

# Money and risk aversion in a DSGE framework: a bayesian application to the Euro zone

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# Objective of the paper

- To build and test a model of the Euro zone based on the New-Keynesian DSGE framework...
- ... with money introduced explicitly and with a specific analysis of its role.

# New Keynesian Models

- Inflation explained by the expected inflation rate and by the output gap.
- Output explained by its expectations and the real interest rate.
- The Interest rate is established via a Taylor rule in function of inflation and output gaps.
- Money does not explicitly appear as an explanatory factor of the output gap, inflation dynamics, and interest rate determination. (Clarida, Galí and Gertler, 1999; Woodford, 2003; Galí and Gertler, 2007; Galí, 2008).
- In this framework, monetary policy impacts aggregate demand and thus inflation and output, only through change in the real interest rate.

# The Question of Money

- The N.K. view of the transmission mechanism neglects the behavior of real money balances:
  - There may exist a real balance effect on aggregate demand resulting from a change in prices.
  - As individuals re-allocate their portfolio of assets, the behavior of real money balances induces relative price adjustments on financial and real assets. In the process, aggregate demand changes, and thus output.

## The Question of Money (follow up)

- Thus, by affecting aggregate demand, real money balances become part of the transmission mechanism.
- The interest rate alone is thus not sufficient to explain the impact of monetary policy and the role played by credit and financial markets (Meltzer, 1995, 1999, Brunner and Meltzer, 1968).
- This monetarist transmission process may also imply a specific role to real money balances when dealing with risk aversion.

# The introduction of money in N.K. DSGE models

- The standard way: money-in-the-utility function whereby real money balances affect the marginal utility of consumption.
- Implications of the (small) literature: conflicting results.
- Some suggest money plays a role (on inflation and/or output, and/or the interest rate), some not, or very small, in the US, Germany, the UK, or the Euro zone.

# Our model and contribution

## Theoretical background:

- As in the standard way, we resort to money-in-the-utility function (MIU) with a non-separability assumption.
- Yet, we specify *all* the micro-parameters of the model: it permits to extract new characteristics and implications of this type of model, notably the role of risk aversion (impossible with aggregated parameters).
- To better unveil the role of money we concentrate on forward-looking components rather than on inertial components on output and inflation that may “hide” the impact of money

## Our model and contribution (follow up)

### **Empirical analysis on the Euro zone:**

- Bayesian techniques (with money in the model).
- Estimation of *all* micro-parameters (existing literature use aggregated parameters).
- Simulation of the model to analyse impact of structural shocks.
- Highlights the role of money on output variability and of monetary policy on inflation variability.
- Demonstrates that the role of money increases as inter-temporal risk aversion increases.

# New Keynesian Framework: micro foundations

- 3 types of agents: households, firms and central bank.
- Households maximize the expected present value of utility.
- Firms maximize profits.
- The central bank determines the nominal interest rate.

# The heart of the model

CES Utility function:

$$U_t = e^{\varepsilon_t^P} \left( \frac{1}{1-\sigma} \left( (1-b) C_t^{1-\nu} + b e^{\varepsilon_t^M} \left( \frac{M_t}{P_t} \right)^{1-\nu} \right)^{\frac{1-\sigma}{1-\nu}} - \frac{\chi e^{\varepsilon_t^N} N_t^{1+\eta}}{1+\eta} \right) \quad (3)$$

Budget constraint:

$$P_t C_t + M_t + Q_t B_t \leq B_{t-1} + W_t N_t + M_{t-1} \quad (2)$$

Production function:

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \quad (7)$$

# Resolution of the model

- By optimizing the utility function with the budget constraint ...
  - ... and by adding a Taylor type rule equation to complete the model,
  - we obtain 6 macro-equations with 6 unknown variables : output, inflation, nominal interest rate, real money balances, flexible-price output, flexible-price real money balances.

# The solution and macro-equations of the model

$$\hat{y}_t^f = v_a^y \hat{a}_t + v_m^y \widehat{mp}_t^f - v_c^y + v_{sm}^y \varepsilon_t^M + v_{sn}^y \varepsilon_t^N \quad (26)$$

$$\widehat{mp}_t^f = v_{y+1}^m E_t [\hat{y}_{t+1}^f] + v_y^m \hat{y}_t^f + \frac{1}{\nu} \varepsilon_t^M \quad (27)$$

$$\hat{\pi}_t = \beta E_t [\hat{\pi}_{t+1}] + \kappa_x (\hat{y}_t - \hat{y}_t^f) + \kappa_m (\widehat{mp}_t - \widehat{mp}_t^f) \quad (28)$$

$$\hat{y}_t = E_t [\hat{y}_{t+1}] - \kappa_r (\hat{i}_t - E_t [\hat{\pi}_{t+1}]) + \kappa_{mp} E_t [\Delta \widehat{mp}_{t+1}] \quad (29)$$

$$+ \kappa_{sp} E_t [\Delta \varepsilon_{t+1}^P] + \kappa_{sm} E_t [\Delta \varepsilon_{t+1}^M] \quad (30)$$

$$\widehat{mp}_t = \hat{y}_t - \kappa_i \hat{i}_t + \frac{1}{\nu} \varepsilon_t^M \quad (31)$$

$$\hat{i}_t = (1 - \lambda_i) \left( \lambda_\pi (\hat{\pi}_t - \pi^*) + \lambda_x (\hat{y}_t - \hat{y}_t^f) \right) + \lambda_i \hat{i}_{t-1} + \rho_i z_{t-1}^i + \varepsilon_{i,t} \quad (32)$$

