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LIQUIDITY CONSTRAINTS, RISK PREMIA, AND THE MACROECONOMIC EFFECTS OF LIQUIDITY SHOCKS

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In 2013 all ECB publications feature a motif taken from the €5 banknote.

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Abstract

We study the transmission of liquidity shocks in a dynamic general equilibrium model where firms and households are subject to liquidity risk. The provision of liquidity services is undertaken by financial intermediaries that allocate the stock of liquid asset between the different sectors of the economy. We find that the macroeconomic effects of liquidity shocks are considerably larger in the model economy that generates a realistic equity premium. Liquidity constraints amplify business cycle volatility and have nonlinear effects on risk premia. Our empirical analysis suggests that the Great Recession was primarily caused by liquidity factors.

- *JEL:* E44, E51, E32.
- *Keywords:* Great Recession, asset pricing, bayesian estimation.

Non-technical summary

One of the most important functions of safe financial assets is to facilitate exchanges by serving as collateral in financial transactions. In this respect, high quality financial assets offer liquidity services that are comparable to the ones provided by a standard medium of exchange such as money. One possible explanation for the severity of the Great Recession is that the effects of the financial crisis were amplified by the shortage of pledgeable assets created by the initial subprime shock. The objective of this work is to formally evaluate this hypothesis by testing whether this mechanism could generate a large recession and a stock market crash.

To address this question, we start by developing a simplified dynamic general equilibrium model of the euro area economy, which features a financial sector and where firms and households are subject to liquidity risk. The key modelling assumption is that agents in this economy need the liquidity services provided by a financial or money-like asset to overcome transaction frictions. The supply of financial assets is endogenously determined by a financial sector whose main task is to allocate the liquidity services provided by these assets between the different sectors of the economy. A negative liquidity shock is an exogenous shock that destroys a fraction of the stock of money-like assets produced by the financial sector.

The first main contribution of this paper is to develop a model mechanism that amplifies and propagates the effects of liquidity shocks and to show that the real effects of these shocks crucially depend on the model's asset pricing implications. In the model economy that matches the equity premium, our main finding is that a small negative liquidity shock can generate a deep recession and a stock market crash. In the version of the model that is unable to generate plausible risk premia, in contrast, the effects of liquidity shocks are considerably smaller.

Second, the role of liquidity factors during the Great Recession is evaluated by estimating the relative contribution of liquidity shocks. Our analysis suggests that the sharp contraction in output was mostly due to a negative liquidity shock originating in the financial sector. The shock was then transmitted to the other sectors of the economy by triggering a tightening of liquidity conditions faced by households and firms. Overall, liquidity factors have the potential to explain a significant fraction of business cycle fluctuations.

1 Introduction

One of the most important functions of safe financial assets is to facilitate exchanges by serving as collateral in financial transactions. In this respect, high quality financial assets offer liquidity services that are comparable to the ones provided by a standard medium of exchange such as money (Gorton and Metrick, 2012; Singh and Stella, 2012). An important empirical regularity observed during the Great Recession is that the financial crisis has been accompanied by a shortage of pledgeable assets. The unprecedented size and severity of the credit rating downgrades, which affected nearly one third of securities that were rated AAA (Benmelech and Dlugosz, 2010), and the collapse in securitization issuance by the private sector led to a massive reduction in the quantity of assets that were considered safe (IMF, 2012).[1]

Together with the widening of spreads between assets of different quality, the tightening in bank lending standards observed during the early stages of the financial turmoil suggests that the shortage of pledgeable assets had a significant impact on the supply of credit.[2] To evaluate whether this mechanism could generate a large recession and a stock market crash, this work studies the effects of liquidity constraints in a dynamic general equilibrium model where the provision of liquidity services is undertaken by a financial sector.

In this economy, the key assumption is that a financial asset is needed to facilitate transactions. The stock of this financial asset, which represents the stock of safe or money-like asset, is owned by a financial intermediation sector. The main task of this financial sector is to manage the production of safe assets and to allocate the liquidity services that it provides between the different sectors of the economy. From the perspective of firms and households, liquidity risk stems from the fact that liquidity services are necessary to consume the market consumption good and to operate firms in the final good sector.

As in King and Plosser (1984), the second main function of financial intermediaries consists in providing financial services to firms, which are required to produce the final output good. Financial services differ from liquidity services in that they are a necessary input that firms need to combine with labor in order to produce the final good. The demand for liquidity services,

[1] In Europe, the total supply of safe assets has fallen from roughly €5.8 trn in 2006 to €1.6trn in 2012. Source: Goldman Sachs.

[2] See chart 1 in the appendix.

in contrast, stems from the liquidity constraints that agents are facing and liquidity services serve to "grease the wheels" of the economy by limiting the impact of transaction frictions on the allocation of resources.

In this economy, a liquidity crisis can be generated by small shocks to the supply of safe assets held by the financial sector. By reducing the quantity of pledgeable assets available in the economy, adverse liquidity shocks impair the mechanism of exchange by raising the cost at which households and firms are able to obtain liquidity services from the financial sector, interest rates rise, and the shortage of safe assets perturbs production and consumption decisions.

Our first main theoretical result is that the macroeconomic effects of liquidity shocks crucially depend on the model's ability to explain risk premia. This is firstly due to the fact that in our economy, as it is the case in most asset pricing models, it is necessary to lower the elasticity of intertemporal substitution in consumption (EIS) to match the equity premium. Liquidity constraints create a dependence towards the financial sector that is dictated by households' intertemporal consumption decisions because liquidity services are needed to achieve consumption smoothing. An unexpected shortage of safe assets forces agents to lower consumption and the decline will be more gradual, and therefore more persistent, if households have a low EIS.

As in Jermann (1998), augmenting the model with habit formation and adjustment costs is necessary to bring the model's asset pricing prediction into closer conformity with the data. Compared to models where labor is fixed, the main difference is the introduction of a specification of habits in the aggregate of consumption and leisure. Together with the assumption that habits are slow moving (Campbell and Cochrane, 1999; Constantinides, 1990), this modification helps to generate more realistic risk premia in models where labor supply is endogenously determined.

The second main reason that explains the large real effects of liquidity shocks is that in this environment it is necessary to reduce the wealth elasticity of labor supply by increasing the complementarity between consumption and hours worked in order to explain asset pricing facts. The macroeconomic effects of liquidity shocks are therefore greater in a model that is able to match the equity premium because the EIS is lower and the complementarity between consumption and hours is stronger.

With a standard preference specification, in contrast, the real effects of liquidity shocks and the equity premium generated by the model are considerably smaller. Intuitively, having access to liquidity services is required to consume and to operate firms but as long as agents are not too concerned about the adjustment margin through which the effects of the shocks will have to be absorbed, exogenous shocks to the supply of safe assets only have a modest impact on output. In this case, liquidity shocks mostly affect the trade-off between consumption and investment and have very little effect on hours worked.

Compared to Fuerst (1992) and Lucas (1990), the main difference is that, in the model that matches the equity premium, the effects of liquidity shocks on economic activity can be very persistent. The qualitative implications can also substantially differ from the ones arising in a standard cash-in-advance model (Cooley and Hansen, 1995), since in our economy, a positive liquidity shock reduces the cost of obtaining credit lines and generates a persistent increase in output, consumption, employment, and investment. The second main difference is that liquidity shocks generate the co-movement between equity prices and output that has been observed during the crisis. As pointed out by Shi (2012), standard models cannot easily generate this co-movement, or explain the lead-lag structure between equity prices and output observed in the data.

As in He and Krishnamurthy (2012), we find that market imperfections have a nonlinear impact on risk premia. Compared to their mechanism, an interesting difference is that in our economy the equity premium has an inverted U-shaped relationship with the tightness of the liquidity constraint. For most values of the velocity parameter, a tightening of the liquidity constraint raises the equity premium and increases the volatility of output. When the constraint is already very tight, however, while a further tightening of the velocity parameter raises the volatility of output, the impact on the equity premium can be ambiguous.

Turning to the empirical analysis, our main empirical finding is that liquidity shocks account for a substantial fraction of business cycle fluctuations in the euro area. Through variance decomposition, we find that liquidity shocks play a major role in explaining the dynamics of both financial and macroeconomic variables. Finally, following Jermann and Quadrini (2012), we examine the behavior of the estimated shock during the financial turmoil. While technology shocks played an important role, our analysis suggests that the Great Recession was primarily caused by liquidity factors.

Attempts to explain the effects of liquidity on real activity include studies that have proposed to modify the financial structure traditionally assumed. In Fuerst (1992), financial intermediaries channel central bank cash injection to firms and shoppers that are subject to cash-in-advance constraints. In Cooley and Quadrini (1999), a model with cash-in-advance constraints and limited participation is developed to study the relation between unemployment and inflation. Alvarez, Atkeson, and Kehoe (2002) consider a cash-in-advance model where the addition of fixed costs to exchange money and bonds gives rise to endogenous market segmentation. Alvarez and Lippi (2011) show how the parameters governing the intratemporal elasticity between cash balances and consumption and the EIS of the consumption bundle affect the persistence of the liquidity effect.

