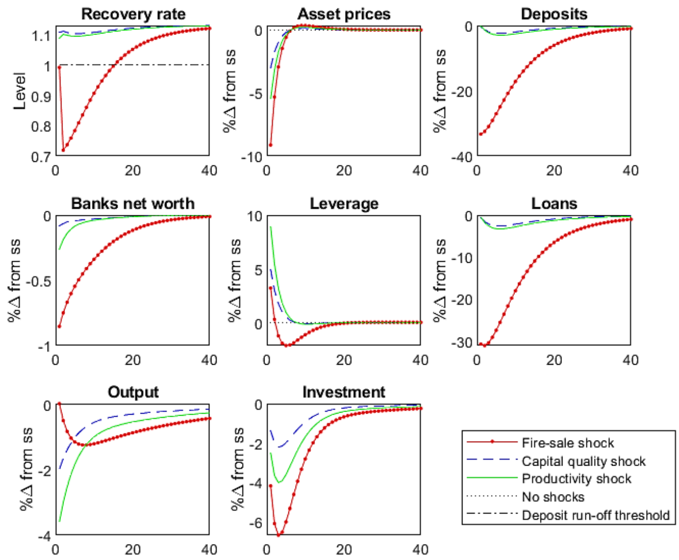
(a) Deposits recovery rate (b) Loan/Deposits adjusted for θ

Source: Author's calculations.

I compare the impact on the fire-sale shock with the results on two other negative shocks calibrated with the same magnitude and persistence: capital quality and productivity. I consider a 5 percent decrease within a quarter with a relatively high persistence (the autoregressive coefficient is set to 0.75) for all the shocks analysed. Given that the model is solved using first-order approximation, the magnitude of the shocks does not affect the results (certainty equivalence). The impulse responses are presented in Figure 2.

The fire sale shock generates a more severe deterioration of banks' financial stance and triggers a deposit run than the other shocks studied, confirming the research hypothesis. The fire-sale shock also determines the most significant decline in investment compared to other shocks, while the impact on output, even if it is less severe, and is corrected more slowly. The impact of the fire-sale shock is larger for the banking sector, as it triggers important balance sheet adjustments as opposed to the capital quality shock that impacts only the return generated by the lending activity.

Figure 2. Banking sector and economy response to a fire-sale shock



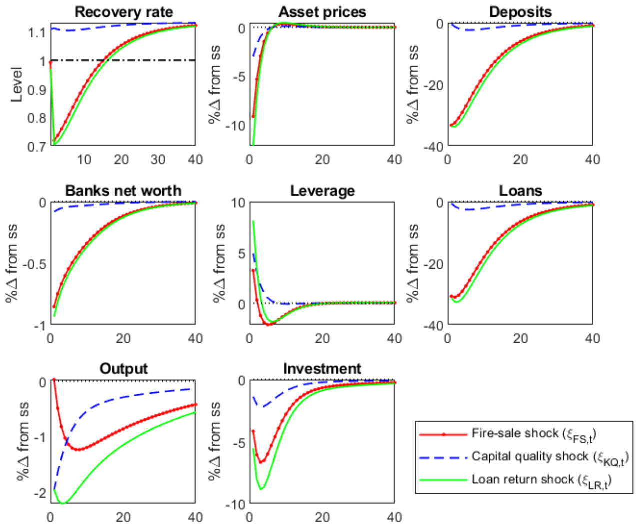
Source: Author's calculations.

The other two negative shocks (the capital quality and productivity shocks), although they generate a reduction in asset prices (but of a smaller magnitude), do not trigger significant changes in the banking sector. The only notable impact is on the leverage ratio due to asset price and banks' net worth declines.

Lastly, I combine the fire-sale shock ($\xi_{FS,t+1}$) with the capital quality shock ($\xi_{KQ,t+1}$). This loan return shock ($\xi_{LR,t+1}$) is similar to the capital quality shock used by Gertler and Kiyotaki (2015) and Gertler et al. (2020).

The response of the banking sector to the loan return shock is very similar to the one on asset prices (fire-sale shock), while the investment and economic growth impact are higher. This result shows that the fire-sale mechanism is an important shock transmission and amplification mechanism for the banking sector. The results are presented in Figure 3.

Figure 3. Banking sector and economy response to a loan return shock



Source: Author's calculations.

These results are robust to changes in the calibrated parameters or to changes in the model features such as household consumption behaviour (for example, adding external habit formation) or investment dynamics. However, the model has some important limitations, the most important one being the uniform treatment of agents (homogenous agents).

5. Conclusions and Further Research

In this paper, I analyse the impact of a systemic liquidity shock on the banking sector and on the economy through a fire-sale mechanism. I use a New Keynesian DSGE model with a banking sector based on Gertler et al. (2020). The liquidity shock triggers a drop in asset prices that significantly impair the banks' profit and lowers investment and economic growth. The results show that the fire-sale mechanism is one of the most important channels for shock transmission and amplification in the banking sector.

Similar to Gertler et al. (2020), the model includes principal-agent financial friction, as bankers can divert a part of their banks' assets to other purposes (such as risky investments that turn into nonperforming assets or paying extra bonuses or dividends to the bankers). As opposed to Gertler et al. (2020), I look at the fire-sale shock directly applied to asset prices. I compare this shock to a macroeconomic one (productivity shock) and to a capital quality shock. The fire-sale shock generates a stronger reduction in banks' profit compared to negative shocks on capital quality and productivity. I also show that the banking sector's response to the loan return shock is mainly due to the fire-sale mechanism. This points to the importance of ex-ante prudential measures for banks' liquidity risk, as well as to the necessity of developing instruments that would allow the central bank to intervene during liquidity crises to limit the occurrence of fire-sale events.