# Bayesian analysis

Table 1: Calibration and estimation of structural parameters<sup>10</sup>

	Law	Prior mean	Posterior deviation	Posterior mean	Standard deviation	Confidence interval
$\beta$	beta	0.99	0.005	0.9933	0.0026	[0.9879; 0.9988]
$\sigma$	normal	2.0	0.05	1.9746	0.0503	[1.8966; 2.0593]
$\nu$	normal	1.2	0.05	1.3271	0.0378	[1.2647; 1.3915]
$\eta$	normal	1.0	0.05	1.0079	0.0498	[0.9219; 1.0884]
$\theta$	beta	0.66	0.05	0.7645	0.0281	[0.7181; 0.8138]
$\varepsilon$	normal	6.0	0.05	6.0029	0.0500	[5.9226; 6.0867]
$\alpha$	beta	0.33	0.05	0.3921	0.0539	[0.3050; 0.4792]
$b$	beta	0.4	0.05	0.3981	0.0508	[0.3209; 0.4810]
$\lambda_i$	beta	0.6	0.05	0.5346	0.0356	[0.4748; 0.5923]
$\lambda_\pi$	normal	3.5	0.05	3.5154	0.0499	[3.4329; 3.5965]
$\lambda_x$	normal	1.5	0.05	1.5288	0.0493	[1.4458; 1.6086]
$\rho_a$	beta	0.5	0.075	0.8600	0.0360	[0.7829; 0.9440]
$\rho_i$	beta	0.5	0.075	0.9892	0.0039	[0.9824; 0.9962]
$\rho_p$	beta	0.5	0.075	0.8841	0.0167	[0.8580; 0.9102]
$\rho_m$	beta	0.5	0.075	0.9389	0.0177	[0.9117; 0.9680]
$\rho_n$	beta	0.5	0.075	0.8105	0.0776	[0.6819; 0.9455]
$\sigma_a$	invgamma	1	1	0.8976	0.0914	[0.6269; 1.1568]
$\sigma_i$	invgamma	1	1	0.6118	0.0660	[0.4953; 0.7232]
$\sigma_p$	invgamma	5	1	7.2887	0.8491	[5.9397; 8.7002]
$\sigma_m$	invgamma	1	1	1.4097	0.1016	[1.2402; 1.5757]

# Estimates of macro-coefficients

Macro-coefficients when  $\sigma = 2$

$$\begin{array}{ll} v_a^y = 0.79327 & \kappa_x = 0.06334 \\ v_m^y = -0.02733 & \kappa_m = 0.00173 \\ v_c^y = 0.04376 & \kappa_r = 0.53741 \\ v_{sm}^y = 0.08356 & \kappa_{mp} = 0.06116 \\ v_{sn}^y = -0.23668 & \kappa_{sp} = -0.53741 \\ v_{y+1}^m = -0.80737 & \kappa_{sm} = -0.18698 \\ v_y^m = 1.8074 & \kappa_i = 0.43389 \end{array}$$

Macro-coefficients when  $\sigma = 6$

$$\begin{array}{ll} v_a^y = 0.46971 & \kappa_x = 0.05074 \\ v_m^y = -0.0878 & \kappa_m = 0.00446 \\ v_c^y = 0.02256 & \kappa_r = 0.18934 \\ v_{sm}^y = 0.21552 & \kappa_{mp} = 0.1343 \\ v_{sn}^y = -0.1238 & \kappa_{sp} = -0.1893 \\ v_{y+1}^m = -2.156 & \kappa_{sm} = -0.3294 \\ v_y^m = 3.1569 & \kappa_i = 0.40838 \end{array}$$