Kiyotaki and Moore (2012) study the effects of liquidity shocks in a real business cycle model where there are differences in liquidity across assets. Nezafat and Slavik (2011) and Shi (2012) study the asset pricing implications of the Kiyotaki-Moore model. Reynard and Schabert (2012) study liquidity premia in a model that reproduces the negative relation between corporate bond yield spreads and the supply of treasuries.

In King and Plosser (1984), financial intermediaries are integrated into real business cycle theory by modelling financial services as the output of the financial-banking industry. Transaction services serve as an intermediate good which is an input into the production and purchase of final goods. Credit market imperfection or liquidity constraints do not play any particular role in this environment.

Following Bernanke (1983), two complementary strand of literatures study the role of information and incentives problems in the banking sector and their ability to explain large recessions. On the nonmonetary side, this literature has led to the development of a generation of models with asymmetric information that are able to generate persistent business cycle fluctuations, even if exogenous shocks have little intrinsic persistence (Bernanke and Gertler, 1989). On the monetary front, models of the credit channel have studied the role of imperfect information or costly enforcement of contracts in the transmission mechanism.[3]

Finally, Gerali, Neri, Sessa and Signoretti (2011), Christiano, Motto and Rostagno (2010), and Jermann and Quadrini (2012) develop models that include financial frictions and nominal rigidities to study the macroeconomic effects of financial shocks.[4]

[3] See Bernanke and Gertler(1995) for a detailed overview of the credit channel.

[4] See Brunnermeier, Eisenbach, and Sannikov (2012) for a more detailed literature review.

2 The environment

The economy is composed of a representative household, a financial intermediation sector, and a final goods-producing sector. The final good is produced using labor and financial services that are purchased from the financial sector. Financial services, or loans, are produced using labor and capital and are an input in the production function of the final output good. The financial sector is endowed with an initial stock of liquid asset, which represents the stock of safe assets. Households and firms face transaction frictions and liquidity services, which are derived from the production of safe assets, are needed to consume and operate firms. The economy is subject to four sources of exogenous disturbances: shocks to total factor productivity in the final good sector, shocks to total factor productivity in the financial sector, monetary policy shocks, and liquidity shocks. Liquidity shocks are shocks to the supply of safe assets produced by the financial sector. The specifications of preferences and technology are compatible with balanced growth. The deterministic growth rate at which the economy is growing, along the balanced growth path, is denoted γ.

2.1 Households

Households derive utility from consuming a market consumption good, c, and leisure, l. Following Jaccard (2012), we assume that habits are formed over the mix of consumption and leisure, where the reference level or habit stock is denoted, x, and lifetime utility is given by:

$$U = E_0 \left\{ \sum_{t=0}^{\infty} \widehat{\beta}^t \frac{1}{1-\sigma} \left[c_t(\psi + l_t^v) - x_{t-1} \right]^{1-\sigma} \right\} \tag{1}$$

Net utility is given by the difference between the composite good, $c(\psi + l^v)$, and the reference level, x. The modified discount factor and the curvature parameter are denoted[5] $\widehat{\beta}$ and σ. As in Constantinides (1990), the following specification for the law of motion of the habit stock is used:

$$\gamma x_t = h x_{t-1} + (1-h) c_t(\psi + l_t^v) \tag{2}$$

[5] where $\widehat{\beta} = \widetilde{\beta}\gamma^{1-\sigma}$

where h captures the rate at which the habit stock depreciates. Together with the assumption that habits are formed over the entire composite good, introducing slow movements in the habit stock (Campbell and Cochrane, 1999; Constantinides, 1990) considerably improves the asset pricing predictions of dynamic general equilibrium models.

The representative household faces the following sequential budget constraint:

$$w_t \left(n_{Ft} + n_{Bt}\right) + r_{Kt} k_{t-1} + d_{Tt} = c_t + i_t + r_{Mt} m_{Ht}$$

where k is the amount of physical capital that is rented to the financial sector, r_K is the remuneration rate of physical capital, i, is the amount of resources invested in physical capital, and d_T is total profits received from the financial and the final good sectors.

Following Jermann (1998), capital accumulation is determined by households' saving and investment decisions and obeys an intertemporal accumulation equation that is given by:

$$\gamma k_t = (1-\delta) k_{t-1} + \left(\frac{\varkappa_1}{1-\epsilon} \left(\frac{i_t}{k_{t-1}} \right)^{1-\epsilon} + \varkappa_2 \right) k_{t-1} \tag{3}$$

where the cost of adjusting the capital stock depends on the elasticity parameter, ϵ. The two parameters $\varkappa_1$ and $\varkappa_2$ are calibrated so that the deterministic steady state of the model is not affected by the introduction of adjustment costs (Baxter and Crucini, 1993).

As far as the allocation of time is concerned, households divide their time endowment between leisure activities, hours worked in the final goods-producing sector, n_F, and hours worked in the financial intermediation sector, n_B. Normalizing the total time endowment to 1, we have that:

$$n_{Bt} + n_{Ft} + l_t = 1$$

We assume that households face a constraint that creates a demand for liquidity services. Liquidity risk stems from the fact that liquidity services are needed to alleviate a transaction friction, and that these services need to be rented from the financial sector. The representative household's holdings of safe assets is denoted m_H, and liquidity services can be borrowed from the financial sector at the interest rate, r_M. Following Lucas (1982), households' purchases of the market consumption good, c, are subject to a constraint that links consumption to the stock of liquid asset:

$$\theta m_{Ht} \geq c_t$$

where θ is the velocity parameter. Compared to a standard cash-in-advance constraint, the difference is that the supply of m_H will be endogenously determined by the financial sector.

2.2 The financial intermediation sector

Financial intermediaries decide how much labor to hire, manage the production of safe assets, and decide how to allocate the liquidity services provided by its stock of financial assets between the household and the final goods-producing sectors. Managers maximize the value of the firm which is equal to the present discounted value of all current and future expected cash flows:

$$E_0 \sum_{t=0}^{\infty} \widehat{\beta}^t \frac{\lambda_t}{\lambda_0} d_{Bt} \tag{4}$$

where $\widehat{\beta}^t / \frac{\lambda_t}{\lambda_0}$ is the discount factor of the representative agent, who is the owner of the firm, and where dividends are given by:

$$d_{Bt} = r_{Lt} y_{Lt-1} - w_t n_{Bt} - r_{Kt} k_{t-1} + r_{Mt} m_{Ft} + r_{Mt} m_{Ht} + \varrho_t \frac{m_{Tt-1}}{1+\pi_t} - \gamma m_{Tt}$$

The production of financial services generates a revenue from renting financial services or extending loans, y_L, to the final-goods producing firms. The rental rate of financial services is denoted, r_L. Financial services are produced via Cobb-Douglas production function using labor and capital:

$$\gamma y_{Lt} = z_t k_{t-1}^{\eta} n_{Bt}^{1-\eta}$$

where the quantity of labor input needed to produce financial services is denoted n_H, and z is a sector specific technology shock, which represents a financial shock. The shock follows an autoregressive process of order 1 with persistence, ρ_z, and standard deviation $std(\varepsilon_z)$. The law of motion characterizing the evolution of y_L embeds the assumption that the stock of financial services fully depreciates after one period, which reflects that financial services are intangible goods that cannot be stored. The stock of financial asset is deflated by the inflation rate, which is denoted π.

Finally, the second main function of the financial sector is to choose how to allocate the liquidity services provided by the stock of safe assets, m_T, between households and final good producers. This portfolio decision is captured by introducing the following constraint into the optimization problem:

$$\frac{m_{Tt-1}}{1+\pi_t} = m_{Ht} + m_{Ft}$$

where m_F is the amount of liquidity services allocated to the final goods-producing sector. This timing reflects the usual cash-in-advance assumption that only liquidity accumulated in previous periods can be used by households and firms for current-period transactions.[6] Adjusting the total amount of liquidity services $m_H + m_F$ is no longer possible once managers have decided on the level of $\frac{m_{Tt-1}}{1+\pi_t}$. However, a rebalancing of liquidity holdings across the two sectors can always occur after $\frac{m_{Tt-1}}{1+\pi_t}$ has been chosen, since the allocation of liquidity services, $m_H + m_F$ is chosen in period t. Finally, as in Lucas (1972), ϱ_t is a modelled as a multiplicative factor whereby the stock of safe assets carried from $t-1$, $\frac{m_{Tt-1}}{1+\pi_t}$, are multiplied by ϱ_t, so that financial intermediaries start periods t with $\varrho_t \frac{m_{Tt-1}}{1+\pi_t}$. The liquidity shock follows an autoregressive process of order 1 with persistence, ρ_m, and standard deviation $std(\varepsilon_m)$.

