Money and risk in a DSGE framework: A Bayesian application to the Eurozone

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The question of money

- In the current New Keynesian literature, the role of monetary aggregates is generally **neglected**.
- The main economic variables of this kind of models are: the output gap, inflation and the interest rate.
- Yet it's hard to imagine money completely "passive" to the rest of the system !

Brunner and Meltzer

- 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.
- By affecting aggregate demand, real money balances become a 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.
- This monetarist transmission process may also imply a specific role to real money balances when dealing with **risk aversion**.

Money and new Keynesian models

- Most of studies about New Keynesian models ignore money because of separable utilities, such as following:

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} + \frac{\gamma}{1-b} \left(\frac{M_{t+i}}{P_{t+i}} \right)^{1-b} - \chi \frac{N_{t+i}^{1+\eta}}{1+\eta} \right]$$

- Solving this problem makes money completely recursive to the rest of the system of equations. Yet, real money holdings could affect household's consumption, and vice versa.
- In other words, real money balances are supposed to affect the marginal utility of consumption, i.e. we have to assume **non-separable utility** between consumption and real money balances.

Selected papers

- Andrés, López-Salido and Vallés, 2006, **Money in an Estimated Business Cycle Model of the Euro Area**, *Economic Journal*.
- Barthélemy, Clerc, and Marx, 2011, **A two-pillar DSGE monetary policy model for the euro area**, *Economic Modelling*.
- Ireland, 2004, **Money's Role in the Monetary Business Cycle**, *Journal of Money, Credit and Banking*.
- Smets and Wouters, 2003, **An Estimated Dynamic Stochastic General Equilibrium Model for the Euro Area**, *Journal of the European Economic Association*.

New Keynesian framework

The model consists of economic agents of 3 types :

- Households: purchase goods for consumption, hold money and bonds, supply labor, and maximize the expected present value of utility.
- Firms: hire labor, produce and sell differentiated products in monopolistically competitive goods markets, and maximize profits.
- Central bank: controls the nominal rate of interest.

Non-separable money in the utility

- Preferences of the representative household are defined over a composite consumption good C_t, real money balances $\frac{M_t}{P_t}$, and leisure $1 - N_t$, where N_t is the time devoted to market employment.
- CES utility function:

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

- Budget constraint:

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

- Production function:

$$Y_t = A_t {N_t}^{1-\alpha}$$

Solving the model

- By using Lagrangian method in order to optimize the utility function with respect to the budget constraint, we obtain three first-order optimal conditions.
- We log-linearize around the steady state these conditions.
- We add an ad-hoc Taylor type rule equation to close our model.
- Finally, we have 6 equations of 6 unknown variables for our economy: output gap ($\hat{y}_t$) and its flexible-price counterpart ($\hat{y}_t^f$), inflation rate ($\hat{\pi}_t$), real money balances ($\widehat{mp}_t$) and its flexible-price counterpart ($\widehat{mp}_t^f$) and nominal interest rate ($\hat{\imath}_t$).
- Structural shocks are assumed to follow a first-order autoregressive process with an *i.i.d.*-normal error term such as $\varepsilon_t^k = \rho_k \varepsilon_{t-1}^k + \omega_{k,t}$ where $\varepsilon_{k,t} \sim N(0; \sigma_k)$ for $k = \{P, M, i, a\}$

Log-linearized model (around the steady state)

$$\hat{y}_t^f = \upsilon_a^y \varepsilon_t^a + \upsilon_m^y \widehat{mp}_t^f - \upsilon_c^y + \upsilon_{sm}^y \varepsilon_t^M \tag{1}$$

$$\widehat{mp}_t^f = \upsilon_{y+1}^m E_t\left[\hat{y}_{t+1}^f\right] + \upsilon_y^m \hat{y}_t^f + \frac{1}{\nu}\varepsilon_t^M \tag{2}$$

$$\hat{\pi}_t = \beta E_t\left[\hat{\pi}_{t+1}\right] + \kappa_x\left(\hat{y}_t - \hat{y}_t^f\right) + \kappa_m\left(\widehat{mp}_t - \widehat{mp}_t^f\right) \tag{3}$$

$$\begin{aligned}\hat{y}_t \quad = \quad & E_t\left[\hat{y}_{t+1}\right] - \kappa_r\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right]\right) + \kappa_{mp} E_t\left[\Delta\widehat{mp}_{t+1}\right] \\ & + \kappa_{sp} E_t\left[\Delta\varepsilon_{t+1}^P\right] + \kappa_{sm} E_t\left[\Delta\varepsilon_{t+1}^M\right]\end{aligned} \tag{4}$$

$$\widehat{mp}_t = \hat{y}_t - \kappa_i \hat{\imath}_t + \frac{1}{\nu}\varepsilon_t^M \tag{5}$$

$$\hat{\imath}_t = (1-\lambda_i)\left(\lambda_\pi \hat{\pi}_t + \lambda_x\left(\hat{y}_t - \hat{y}_t^f\right)\right) + \lambda_i \hat{\imath}_{t-1} + \varepsilon_t^i \tag{6}$$