# Simulation: Preference Shock

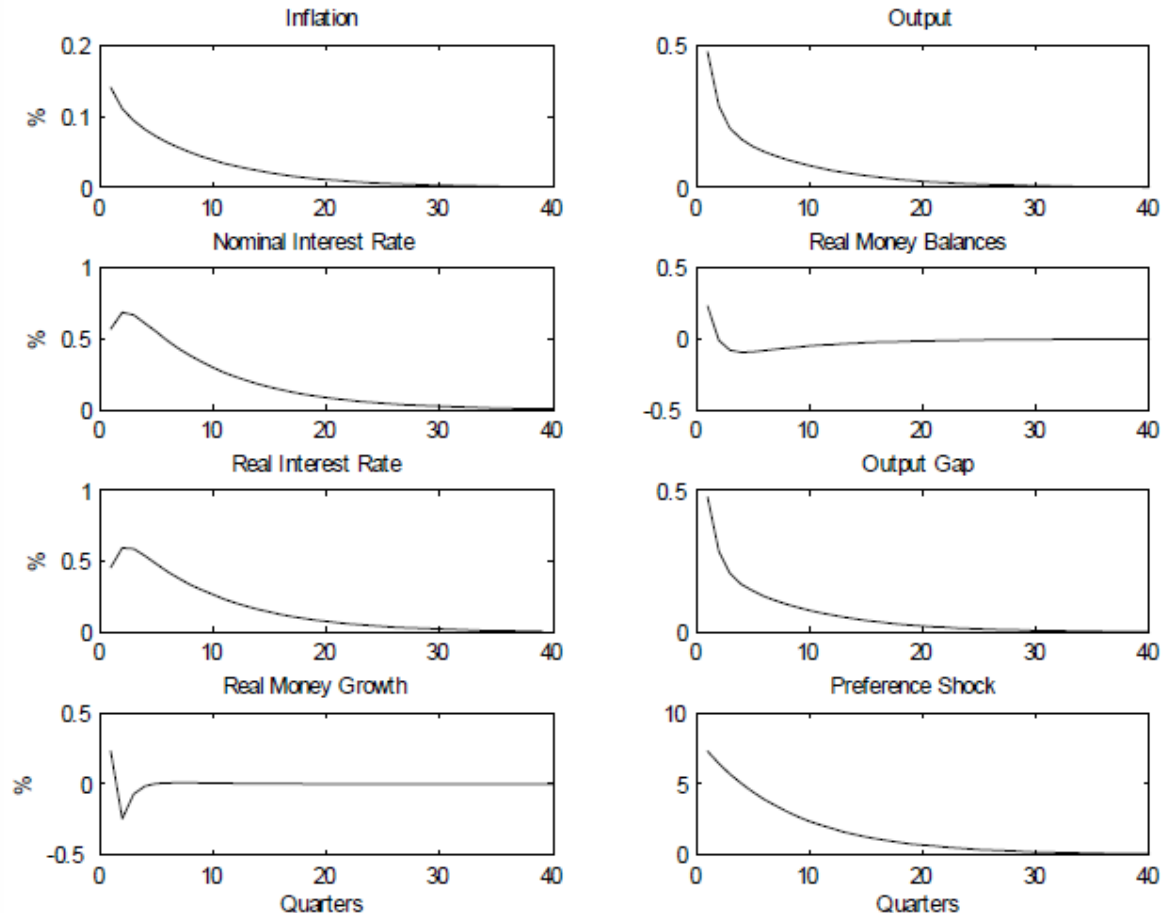


Figure 1: Preference shock

Figure 1 presents the response of key variables to a preference shock. In response to the shock, the inflation rate, the output, the output gap, real money balances, the nominal and the real rate of interest rise; real money growth displays a little overshooting process in the first periods, then returns quickly to its steady state value.

# Simulation: Technology Shock

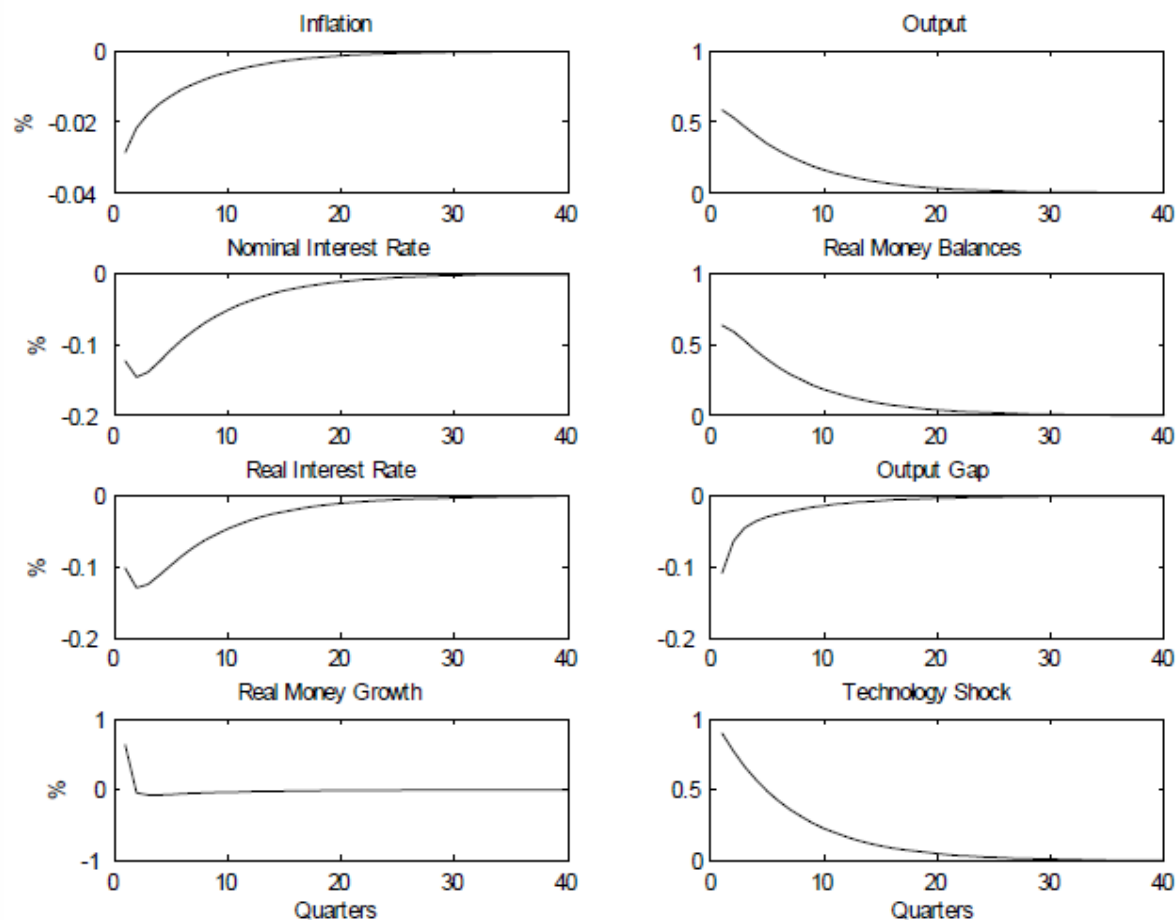


Figure 2: Technology shock

In Figure 2, we plot the response of the same variables to a technology shock. The output gap, the inflation, the nominal and the real interest rate decrease whereas output as well as real money balances and real money growth rise.