2.3 The final goods-producing sector

The final output good, y_T, is produced via a Cobb-Douglas production function using financial services that are rented from the banking sector and labor:

$$y_{Tt} = a_t y_{Lt-1}^{\alpha} n_{Ft}^{1-\alpha}$$

where labor input and the stochastic total factor productivity level are denoted, n_F and a. The technology shock follows an autoregressive process of order 1 with persistence, ρ_a, and standard deviation $std(\varepsilon_a)$. Profits of the final goods-producing firms are given by:

[6] See Svensson (1985) for a discussion of the importance of timing assumptions in cash-in-advance models.

$$d_{Ft} = a_t y_{Lt-1}^{\alpha} n_{Ft}^{1-\alpha} - w_t n_{Ft} - r_{Lt} y_{Lt-1} - r_{Mt} m_{Ft}$$

where the wage rate, real balances borrowed from the banking sector, and the interest rate are denoted w, m_F and r_M. The firm's demand for liquidity services stems from a liquidity constraint that is given by:

$$\kappa m_{Ft} \geq w_t n_{Ft} + r_{Lt} y_{Lt-1}$$

where κ is the firm velocity parameter. This constraint captures the assumption that liquidity services are needed to finance a share of the firm's current expenditures on wages and financial services. The borrowing rate for liquidity services is determined by the interest rate, r_M.

2.4 Monetary policy

The conduct of monetary policy is captured by an interest rate rule linking the money market rate, r_M, to the inflation rate, π. In Europe, price stability being the primary objective of monetary policy, we abstract from any measure of output gap and ω_π, which denotes the sensitivity of the targeted rate to a change in inflation, is the only policy parameter set by the monetary policy authorities.

$$r_{Mt} = \omega_\pi \pi_t + \xi_t$$

The non-sytematic component of monetary policy is denoted ξ_t, which is an autoregressive process of order 1 with persistence ρ_{MP} and standard deviation $std(\varepsilon_{MP})$.

2.5 Market equilibrium

An equilibrium is a set of prices for all possible states and for all $t \geq 0$ such that, when households and firms in the financial and in the final good sectors maximize utility and profits, taking these prices as given, all markets clear. Market clearing for the final goods market implies that all produced goods are either consumed or invested:

$$y_{Tt} = c_t + i_t + \gamma m_{Tt} - \varrho_t \frac{m_{Tt-1}}{1+\pi_t}$$

where $\gamma m_{Tt} - \varrho_t \frac{m_{Tt-1}}{1+\pi_t}$ is the amount of resources invested in the production of liquidity services. Labor supply equals labor demand, the quantity of safe assets produced by the financial sector equals the quantity of liquidity services demanded by households and firms, and the quantity of loans or financial services produced by financial intermediaries equals the quantity demanded by firms in the final good sector.

3 Inspecting the mechanism

In order to illustrate the mechanism through which liquidity shocks affect the main macroeconomic aggregates, we start by studying a simplified version with liquidity shocks only. The objective is to inspect the transmission mechanism and to study how it is affected by the EIS and the complementarity between consumption and hours.

Calibration

A first set of parameters is calibrated to match a series of key steady state ratios. The adjustment costs and the habit parameters are calibrated to match the equity premium and the volatility of investment.

Financial intermediation sector, investment share, curvature parameter and growth rate

The share of financial services, α, can be calibrated using the available evidence on value added by economic activity. As an average over the period 1995-2011, financial intermediation represents about 29% of total value added in the euro zone.[7] The depreciation parameter, δ, can be calibrated to match the investment share of gross domestic product. As an average over the period 1995-2011, non-residential investment accounts for about 14% of total output. Given that the annual growth rate of output in the euro zone for the period 1995-2011 is of about 2%, we set the quarterly trend growth rate γ to 1.005, and the curvature parameter σ is set to 1.

Velocity parameters and shock process

Data on output and cash holdings by firms and households can be used to calibrate the two velocity parameters, κ and θ. First, the fact that, on

[7] Financial intermediation regroups information and communication, finance and insurance, real eastate and professional services and support services. Source: ECB, Table 5.2.

average, the ratio of aggregate consumption to the stock of short-term assets owned by households is equal to 0.35, can be used to derive a first empirical restriction on the corresponding steady state ratio, c/m_H.[8] This pins down the first velocity parameter, θ. The second velocity parameter can be selected using available empirical evidence on cash holdings by firms and households. In particular, the fact that money holdings by households, as an average over the period 1995-2011, are about three times larger than money holdings by firms can be used to set a target for the steady rate ratio m_H/m_F.[9]

In this first experiment, we set the persistence parameter, ρ_m to 0.6, and the shock standard deviation $std(\varepsilon_m)$ to 0.006 to study the effects of small transitory liquidity shocks. A formal estimation of these shocks is performed in the next section.

TABLE 1: CALIBRATED PARAMETERS

Parameter	Value	Steady state	Data	Model
ψ	0.25	n_T	0.25	0.25
η	0.57	n_B/n_T	0.18	0.18
υ	3.5	$Frisch$	1	1
δ	0.022	i/y_T	0.14	0.14
α	0.29	$r_L y_L/y_T$	0.29	0.29
κ	1.30	m_H/m_F	3.0	3.0
θ	0.35	c/m_H	0.35	0.35
ω_π	1.68	r_M/π	1.68	1.68

Table 1: The above 8 parameters are calibrated to match the corresponding steady state ratios. n_T is the steady state level of hours worked, n_B/n_T is the ratio of hours worked in the financial intermediation sector to total hours, i/y_T is the investment share of output, $r_L y_L/y_L$ is the share of the financial intermediation sector in total value added, c/m_H is the ratio of total holdings of short-term assets to nominal output, m_H/m_F is the ratio of short-term assets held by the households to short-term assets held by the firms.

Hours worked and labor supply

Labor market data can be used to calibrate υ and ψ, the two labor supply parameters, and η, the capital share parameter in the production function

[8] Source for short-term assets held by households: ECB, Table 3.3.

[9] Source: ECB, Table 3.3 and 3.4.

of financial services. First, according to the European labor force survey, in 2011, about 50% of the euro zone population was active. Second, assuming that active agents work on average 8 hours per day, the representative European agent should spend on average 4 hours per day on work related activities. If the available time for leisure and working activities is 16 hours per day, this implies a fraction of time spent working in the financial industry and the final goods-producing sectors, $n_B + n_F$ of 0.25. This steady state restriction pins down the first labor supply parameter, ψ.

A second restriction can be derived from the fact that, in 2011, hours worked in the financial intermediation sector accounted for about 18% of total employment.[10] The steady state share of employment in financial intermediation can be matched by varying the capital share parameter in the production function of financial services, η. Finally, following the business cycle literature, estimates of the Frisch elasticity of labor supply can be used to pin down the remaining labor supply parameters, υ. Following Hall (2009), we set υ to 3.5 which implies a Frisch elasticity of about 1.[11]

Habit formation, subjective discount factor and adjustment costs

The three remaining parameters, namely the adjustment costs parameter ϵ, the habit parameter, h, and the discount rate, β, are set so as to match the equity premium, $E(r_{Et} - r_{Ft})$, the volatility of investment, $std(i_t)$, and the mean real money market rate, $E(rr_{Mt}) = E[(1 + r_{Mt})/(1 + \pi_t) - 1]$.[12] Following Shi (2012), the asset pricing implications of the model are evaluated by using Tobin's Q as a proxy for equity prices. The equity premium therefore denotes the difference between the return on physical capital and the risk-free rate, where the dynamics of q_t is governed by the Euler equation[13]:

[10] Financial intermediation regroups information and communication, finance and insurance, real eastate and professional services and support services. Source: ECB, Table 5.3.

[11] With this preference specification, the Frisch elasticity of labor supply depends on several additional parameters. The forumula is derived in Jaccard (2012).

[12] The euro area equity premium is proxied by the difference between total return on the CAC 40 and the French T-bill rate.

[13] where:

$$\omega(i_{t+1}, k_t) = \frac{\theta_1}{1-\epsilon}\left(\frac{i_{t+1}}{k_t}\right)^{1-\epsilon} + \theta_2 - \theta_1\left(\frac{i_{t+1}}{k_t}\right)^{1-\epsilon}$$

$$q_t\lambda_t = \beta E_t\lambda_{t+1}q_{t+1}\left[(1-\delta)+\omega(i_{t+1},k_{t+1})\right]+\beta E_t\lambda_{t+1}r_{Kt+1}$$

$\omega(i_{t+1},k_t)$ and where the risk-free rate is given by:

$$\frac{1}{1+r_{ft}} = \beta E_t\frac{\lambda_{t+1}}{\lambda_t}$$

In Table 2, the upper panel shows the calibration that allows the benchmark model to successfully match the three moments that we are targeting. As shown by the lower panel which reports the case $h = 1$, and which corresponds to the case without habits, the model augmented with a standard preference specification cannot generate a plausible equity premium. The mechanism which allows this preference specification to successfully explain the equity premium essentially relies on its ability to increase the volatility of the stochastic discount factor, while at the same time reducing the wealth elasticity of labor supply. The asset pricing implications of this preference specification are studied in Jaccard (2012).