Micro-funded model

$$\upsilon_a^y = \frac{1+\eta}{(\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha}$$
$$\upsilon_m^y = \frac{(1-\alpha)(\nu-\sigma)(1-a_1)}{(\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha}$$
$$\upsilon_c^y = \frac{(1-\alpha)\log\left(\frac{\varepsilon}{\varepsilon-1}\right)}{(\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha}$$
$$\upsilon_{sm}^y = \frac{(\nu-\sigma)(1-a_1)(1-\alpha)}{((\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha)(1-\nu)}$$
$$\upsilon_{y+1}^m = -\frac{a_2}{\nu}\left(\nu-(\nu-\sigma)a_1\right)$$
$$\upsilon_y^m = 1+\frac{a_2}{\nu}\left(\nu-(\nu-\sigma)a_1\right)$$
$$\kappa_m = (1-a_1)(\sigma-\nu)\frac{(1-\alpha)(1-\beta\theta)(1-\theta)}{\theta(1-\alpha+\alpha\varepsilon)}$$
$$\kappa_x = \left(\nu-(\nu-\sigma)a_1+\frac{\eta+\alpha}{1-\alpha}\right)\frac{(1-\alpha)(1-\beta\theta)(1-\theta)}{\theta(1-\alpha+\alpha\varepsilon)}$$

$$\kappa_r = \frac{1}{\nu-a_1(\nu-\sigma)}$$
$$\kappa_{mp} = \frac{(\sigma-\nu)(1-a_1)}{\nu-a_1(\nu-\sigma)}$$
$$\kappa_{sp} = -\frac{1}{\nu-a_1(\nu-\sigma)}$$
$$\kappa_{sm} = -\frac{(1-a_1)(\nu-\sigma)}{(\nu-a_1(\nu-\sigma))(1-\nu)}$$
$$\kappa_i = a_2/\nu$$
$$a_1 = \frac{1}{1+(b/(1-b))^{1/\nu}(1-\beta)^{(\nu-1)/\nu}}$$
$$a_2 = \frac{1}{\exp(1/\beta)-1}$$

Methodology

- As in Smets and Wouters (2003) and An and Schorfheide (2007), we apply **Bayesian techniques** to estimate our DSGE model.
- We use **Eurozone data** like Andrès et *al.* (2006) and Barthélemy, Clerc and Marx (2011) from the Euro Area Wide Model database (Fagan, Henry and Mestre, 2001).
- We use the $M3$ monetary aggregate from the Eurostat database, which is the broadest monetary aggregate.
- To make output and real money balances stationary, we use first log differences, as in Adolfson and *al.* (2008).

Data

- $\hat{\pi}_t$ is the log-linearized **inflation** rate measured as the yearly log difference of GDP Deflator from one quarter to the same quarter of the previous year;
- $\hat{y}_t$ is the log-linearized **output** measured as the yearly log difference of GDP from one quarter to the same quarter of the previous year;
- $\hat{\imath}_t$ is the short-term (3-month) **nominal interest rate**.
- $\widehat{mp}_t$ is the log-linearized **real money balances** measured as the yearly log difference of real money from one quarter to the same quarter of the previous year, where real money is measured as the log difference between the money stock and the GDP Deflator.
- $\hat{y}_t^f$, the **flexible-price output**, and $\widehat{mp}_t^f$, the **flexible-price real money balances**, are completely determined by structural shocks.

Calibration

- Following standard conventions, we calibrate **beta** distributions for parameters that fall between zero and one, **inverted gamma** distributions for parameters that need to be constrained to be greater than zero, and **normal** distributions in other cases.
- The calibration of σ is inspired by Rabanal and Rubio-Ramírez (2007) and by Casares (2007), respectively of 2.5 and 1.5.
- $\sigma = 2$ corresponds to a standard risk aversion while values.
- $\sigma = 4$, twice the standard value, represents a high level of risk aversion.
- As our goal is not to estimate risk aversion but to analyze two different configurations of risk, we adopt the same priors in the two models with different risk aversion calibration.
- Detailed calibration in the paper.

Methodology

- Sample: 117 observations from 1980 (Q4) to 2009 (Q4) in order to avoid high volatility periods before 1980.
- Algorithm: Metropolis-Hastings of 10 distinct chains, each of 100000 draws (Smets and Wouters, 2007; Adolfson et *al.*, 2007).
- Average acceptation rate per chain for the benchmark model $(\sigma = 2)$ are included in the interval $[0.2601; 0.2661]$ and for $(\sigma = 4)$ in the interval $[0.2587; 0.2658]$.