# Simulation: Money Shock

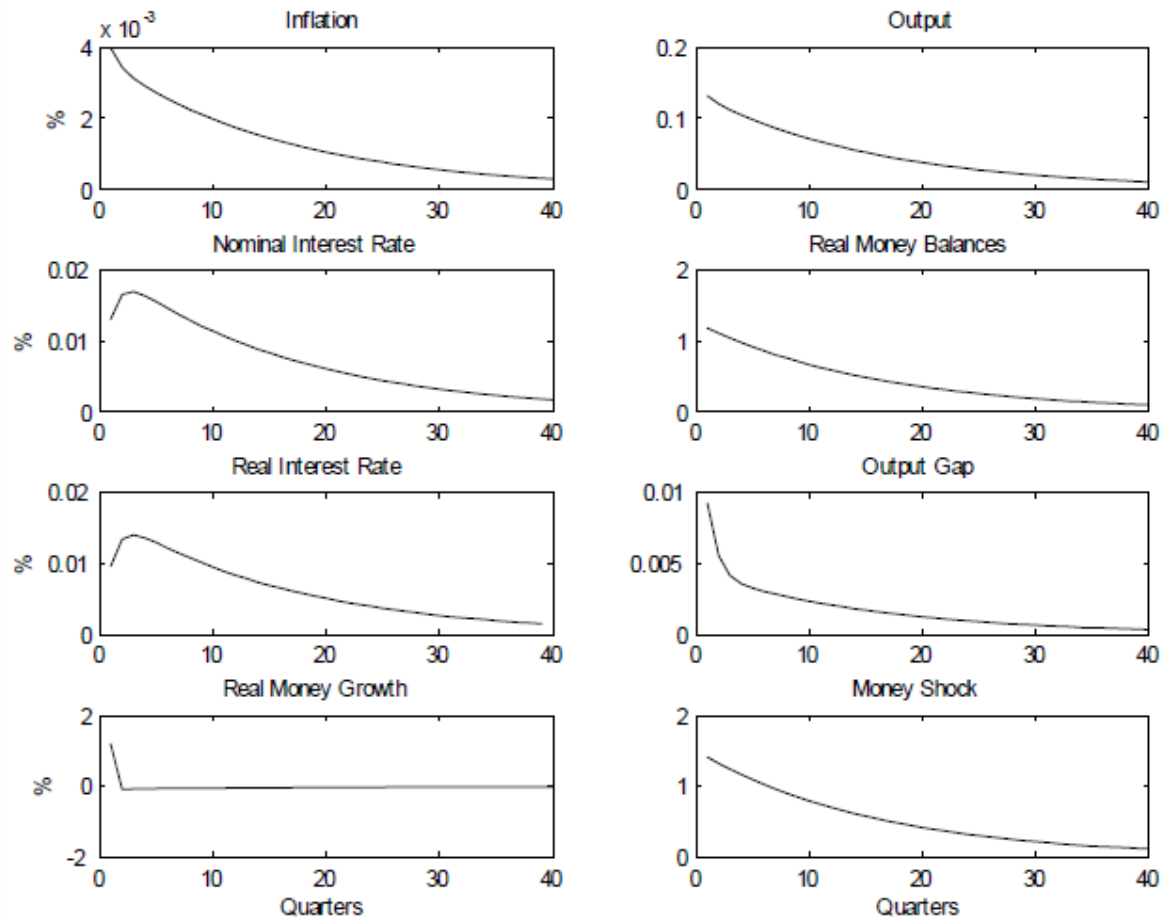


Figure 3: Money shock

Figure 3 exhibits the response to a money shock. Inflation, the nominal and the real rate of interest, the output and the output gap rise.

# Simulation: Interest Rate Shock

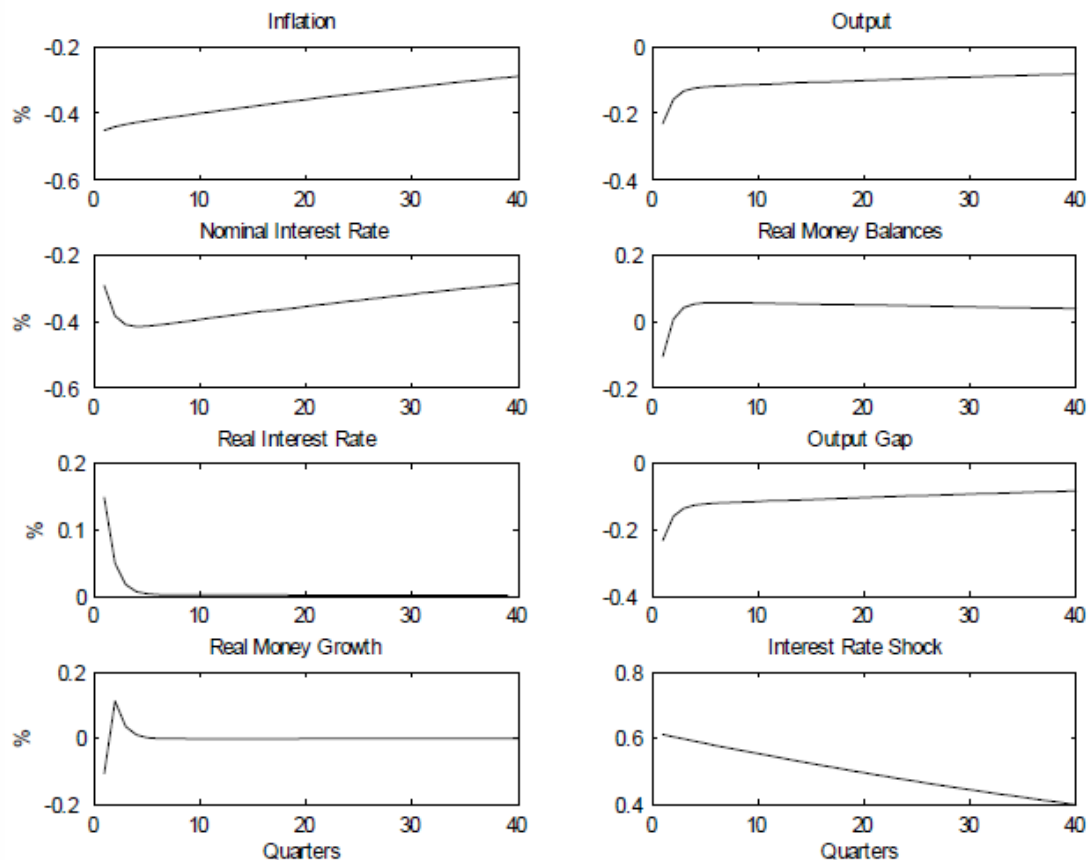


Figure 4: Interest rate shock

Figure 4 presents the response to an interest rate shock. Inflation, the nominal rate of interest, output and the output gap fall. The real rate of interest rises. A positive monetary policy shock induces a fall in interest rates due to a low enough degree of intertemporal substitution (i.e. the risk aversion parameter is high enough) which generates a large impact response of current consumption relative to future consumption. This result has been noted in, *inter alia*, Jeanne (1994) and Christiano et al. (1997).