Table 2: Matching the Moments

Model 1: Benchmark model with habits

Parameter	Calibration	Moment	Model	Data
ϵ	2.63	$std(i_t)$	5.98	5.98
h	0.91	$E(r_{Et}-r_{Ft})$	3.64	3.64
β	0.994	$E(rr_{Mt})$	1.47	1.47

Model 2: Standard specification

Parameter	Calibration	Moment	Model	Data
ϵ	0.0747	$std(i_t)$	5.98	5.98
h	1	$E(r_{Et}-r_{Ft})$	0	3.64
β	0.9999	$E(rr_{Mt})$	2.02	1.47

Can liquidity shocks generate business cycle fluctuations?

Table 3 below reports the business cycle implications of the benchmark model and compare them with Model 2, which corresponds to the case with a standard preference specification. Compared to the model with a standard specification, the first main difference is that the model with habits can generate much larger fluctuations in output. Second, once the habit channel is turned on, the co-movement between output and the main business cycle variables generated by liquidity shocks is broadly consistent with the data.

As shown by the lower panel of Table 3, the benchmark model is also able to generate a sizeable liquidity premium, $E(rr_{Mt} - r_{Ft})$ which in the data is proxied by the difference between the money market rate and the risk-free rate. Interestingly, it is also possible to generate the low correlation between output and equity prices.

The results shown in Table 3 also illustrate that small liquidity shocks generate fluctuations in inflation rates that are implausibly large. As we show in the next section, this issue can be fixed by assuming a more aggressive monetary policy stance. In the next section, we introduce more shocks and estimate the model using inflation as an observable to ensure that the dynamics of inflation will be perfectly matched.

TABLE 3: SIMULATING THE MODEL

	Standard Deviation				Correlation with output		
	Data	Model 1	Model 2		Data	Model 1	Model 2
σ_{y_T}	1.94	1.45	0.10	$\rho(y_T, y_T)$	1	1	1
σ_c	1.07	2.06	2.81	$\rho(y_T, c)$	0.70	0.95	-0.82
σ_i	5.98	5.98	5.98	$\rho(y_T, i)$	0.89	0.46	-0.88
σ_{n_T}	2.30	1.61	0.13	$\rho(y_T, n_T)$	0.81	0.98	0.82
σ_w	0.54	0.46	0.59	$\rho(y_T, w)$	-0.21	0.81	-0.83
σ_{y_L}	3.09	1.41	0.22	$\rho(y_T, y_L)$	0.58	0.88	0.08
σ_q	25.1	15.28	0.45	$\rho(y_T, q)$	0.58	0.32	-0.86
σ_π	0.73	8.40	1.75	$\rho(y_T, \pi)$	0.32	-0.21	0.53

	Mean			Standard Deviation		
	Data	Model 1	Model 2	Data	Model 1	Model 2
$rr_{Mt} - r_{Ft}$	0.42	0.31	0	0.42	2.38	2.38
rr_{Mt}	1.47	1.47	2.02	1.88	5.63	1.17

Can liquidity shocks explain the lead-lag correlation between equity prices and output?

As illustrated by Figure 1 below, a main distinguishing feature of the recent crisis is that the recession was preceded by a large drop in stock market value. As shown by Table 4, which reports the lead-lag correlation between equity prices and output, this lead-lag structure is also a more general empirical characteristic. As shown by Shi (2012), the response of equity prices to liquidity shocks generated by standard business cycle models is usually difficult to reconcile with the data. An interesting implication of the mechanism postulated in this study is that it not only implies that liquidity shocks can explain the low contemporaneous correlation between equity prices and output but also the lead-lag structure observed during the crisis, and at business cycle frequency over the entire sample. The behaviour of equity prices implied by this mechanism would therefore be consistent with the hypothesis that the crisis was caused by a liquidity shock.

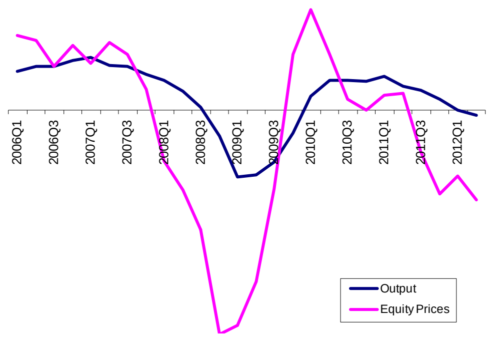

Figure 1: Output and equity prices in annualized growth rate, normalized data.

	$i = 1$			$i = 2$		
	Data	Model 1	Model 2	Data	Model 1	Model 2
$\rho\,(q(+i), y_T)$	0.36	0.10	-0.45	0.11	-0.06	-0.07
$\rho\,(q(-i), y_T)$	0.72	0.68	-0.92	0.73	0.83	-0.53

Table 4: Lead-lag structure equity prices and output, 1995-2012. Model vs. data

As discussed by Shi (2012), the response of equity prices to liquidity shocks generated by standard business cycle models is usually difficult to reconcile with these facts. An interesting implication of the mechanism postulated in this study is that it not only implies that liquidity shocks can reproduce the low contemporaneous correlation between equity prices and output but also the lead-lag structure observed during the crisis, and at business cycle frequency over the entire sample. The behaviour of equity prices implied by this mechanism would therefore be consistent with the hypothesis that the crisis was caused by a liquidity shock.

The transmission of liquidity shocks

Liquidity shocks firstly impact the economy through the resource constraint by directly affecting the stock of existing financial assets:

$$y_{Tt} = c_t + i_t + \gamma m_{Tt} - \varrho_t \frac{m_{Tt-1}}{1+\pi_t}$$

and secondly, by affecting the expected return of liquidity creation through the Euler equation:

$$1 = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\left(\varrho_{t+1} + r_{Mt+1}\right)}{1+\pi_{t+1}}$$

Figure 2 below shows the impulse response of the main financial and macroeconomic variables to a positive liquidity shock, and compares the impulse responses obtained with the two models. The response generated by the benchmark model is denoted by the blue continuous line, while the red dotted line is the case with standard preferences. As can be seen from the response of output, the habit channel not only amplifies the effects of liquidity shocks but also generates a substantial increase in the model's propagation mechanism.

As illustrated by the small impact of liquidity shocks that is obtained with Model 2, without habits, as long as agents are not too reluctant to engage in intertemporal substitution, a shock to the supply of safe assets only has a limited impact on the dynamics of the main business cycle and financial market variables. Much of the adjustment occurs through a change in consumption, and as shown by the simulations reported in Table 2 above, liquidity shocks have a large impact on the volatility of consumption. The initial decline in investment and the fall in total employment illustrate that a positive liquidity shock is an opportunity to consume more while working less, and since smoothing the effects of the shock is not a priority, on impact, investment can fall.

With this particular preference specification, as illustrated by the results obtained with Model 1, lowering the EIS, by decreasing the habit parameter

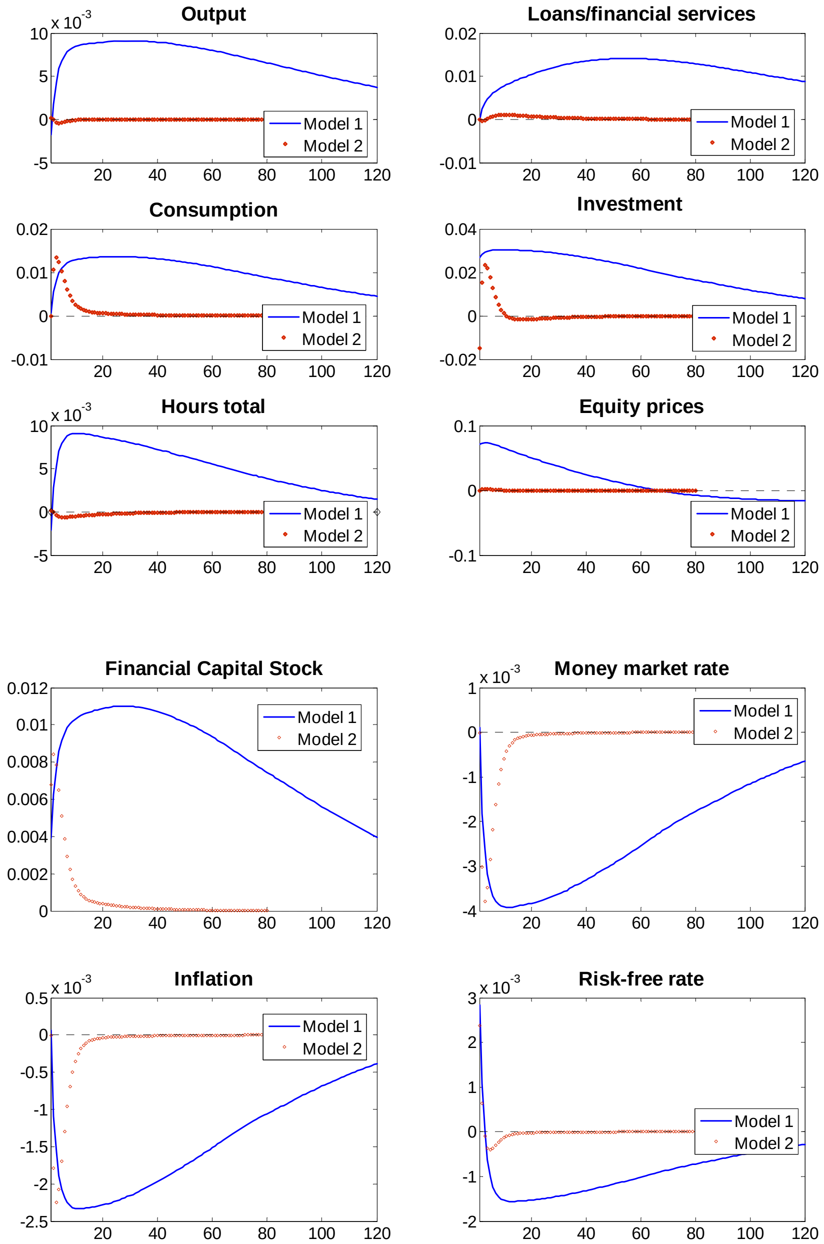

Figure 2: Positive one standard deviation liquidity shock. Mod. 1 vs. Mod. 2.