The model can be extended further by adding the macroprudential policy. For example, the model can be used to assess how banks respond to a fire-sale shock when under a macroprudential measure. Such a measure can, for example, require banks to hold a certain level of liquid assets, either by setting a simple limit or by using more complicated instruments like Liquidity Cover Ratio and Net Stable Funding Ratio.

In conclusion, studying the financial sector responding to shocks within a dynamic stochastic general equilibrium framework has its merits in helping policymakers have a better comprehension of the main shock transmission and amplification mechanisms, like fire-sale.

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Appendix – The baseline DSGE model

Households maximize their utility:

$$\mathrm{U_t} = \mathrm{E_t}\left\{\sum_{\tau=\mathrm{t}}^{\infty} \beta^{\tau-t}\left[\frac{C_\tau^{1-\varsigma_c}}{1-\varsigma_c} - \frac{H_\tau^{1+\varsigma_h}}{1+\varsigma_h}\right]\right\} \tag{8}$$

subject to the budgetary constraint:

$$\begin{aligned} C_t + D_t + Q_t S_{H,t} + B_t \\ &= w_t H_t - T_t + \Pi_t + R_t D_{t-1} + \frac{R_{t-1}^n}{\pi_t} B_{t-1} \\ &+ \left[\xi_{KQ,t} Z_t + (1-\delta)\xi_{FS,t} Q_t\right] S_{H,t-1} \end{aligned} \tag{9}$$

There are three types of firms: companies that produce final goods, companies that produce intermediate goods, and companies that produce capital goods.

The firms producing intermediate goods operate in a monopolistic market. For this type of competitive market, the real wage is equal to the marginal increase in production given a unit increase of labour, and the real rent on capital is equal to the marginal increase in production given a unit increase of capital.

Each period, the firms adjust their prices according to Rotemberg (1982) with $\varrho > 0$ being the Rotemberg's parameter for cost adjusting prices ($\varrho = 0$ indicates fully flexible prices):

$$(\pi_t - 1)\pi_t = \frac{\varepsilon}{\varrho}\left(MC - \frac{\varepsilon - 1}{\varepsilon}\right) + E_t\left[\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}(\pi_{t+1} - 1)\pi_{t+1}\right] \tag{10}$$

The capital goods producers maximizing their profits similar to the ones described by Gerali et al. (2010) and Gambacorta and Signoretti (2014):

$$E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau}\{Q_\tau[S_\tau - (1-\delta)S_{\tau-1}] - I_\tau\} \tag{11}$$

where S_t is subject to the following dynamics with quadratic adjustment cost of investments:

$$S_t = (1-\delta)S_{t-1} + \left[1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \tag{12}$$

where Q_t is the real price for capital goods, and κ is the parameter for the cost of adjusting investments.

I follow Gertler et al. (2020) and consider that the monetary policy sets the nominal interest rate ($R_{n,t}$) according to the Taylor rule:

$$R_{n,t} = \frac{1}{\beta} {\pi_t}^{\rho_\pi} {\Theta_t}^{\rho_y}, \quad \rho_\pi > 1 \tag{13}$$

where Θ_t is a measure of cyclical utilization of resources in the economy defined as the ratio between the steady-state markup and the current markup. In this model, the public sector is financing its consumption entirely through lump-sum taxes.

The model for the banking sector is similar to Gertler et al. (2020). Banks, as other types of agents in this model, are homogeneous. Each banker seeks to maximize the bank's value:

$$V_t = E_t\left\{\Lambda_{t,t+1}[(1-\sigma_B)N_{t+1} + \sigma_B V_{t+1}]\right\} \tag{14}$$

A bank can exit the market at time t with probability $1-\sigma_B$. In addition, bankers can decide to divert a part of the bank's assets (θ) to less profitable purposes. The necessary condition for a bank to continue to operate (considering that σ_B is high) is:

$$\theta Q_t S_{B,t} \leq V_t \tag{15}$$

To simplify the optimization problem, I use two notations. One for the bank's Tobin rate $\left(\Psi_t = {V_t}/{N_t}\right)$ and another for the bank's leverage $\left(\Phi_t = {Q_t S_{B,t}}/{N_t}\right)$. The maximization problem for banks can be written as follows. The banker chooses the level of bank's leverage that maximizes the bank's value:

$$\Psi_t = \mu_{t+1}\Phi_t + \upsilon_{t+1} \tag{16}$$

where:

$$\mu_{t+1} = E_t\left\{\Omega_{t+1}\left(R_{B,t+1} - R_{t+1}\right)\right\} \text{ and } \upsilon_{t+1} = E_t\{\Omega_{t+1}R_{t+1}\} \tag{17}$$

with:

$$\Omega_{t+1} = \Lambda_{t,t+1}[1-\sigma_B + \sigma_B\Psi_{t+1}] \tag{18}$$

subject to:

$$\theta\Phi_t \leq \mu_{t+1}\Phi_t + \upsilon_{t+1} \tag{19}$$

The model includes five exogenous shocks as follows: negative technology, capital quality, and asset prices (fire sale) shocks, and positive government expenditure and risk premium shocks.