# Simulation: Labor Shock

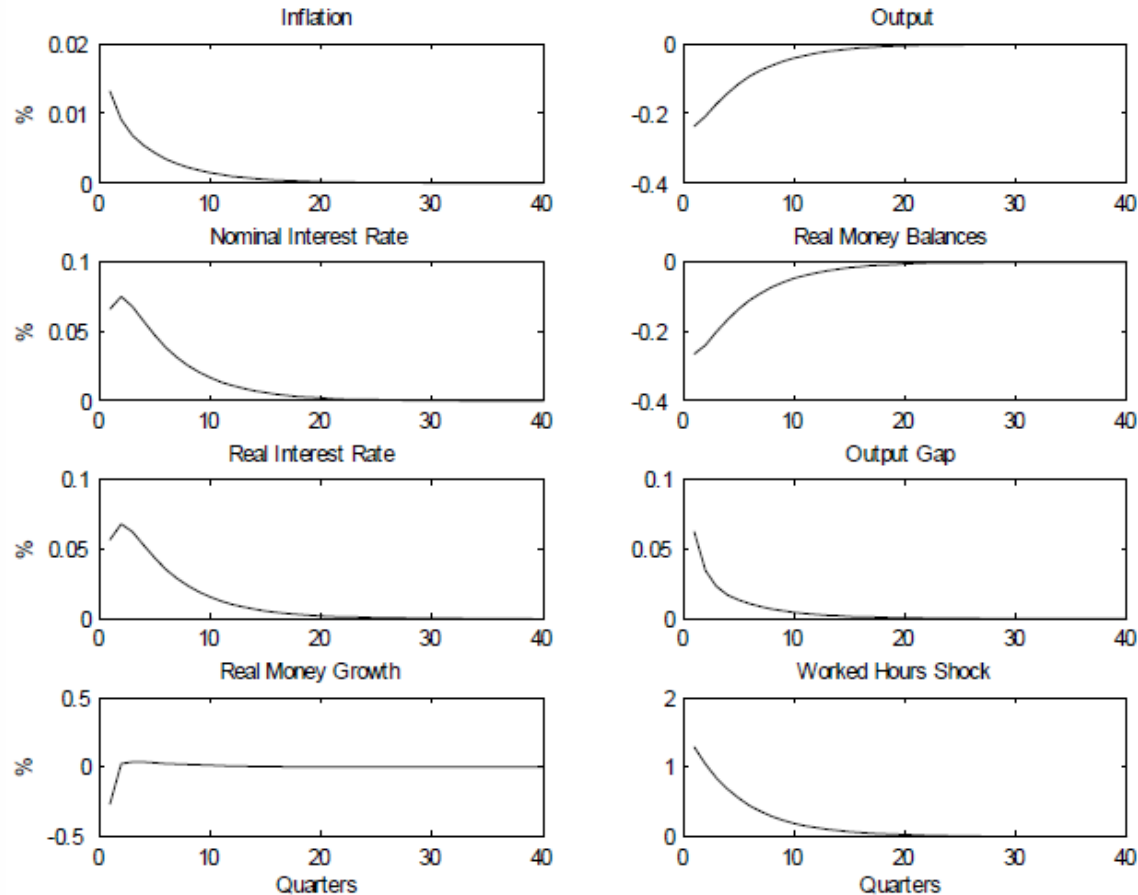


Figure 5: Labor shock

When there is a labor shock (Figure 5), inflation, the real and the nominal rate of interest, and the output gap increase. Output and real money balances decrease.

All these results are in line with the DSGE literature, especially with Galí (2007) and other studies on impulse response functions.

# Variance Decompositions

Table 3: Unconditional variance decomposition (%)

	With $\sigma = 2$					With $\sigma = 6$				
	$\varepsilon_t^N$	$\varepsilon_t^P$	$\varepsilon_t^i$	$\varepsilon_t^M$	$\varepsilon_t^a$	$\varepsilon_t^N$	$\varepsilon_t^P$	$\varepsilon_t^i$	$\varepsilon_t^M$	$\varepsilon_t^a$
$\hat{y}_t$	6.19	15.6	25.7	4.47	48.1	0.20	10.1	22.6	17.0	50.2
$\hat{\pi}_t$	0.00	0.77	99.2	0.00	0.03	0.00	0.37	99.3	0.01	0.36
$\hat{i}_t$	0.21	25.5	73.3	0.03	0.98	0.14	21.1	67.7	0.26	10.8
$\widehat{mp}_t$	1.77	0.77	1.27	83.2	13.0	0.12	0.58	0.13	76.4	22.8
$\hat{y}_t^f$	11.8	0.00	0.00	5.67	82.6	0.55	0.00	0.00	16.5	82.9
$\widehat{mp}_t^f$	2.37	0.00	0.00	82.2	15.5	0.25	0.00	0.00	72.1	27.7

The unconditional variance decomposition shows that with a standard calibration of our model ( $\sigma = 2$ ), about half of the variance of output results from the productivity shock, about a quarter from the interest rate shock, the remaining quarter from the other shocks. If money plays some role, this role is rather minor (an impact of less than 5%).