increases the importance of liquidity services because consumption smoothing becomes a priority. Together with the presence of liquidity constraints, the stronger consumption smoothing motive that is induced by the lower EIS renders the access to safe assets essential. Liquidity constraints therefore create a dependence towards the financial sector that is dictated by households' intertemporal consumption decisions.

The role of labor

As shown by the response of hours worked, in the benchmark model, most of the amplification of liquidity shocks works through the labor market. This particular effect is due to the complementarity between consumption and hours worked that is induced by this preference specification. A positive liquidity shock relaxes the liquidity constraint and allows agents to increase consumption. Since habits are formed over the composite of consumption and leisure, compared to a standard cash-in-advance model (Cooley and Hansen, 1995), the key difference is that agents choose to reduce leisure and work harder to prevent the habit stock from rising too quickly. This particular smoothing motive helps to avoid the leftward shift in labor supply that normally occurs in these models when agents feel wealthier. Given that the habit parameter has a direct effect on the asset pricing implications of the model, the exact magnitude of this complementarity between consumption and hours is determined by the target that is set for the equity premium. The higher is the equity premium that the model has to match, the stronger is this complementarity, and the larger is the effect on output.

Intratemporal vs. intertemporal elasticity of substitution

The main effect that is obtained with this preference specification shares some important similarities with the mechanism studied by Alvarez and Lippi (2011) who show that the magnitude and the persistence of liquidity effects are governed by the intertemporal elasticity of substitution of the consumption bundle and the intratemporal elasticity of substitution between real balances and consumption. In our economy, the case without habits implies a high elasticity of intertemporal substitution in consumption and a low degree of complementarity between consumption and hours worked. This explains why much of the adjustment occurs through an increase in consumption that is short-lived, and that hours worked hardly react.

Habits in the composite of consumption and leisure reduce the elasticity of intertemporal substitution and increase the complementarity between consumption and hours worked. The stronger smoothing motive that is induced by the lower elasticity of intertemporal substitution increases the impact of the shock on consumption, which responds very gradually, and consumption smoothing is achieved by increasing investment. The intratemporal effect is due to the stronger complementarity between consumption and hours created by this preference specification. The more gradual and persistent increase in consumption leads to an increase in hours worked that amplifies and propagates the effect of liquidity shocks on output.

The role of the financial sector

Compared to a standard monetary real business cycle model (Cooley and Hansen, 1995), the second main difference is the introduction of financial intermediaries. We now discuss the role of the financial sector in amplifying the effects of liquidity shocks.

The volatility of asset prices

Fluctuations in the price of financial services are the first main channel through which the effects of shocks are propagated. The pricing equation for the price of financial services or loans can be derived from the first-order conditions with respect to y_L:

$$p_{y_{Lt}} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} r_{Lt+1}$$

Given that financial services depreciates fully within the period, the expected return only depends on the rental price, r_L. Except for the capital gain component, the price of financial services is given by a standard arbitrage equation linking today's price to tomorrow's expected return, and where $\beta E_t \frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic discount factor for real assets.

As in Jermann (1998), compared to a standard model, the increase in the volatility of p_{y_L}, is obtained by combining adjustment costs and habit formation. Compared to Jermann (1998) and models where there is no feedback effect from asset prices to the real economy, the key difference is that these larger fluctuations in p_{y_L} amplify the effects of shocks through two main channels.

The price of financial services and the demand for labor

First, changes in the price of financial services affect the demand for labor in the financial sector. This can be illustrated by inspecting the optimization program describing the behavior of the financial sector. The first-order condition with respect to n_B gives the following labor demand equation:

$$w_t = p_{y_{Lt}}(1-\eta)z_t k_{t-1}^{\eta} n_{Bt}^{-\eta}$$

Variations in p_{y_L} therefore have a direct impact on the labor demand curve for hours worked in the banking sector. Like a technology shock, movements in p_{y_L} affect the equilibrium quantities of hours by shifting the labor demand curve. For instance, a positive technology shock in the final goods-producing sector raises the demand for financial services and leads to an increase in the rental price r_L. The resulting increase in agents' willingness to save generates a persistent decline in the risk-free rate.

In combination with the rise in the rental rate, the decline in the risk-free rate generates a boom in the price of financial services. Since an increase in the price of financial services shifts the labor demand curve to the right, this effect contributes to further increase the demand for hours worked in the banking sector. Over the business cycle, these procyclical variations in the price of financial services amplify the effects of liquidity shocks by generating larger shifts in labor demand.

The investment channel

Fluctuations in the price of financial services have a similar effect on investment through their effect on the return of capital. The arbitrage condition linking the opportunity cost of investing in capital today with next period's expected return is given by:

$$q_t\lambda_t = \beta E_t\lambda_{t+1}\left[q_{t+1}\left[(1-\delta)+\omega(i_{t+1},k_{Bt})\right]+r_{Kt+1}\right]$$

where:

$$r_{Kt+1} = p_{y_{Lt+1}}\eta z_{t+1}k_t^{\eta-1}n_{Bt+1}^{1-\eta}$$

The capital gain component of expected return is standard and depends on future capital gains that are adjusted for capital depreciation and adjustment costs. By contrast, the component related to the expected payoff of the asset, which is given by the marginal productivity of capital depends on the relative price of financial services, p_{y_L}.

Adjustment costs increase fluctuations in the price of capital, q, by reducing the supply elasticity of capital as well as the volatility of investment. On the contrary, fluctuations in p_{y_L} generate larger shifts in the demand for capital, which jointly increase the volatility of prices and quantities. In combination with this preference specification, in addition to its impact on the supply elasticity of capital, the second effect of capital adjustment costs is therefore to generate larger variations in p_{y_L} that amplify the effects of shocks through larger fluctuations in the demand for capital.

The economy without financial intermediaries

In the economy described above, the presence of a financial sector can be justified by assuming that extending loans to the final goods-producing sector requires a particular monitoring technology that is not available to households. To identify the contribution of the financial sector to the volatility of investment and output, we have solved a version of the model in which financial intermediation is not needed and where households are able to lend directly to the final good producers, as it would be the case in a standard neoclassical growth model. Keeping all other parameters unchanged, we simulate the model and compare the volatility of investment and output in the two cases and find that the volatility of output and investment is respectively 13% and 25% higher in the model with a financial sector.

Liquidity constraints, output volatility, and the equity premium

As shown by Figure 3 below, the relationship between the velocity parameter, θ and the equity premium generated by the model is highly non-linear. The left panel presents this relationship for the benchmark calibration discussed above (blue continuous line) and shows how it is affected by an increase in the intensity of habit formation (red dotted line). The right panel shows how a change in the velocity parameter affects the volatility of output.

As shown by the right panel, a tightening of liquidity constraints unambiguously increases the volatility of output. Intuitively, this is due to the fact that liquidity shocks have a larger impact on consumption when the liquidity constraint is tighter. The complementarity between consumption and hours that is induced by this mechanism generates larger movements in hours worked, and the impact on the volatility of output is stronger when the intensity of habits increases.

The inverted U-shaped relationship between the tightness of the liquidity constraint and the equity premium illustrates that the increase in output volatility that is obtained as θ decreases does not always translate into greater risk premia. The main reason is that the effects of liquidity shocks on the money market rate can change when the liquidity constraint is very tight.

For most values of the velocity parameter, the demand for liquidity services remains relatively stable and a positive liquidity shock increases the supply of safe assets, which leads to a fall in the money market rate.

When the liquidity constraint is very tight, however, liquidity shocks can also have an impact on the demand for liquidity services because the precautionary motive becomes very strong. A positive shock for instance increases the supply of safe assets produced by the financial sector and if the precautionary motive is sufficiently strong, agents' demand for liquidity services can also increase. In this case, the joint effect on supply and demand amplifies the impact on the quantity of liquidity services that is produced and contributes to dampen the reaction of interest rates. The precautionary demand effect decreases risk premia because it reduces the procyclicality of the money market rate. The lower risk premium therefore reflects that, when liquidity constraints are very tight, agents will choose to decrease their exposure to liquidity risk by building-up higher liquidity buffers.

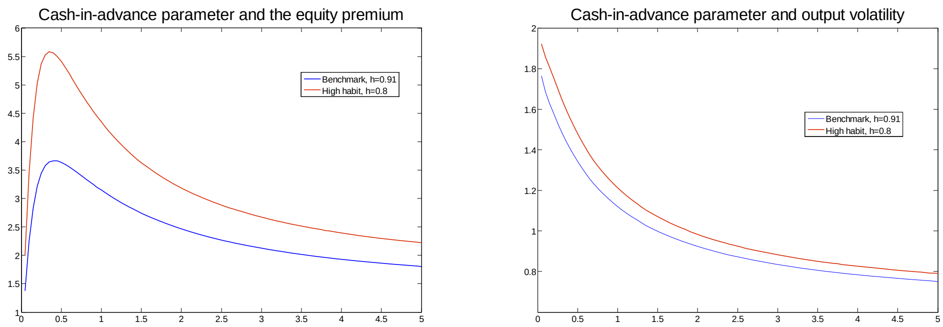

Figure 3: Left panel, y axis: equity premium in annualized percent. x axis: velocity, θ. Right panel, y axis: output growth standard deviation in annualized %. x axis: velocity parameter, θ.

Inflation volatility and the welfare cost of inflation

As noted above, one main limitation of Model 1 is that it generates movements in inflation that are more than ten times larger than what is observed in the data. This issue can however be addressed by modifying the monetary policy rule. A more aggressive monetary policy, which can be implemented by raising the policy parameter, ω_π, leads to smaller fluctuations in inflation, and reduces the mean inflation level. Compared to the benchmark calibration, raising ω_π from 1.68 to 7.0 would lower the volatility of the inflation rate from 8.4 to 0.72, which is the level that is observed in the data. It would also lower the mean inflation rate from 2.2% down to 0.63%. A more aggressive monetary policy stance would have a more limited impact on the volatility of output, which would rise from 1.45% to 1.5%.

In this economy, it can also be shown that inflation reduces welfare. This result essentially follows from the fact that the production of liquidity services by the financial sector generates a resource cost. Each period, a fraction $(\gamma m_{Tt} - \varrho_t \frac{m_{Tt-1}}{1+\pi_t})/y_{Tt}$ has to be invested in this asset that is needed to "grease the wheels of the economy". Inflation increases the resource cost generated by the production of liquidity services by eroding the stock of safe assets that is held by the financial sector, and reduces the overall quantity of liquidity services that can be provided.

To illustrate the welfare cost of inflation, suppose now that the monetary authority decides to set the policy parameter, ω_π, to 50. Adopting this policy allows the Central Bank to fully stabilize inflation and to reduce the mean inflation level to a value that is close to zero. Compared to the benchmark case, increasing ω_π from 1.68 to 50 reduces the average fraction of resources invested in the production of liquidity services, i.e. $E\left[(\gamma m_{Tt} - \varrho_t \frac{m_{Tt-1}}{1+\pi_t})/y_T\right]$ from 2.8% down to 1.63%. A lower inflation rate enhances welfare because it implies that a smaller fraction of output needs to be invested in the production of safe assets and therefore that a higher share can be allocated to consumption. Compared to the benchmark model, the fraction of output allocated to consumption increases from 82% to 85% when inflation decreases from 2.2% to 0, and the annualized welfare gain from eliminating inflation is 4.4%.

4 Estimation

The previous section has shown that liquidity shocks have the potential to explain a non-negligible fraction of business cycle fluctuations, as well as the co-movement between equity prices and output observed during the crisis. The objective of this section is to further assess the plausibility of this hypothesis by estimating the contribution of each of the four shocks that we have introduced to the observed dynamics of business cycle variables in the euro area. In the context of our analysis, a financial shock is a technology shock that affects the production of financial services, and a monetary policy shock is a shock to the interest rule linking the money market rate to the inflation rate. Liquidity shocks are shocks to the existing supply of safe assets held by financial intermediaries, and technology shocks affect the production of the final output good.

The liquidity, monetary policy, financial, and the technology shocks are estimated with Bayesian techniques using four key time-series as observable variables: output, the short term money market rate, loans, and the consumer price index. A full description of the data that is used is provided in the data appendix. To avoid complications stemming from non-stationarity, first differences rather than levels are used in the case of output, prices, and loans.[14]

To enhance the robustness of the empirical analysis, we do not attempt to estimate any structural parameters and keep them at the calibrated value discussed in the previous section. The standard deviations and the persistence of the four exogenous processes are the only parameters that are estimated. This is to avoid problems related to the lack of identification of structural parameters, which commonly arises in this class of models (Canova and Sala, 2009).

Choice of the priors

Following Smets and Wouters (2003), we assume that the standard errors of the innovations follow an inverse gamma distribution and that the persistence of the AR(1) processes is beta distributed. For all four shocks, the standard errors of the innovation have a prior mean of 0.007 and a standard deviation of 0.05. The persistence of the AR(1) processes have a prior mean of 0.7 and a standard deviation of 0.15.

Posterior estimates of the parameters

Table 5 reports the posterior mode of the parameters, their posterior mean, and the 95 percent confidence interval for the estimated mean. Figure 8 reports the assumed prior distribution and the estimated posterior distribution.[15] The low shock standard deviation and the low persistence

[14] This choice is based on a unit root test performed on the level of the 4 variables used for the estimation. Including this 4 variables in the set of observables implies that the model will be able to closely replicate their observed behaviour during the period under study (see Figure 5 below).

[15] See section 8 in the appendix.

of the estimated liquidity shock indicates that, over the period 1995-2012, the magnitude of these shocks remains fairly small. It also illustrates that the model's endogenous propagation mechanism has to play an important role, since liquidity shocks, as we will discussed later, are able to explain a substantial fraction of output fluctuations.

Table 5: Prior and Posterior Distribution

	Prior distribution			Posterior mode		Posterior mean		
	Distr.	Mean	St. Dev.	Mode	St. dev.	Mean	Low	High
$std(\varepsilon_a)$	Inv G.	0.007	0.05	0.0047	0.004	0.0048	0.0041	0.0055
$std(\varepsilon_m)$	Inv G.	0.007	0.05	0.0047	0.004	0.0048	0.0040	0.0055
$std(\varepsilon_z)$	Inv G.	0.007	0.05	0.0086	0.007	0.0089	0.0076	0.0101
$std(\varepsilon_{MP})$	Inv G.	0.007	0.05	0.0050	0.004	0.0052	0.0044	0.0059
ρ_a	Beta	0.7	0.15	0.9376	0.0254	0.9316	0.8918	0.9732
ρ_m	Beta	0.7	0.15	0.7428	0.0767	0.7387	0.6127	0.8637
ρ_z	Beta	0.7	0.15	0.9803	0.0128	0.9738	0.9539	0.9957
ρ_{MP}	Beta	0.7	0.15	0.7146	0.1087	0.7136	0.5459	0.8803

Table 5: See Adjemian et al. (2012) for a detailed overview of the computation algorithm that is used for the estimation

Table 6: Variance Decomposition

	Technology	Banking Technology	Liquidity	Monetary policy
Output	22.1	6.8	53.4	17.7
Consumption	9.0	2.9	47.5	40.6
Investment	0.1	0.1	60.1	39.7
Hours	15.5	3.9	62.6	18.0
Equity prices	0.1	0.1	60.1	39.7
Loans	2.5	73.1	17.0	7.4
Inflation	1.9	0.9	57.9	39.3
Wages	68.6	18.0	8.8	4.6
Money market	2.0	1.0	61.3	35.7

Table 6: Variance decomposition, quarterly data, 1995-2012

Variance decomposition

Table 6 which shows the variance decomposition illustrates our first main empirical finding, namely that liquidity shocks originating in the banking sector are a key driver of business cycle fluctuations in the euro area. Interestingly, this mechanism also creates an important source of monetary non-neutrality, since the effects of a change in interest rates induced by a monetary policy shock affect the economy through a similar channel.

Compared to the literature that studies the effects of monetary policy in cash-in-advance models (Cooley and Hansen, 1995), a main difference is therefore that in this environment, monetary policy shocks, which are captured by shocks to an interest rule, can have a significantly impact on the dynamics of an otherwise standard neoclassical growth model.

Together with their predominance, the low standard deviation and the low persistence of liquidity shocks that is obtained can be explained by the particular propagation mechanism embedded in this model. As discussed in the previous section, their ability at generating persistent increases in output is the main distinguishing feature of liquidity shocks. Standard real business cycle models, in contrast, are unable to propagate the effects of technology shocks, and this problem leads this class of models to significantly understate the degree of autocorrelation in quarterly output growth (Cogley and Nason, 1995; Chang, Gomes, and Schorfheide, 2002). To illustrate this point, the autocorrelation of output growth generated by the model when simulated with the four estimated shocks is shown in Table 7 below, and is compared with two cases: (i) the simulated model with technology shocks only, and (ii) the simulated model with financial shocks only.