Yet, as Table 3 shows, the money shock contribution to the business cycle depends on the value of agents' risk aversion. Indeed, an estimation of our model with a higher risk aversion<sup>11</sup> ( $\sigma = 6$ ) gives interesting information as to the role of money, and more generally as to the role of each shock.

Notably, it shows that a higher coefficient of relative risk aversion increases significantly the role of money in a business cycle.

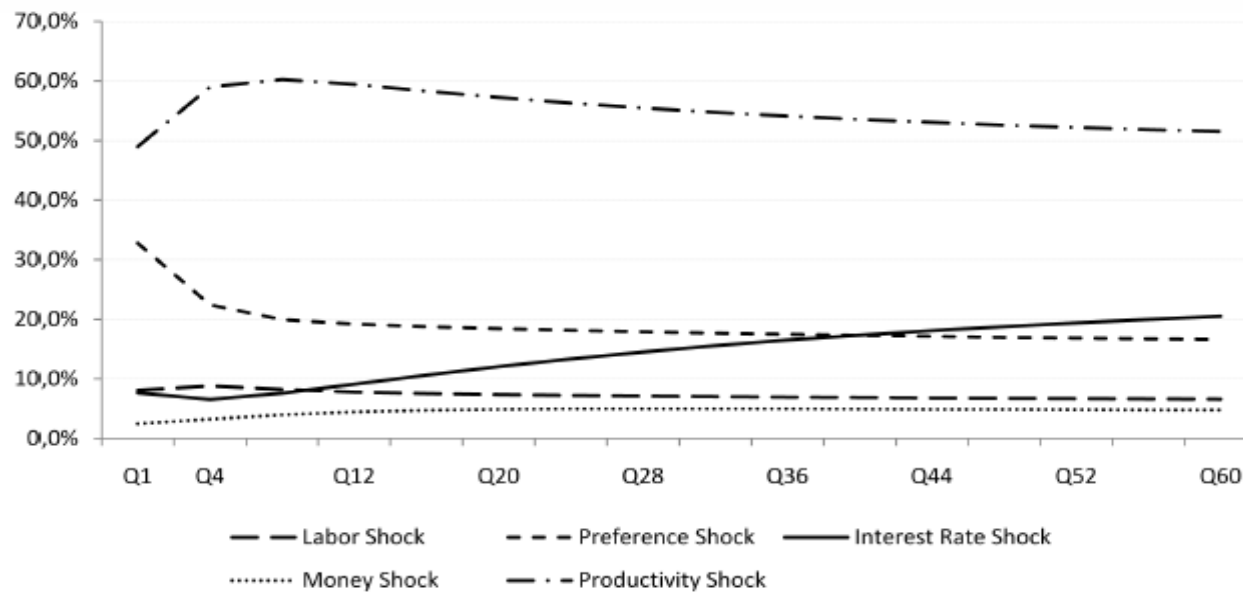


Figure 6: Forecast error variance decomposition of  $\hat{y}_t$  with  $\sigma = 2$

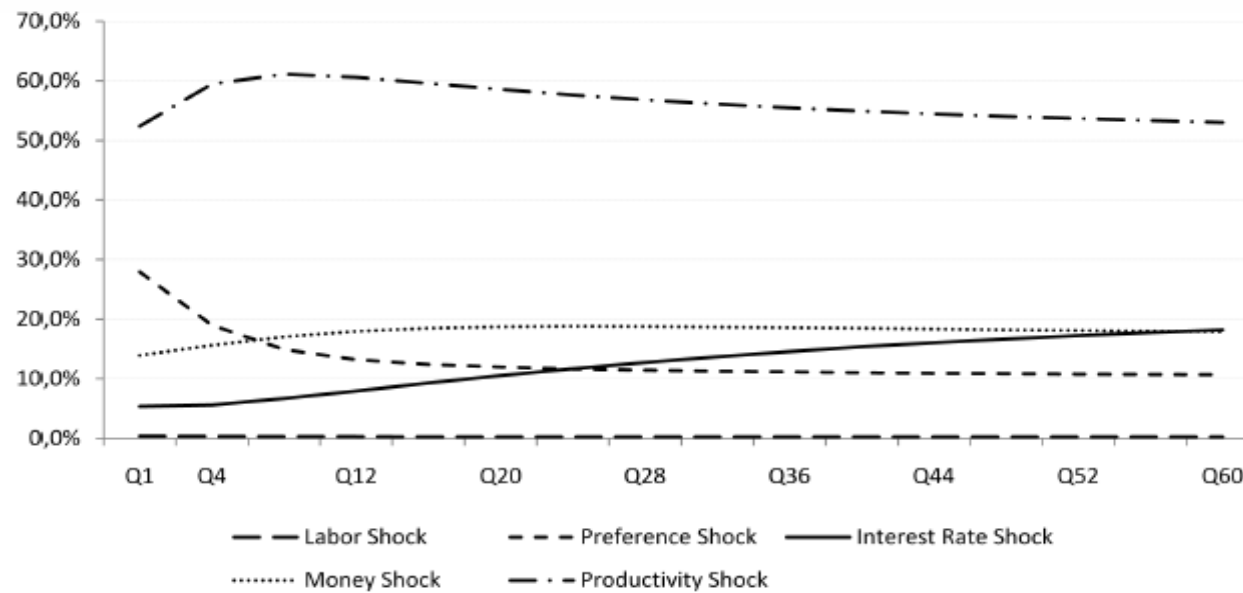


Figure 7: Forecast error variance decomposition of  $\hat{y}_t$  with  $\sigma = 6$