TABLE 7: AUTOCORRELATION OF OUTPUT GROWTH

Autocorr.	Data	Simulated model		
order	$\rho(gy_{Tt}, gy_{Tt-1})$	All shocks	Tech. shocks	Fin. shocks
1	0.50	0.37	-0.11	-0.19
2	0.28	0.29	-0.01	0.03
3	0.16	0.23	-0.01	0.01
4	0.07	0.19	-0.01	0.01

Clearly, when simulated with liquidity and monetary policy shocks, the model's ability at explaining the high autocorrelation of output growth significantly improves. In contrast, when simulated with standard technology or financial shocks only, the model fails to reproduce this important empirical regularity. Using output growth as an observable therefore increases the relative importance of liquidity and monetary policy shocks because their ability to generate persistent responses of output helps the model to explain the high degree of autocorrelation observed in the data. And the model's strong internal propagation mechanism makes it possible to capture this feature of the data with exogenous shocks that have a low standard deviation and a low degree of persistence.

Liquidity factors during the Great Recession

Figure 6 below shows the technology, financial, liquidity, and monetary policy shocks that have been estimated using the procedure described above. The empirical analysis suggests that the Great Recession was mostly caused by a combination of negative liquidity and technology shocks. The second key information revealed by this analysis is that, while liquidity factors have been a major cause of the financial turmoil, as can bee seen by the large positive innovation observed at the end of 2008, they have also contributed to the recovery.

Given that the positive innovation coincides with the introduction of more aggressive measures aimed at enhancing credit in the banking sector, a possible explanation is that the non-standard measures introduced by the ECB in October 2008 have helped to restore liquidity.[16] A more detailed model would however be needed to evaluate the effectiveness of the ECB's non-standard monetary policy measures.

During the period that corresponds to the intensification of the crisis, the effects of the negative liquidity shock are partially compensated by a positive innovation in the monetary policy rule. One possible interpretation is that the series of interest rate cut implemented by the ECB during this period contributed to attenuate the effects of the liquidity shortage.[17] The small negative innovation detected in 2011 could correspond to the short-lived increase in policy rates observed during this period.

Figure 7 below shows the historical decomposition of annualized output growth, expressed in deviation from its mean, over the period 1995 to 2012.

[16]In October 2008, the ECB reacted to the intensification of the crisis by directly taking up an intermediation role for the provision of liquidity to individual banks, normally played by the money market, by switching from variable tenders to fixed rate tenders with full allotment of the liquidity demanded by counterparts (see ECB Monthly Bulletin article "The ECB's non-standard measures-impact and phasing out", July 2011).

[17]Between October 2008 and May 2009, the ECB lowered the interest rate on its main refinancing operations by 325 basis points.

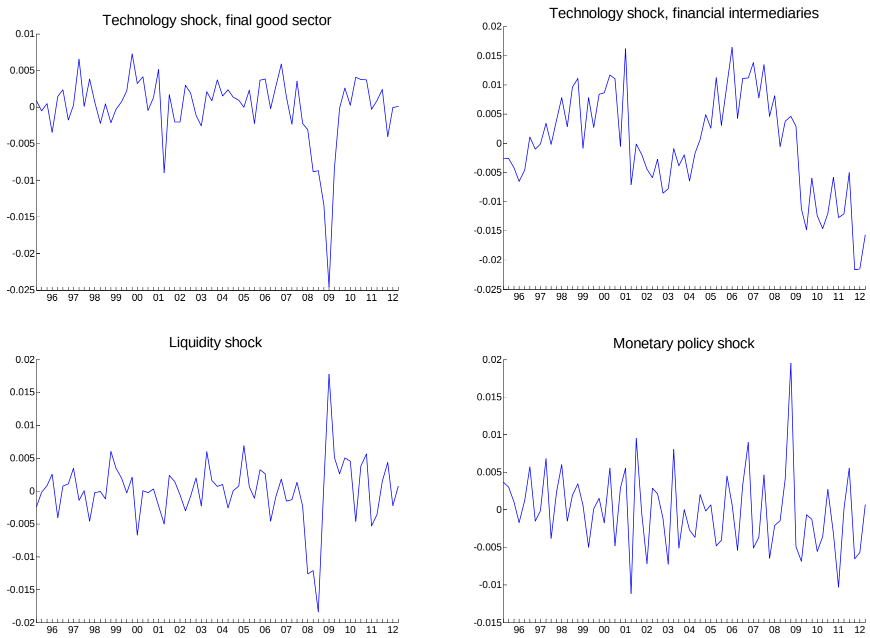

Figure 6: Estimated technology, financial, liquidity, and monetary policy shocks (innovation).

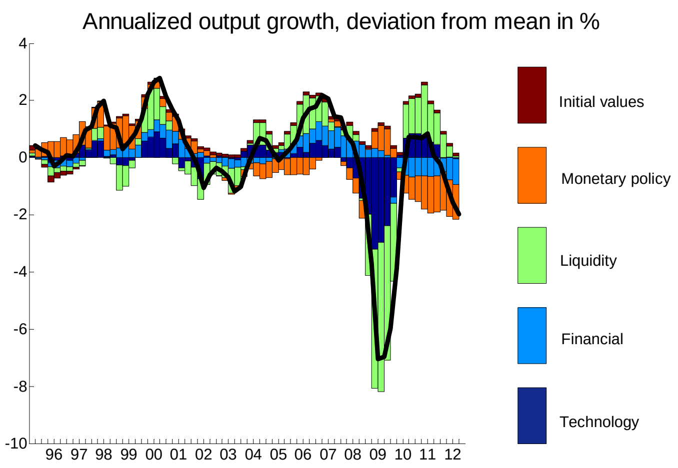

Figure 7: Historical decomposition of output growth

This chart confirms that liquidity shocks have been playing a particularly important role during the Great Recession period. While technology shocks remain an important source of business cycle fluctuations, our analysis therefore suggests that the Great Recession was primarily caused by liquidity factors.

Finally, as illustrated by Figure 8 below, the behaviour of the Lagrange multiplier associated with the liquidity constraints confirms that liquidity conditions faced by households and firms were exceptionally tight during the financial turmoil period. The shock originating in the financial sector was transmitted to the real economy through the liquidity constraints, and by impairing the mechanism of exchange, the liquidity crisis created by the shortage of pledgeable assets forced firms and households to abruptly adjust consumption and production.

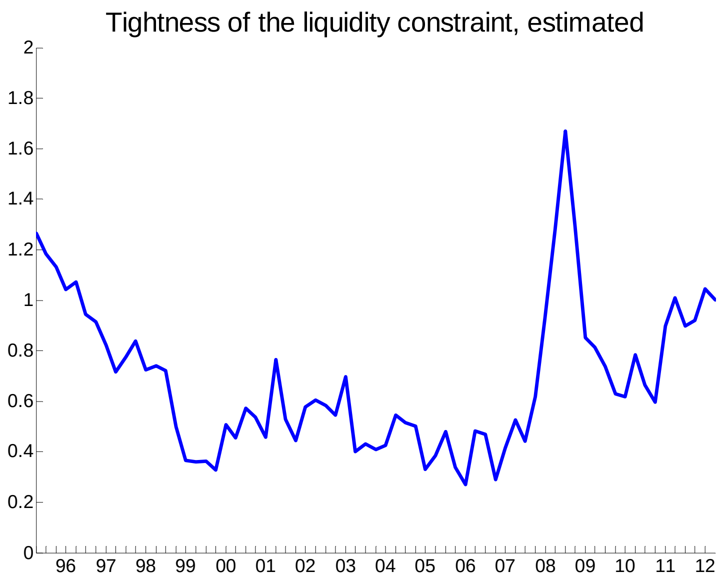

Figure 8: Value of the Lagrange multiplier associated with the liquidity constraint on households.

5 Conclusion

Early attempts to study the role played by liquidity constraints in dynamic general equilibrium models concluded that standard frictions, such as cash-in-advance constraints, were unlikely to significantly alter the dynamics of a basic real business cycle model. Without nominal rigidities, the welfare cost of inflation is negligible and liquidity shocks do not contribute much to the fluctuations in real variables (Cooley and Hansen, 1989 and 1995).

In our environment where the supply of liquidity is endogenously determined, by contrast, liquidity frictions have a major impact on the model dynamics, and exogenous changes in liquidity conditions can have large real effects. The introduction of a financial sector opens a first channel of propagation that depends on the volatility of the relative price of financial services. Over the business cycle, more volatile fluctuations in relative prices leads to larger variations in the demand for inputs in the financial sector, thereby amplifying the effects of exogenous shocks on output. The second effect is obtained by lowering the EIS in consumption and the wealth elasticity of labor supply. This joint effect, which in our environment depends on one single preference parameter, can be calibrated by using the model's asset pricing predictions.