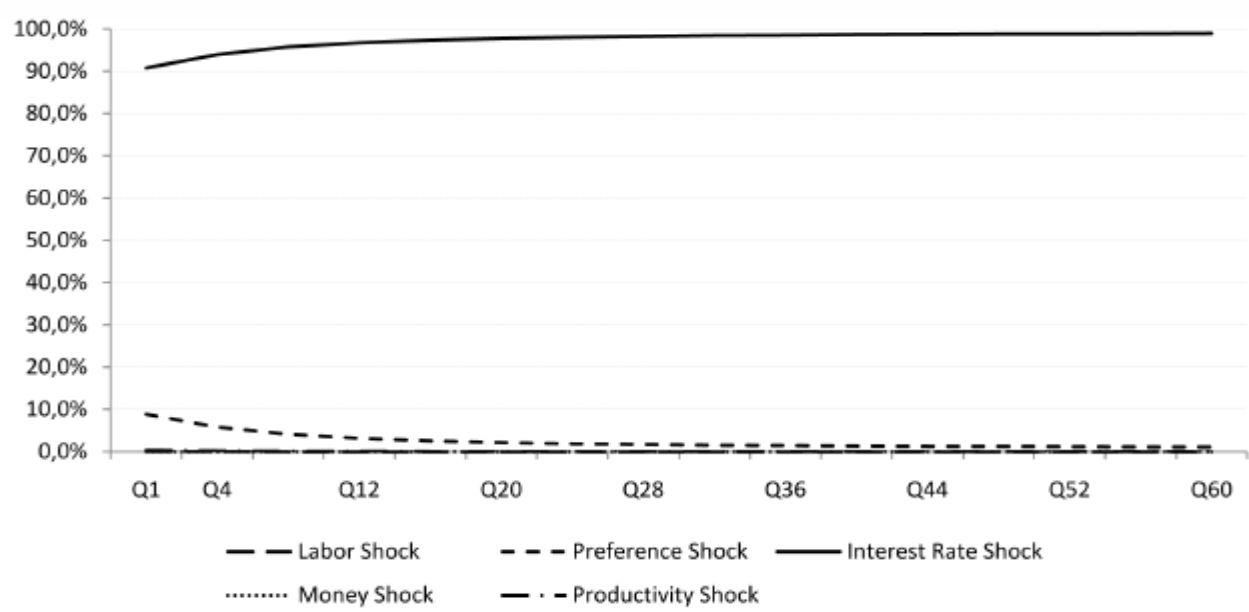


Figure 8: Forecast error variance decomposition of  $\hat{\pi}_t$  with  $\sigma = 2$

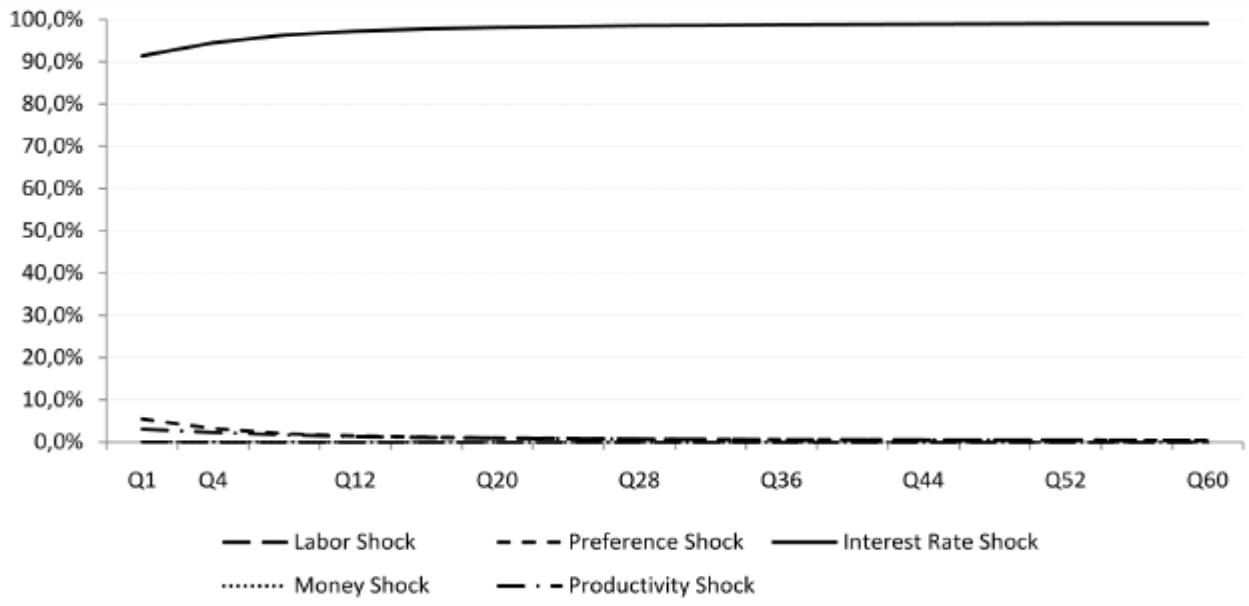


Figure 9: Forecast error variance decomposition of  $\hat{\pi}_t$  with  $\sigma = 6$