Finally, the role of liquidity factors during the Great Recession is evaluated by estimating the relative contribution of liquidity shocks. Our analysis suggests that the sharp contraction in output was mostly due to a negative liquidity shock originating in the financial sector. The shock was then transmitted to the other sectors of the economy by triggering a tightening of liquidity conditions faced by households and firms. Overall, liquidity factors have the potential to explain a significant fraction of business cycle fluctuations.

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7 Appendix

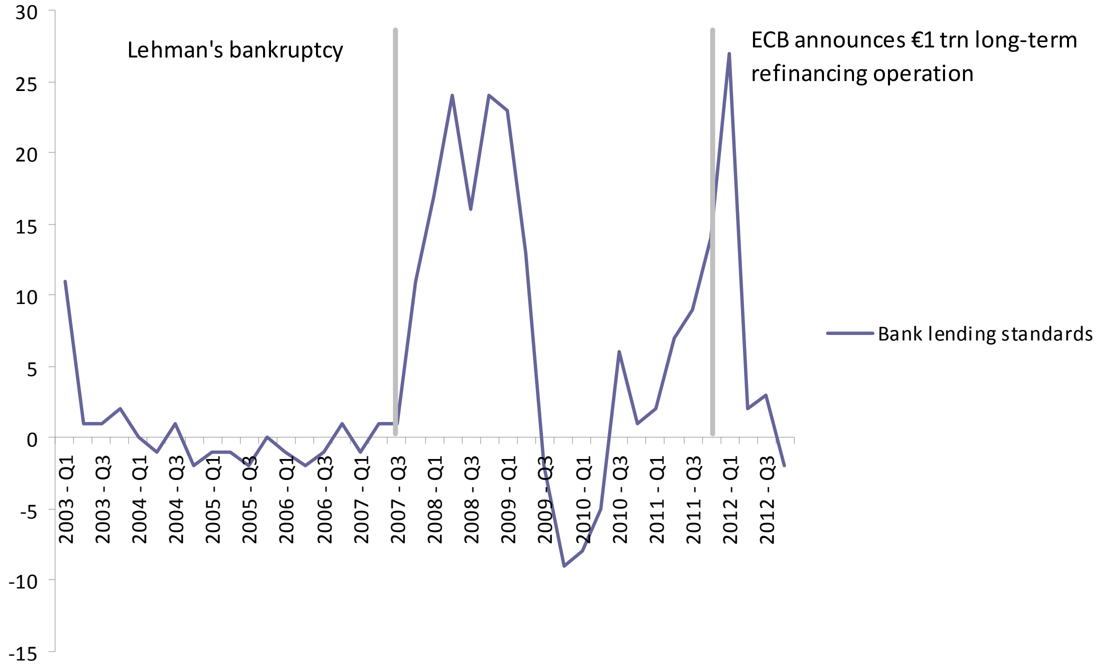
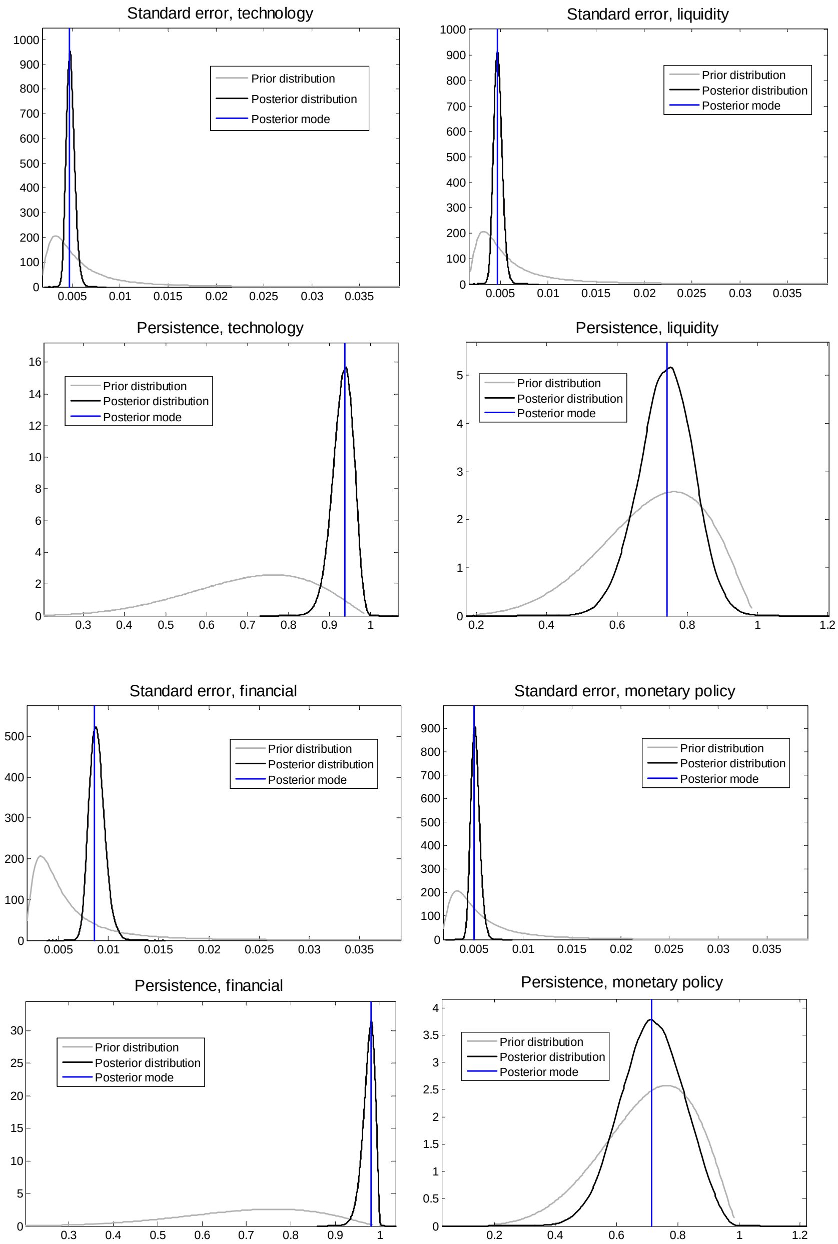


Chart 1: Euro area bank lending survey. Over the past three months, how have your bank liquidity position affected your bank's credit standards as applied to the approval of loans or credit lines to enterprises. A positive net percentage balance indicates that a larger proportion of banks have tightened credit standards (net tightening).

8 Data appendix

Variable	Description	Source
Output	Real GDP	Stat. Office of the EC
Consumption	Real final consumption	Stat. Office of the EC
Investment	Real non-residential investment	Stat. Office of the EC
Hours worked	Indexes of hours worked, (1996-2012)	Stat. Office of the EC
Wages	Real compensation per employee	ECB, Table 5.1.4
Loans	Real loans to private sector	ECB, Table 2.3
Equity prices	Euro stoxx 50 price index	ECB, Table 4.8
Inflation	HICP inflation	ECB, Table 5.1
Money market rate	Euribor 3 months	ECB, Table 4.6
Equity returns	Total return index, CAC 40, France	NYSE Euronext
Risk-free rate	3 months Tbill rate, France	Banque de France

9 Prior and estimated posterior distributions



10 Observables and predicted variables

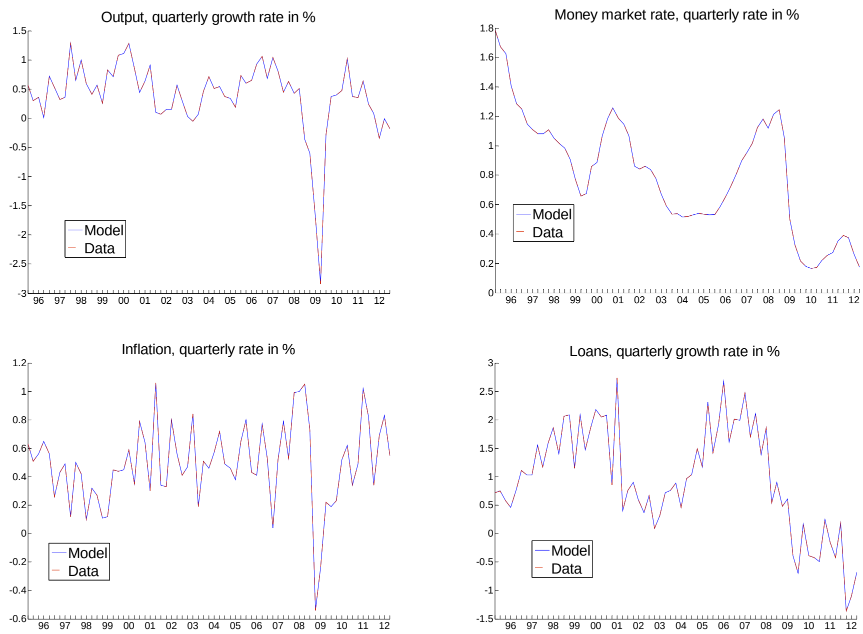


Figure 5: Output, money market rate, inflation and loans. Data vs. model (smoothed variables).