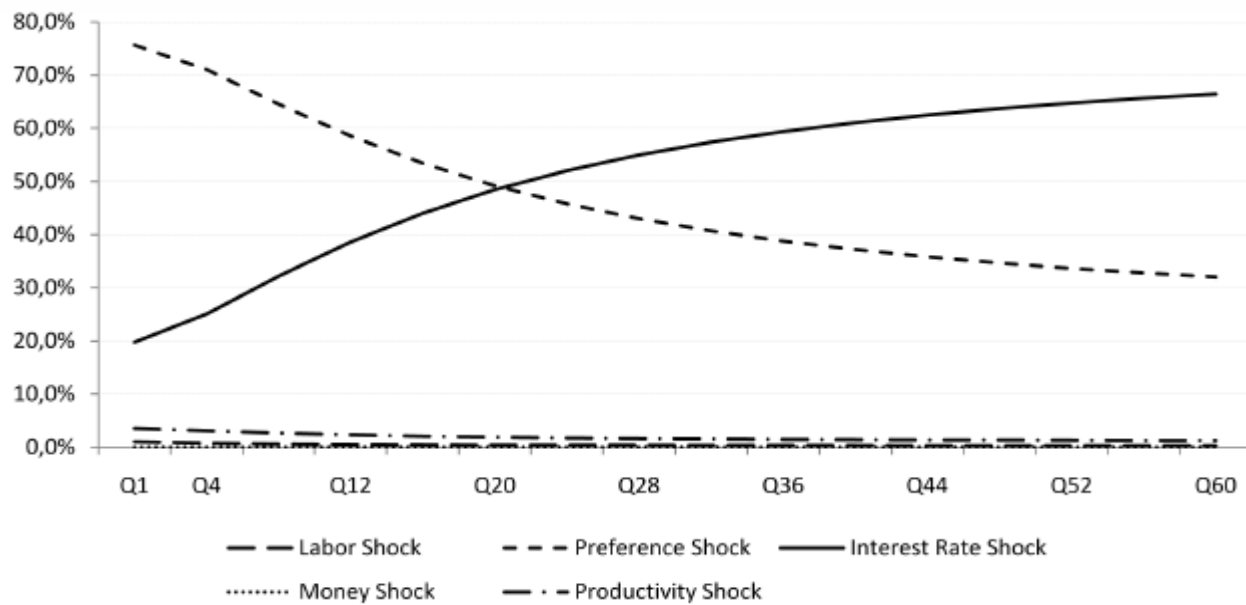


Figure 10: Forecast error variance decomposition of  $\hat{v}_t$  with  $\sigma = 2$

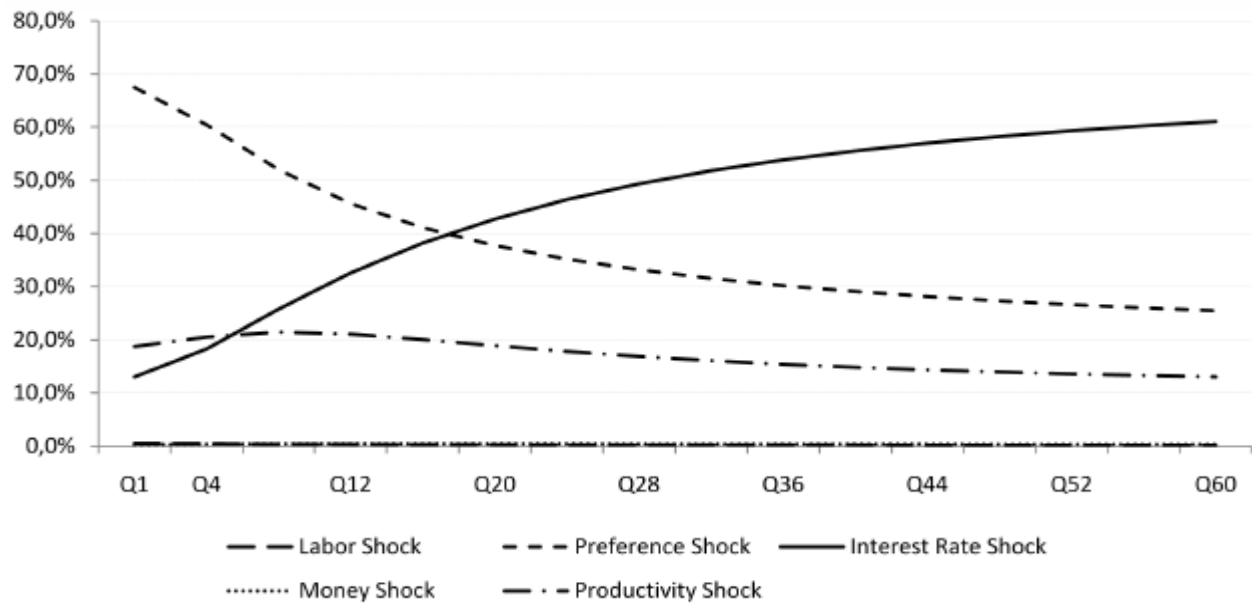


Figure 11: Forecast error variance decomposition of  $\hat{v}_t$  with  $\sigma = 6$

# Conclusion

-In this paper, we built and empirically tested a New Keynesian DSGE model of the Euro zone, with money in the utility function whereby real money balances affect the marginal utility of consumption.

- By using bayesian estimation techniques, we shed light on the determinants of **output** and **inflation**, but also of **interest rate**, **real money balances**, **flexible-price output** and **flexible-price real money balances** variances.

## Conclusion (follow up)

- Half of the variance of output is explained by the productivity shock, the other half by a combination of labor, preference, interest rate and money shocks.
- Almost the totality of the inflation variance is a consequence of the interest rate shock.
- The interest rate variance depends mainly on the interest rate shock, but the preference shock is also significant, as well as, to a lesser extent, the productivity shock.

## Conclusion (follow up)

- Interestingly, the flexible-price output variability depends strongly on the productivity shock, but the money shock remains significant.
- The calibration of the model with a standard risk aversion shows that money plays a minor role in explaining output variability, a result in line with current literature (Andrès et al., 2006; Ireland, 2004).

## Conclusion (follow up)

- Other calibrations with higher risk aversion imply that money plays a non-negligible role in explaining output fluctuations.

**And the more agents are risk averse, the higher the impact of money on output.**

- This result differs from existing literature using New Keynesian DSGE frameworks with money, neglecting the role of a high enough risk factor.

- Inference: the financial crisis, by changing agents' perception of risks, may have increased the role of money in output changes.