Bayesian estimation of structural parameters (1)

	Priors			Posteriors	
				$\sigma = 2$	$\sigma = 4$
	Law	Mean	Std.	Mean	Mean
α	beta	0.33	0.05	0.434	0.516
θ	beta	0.66	0.05	0.789	0.816
v	normal	1.25	0.05	1.431	1.492
b	beta	0.25	0.10	0.251	0.249
η	normal	1.00	0.10	1.041	1.088
ε	normal	6.00	0.10	6.007	6.010
λ_i	beta	0.50	0.10	0.507	0.549
λ_π	normal	3.00	0.20	3.167	3.132
λ_x	normal	1.50	0.20	1.796	1.765

Bayesian estimation of structural parameters (2)

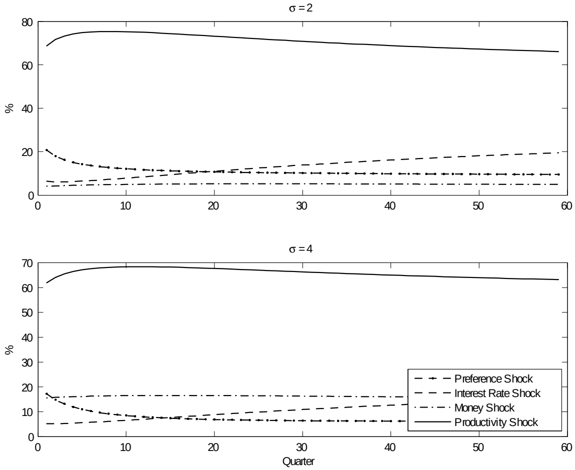
	Priors			Posteriors	
				$\sigma = 2$	$\sigma = 4$
ρ_a	beta	0.75	0.10	0.914	0.937
ρ_p	beta	0.75	0.10	0.880	0.840
ρ_i	beta	0.75	0.10	0.991	0.989
ρ_m	beta	0.75	0.10	0.938	0.941
σ_a	invgamma	0.02	2.00	0.011	0.017
σ_i	invgamma	0.02	2.00	0.006	0.005
σ_p	invgamma	0.02	2.00	0.076	0.077
σ_m	invgamma	0.02	2.00	0.016	0.017

Simulations with posterior means

Unconditional variance decomposition (%)

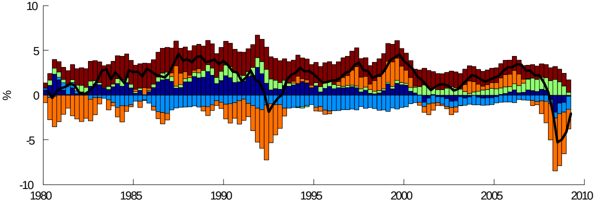
	with $\sigma = 2$				with $\sigma = 4$			
	ε_t^P	ε_t^i	ε_t^M	ε_t^a	ε_t^P	ε_t^i	ε_t^M	ε_t^a
$\hat{y}_t$	8.59	26.92	**4.47**	60.02	5.7	19.81	**14.76**	59.73
$\hat{\pi}_t$	0.44	99.53	0	0.03	0.27	99.54	0.01	0.18
$\hat{\imath}_t$	24.72	74.16	0.06	1.05	25.85	68.2	0.58	5.37
$\widehat{mp}_t$	0.43	0.15	75.75	23.68	0.41	0.96	69.16	29.46
$\hat{y}_t^f$	0	0	**5.6**	94.4	0	0	**15.29**	84.71
$\widehat{mp}_t^f$	0	0	74.75	25.25	0	0	68.83	31.17

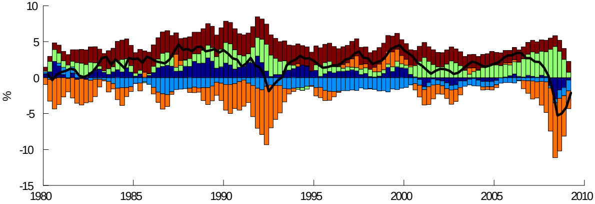
Conditional variance decomposition of output



Shock decomposition of output

Under standard (above) and high (below) risk aversion (ε_t^P in blue, ε_t^M in yellow, ε_t^i in azure and ε_t^a in red).





Interpretation

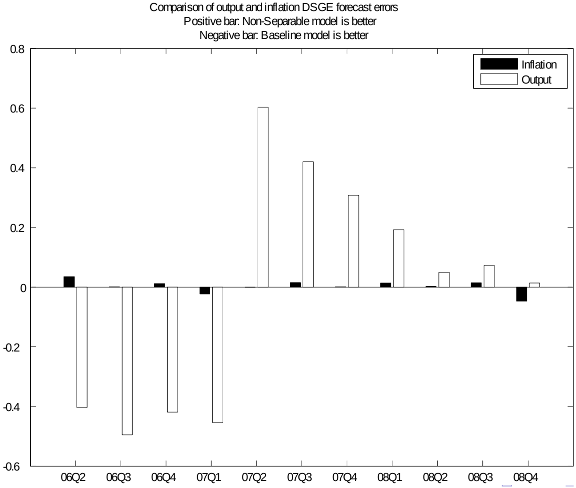
- The weight of the money shock on output dynamics, κ_{sm}, and on flexible-price output, υ^{y}_{sm}, increases with risk aversion.
- **The higher the risk aversion, the higher the role of money on output.**
- The central bank strives for financial stability in crisis periods. The smoothing parameter in the Taylor rule equation, λ_i, increases with risk aversion.

Conclusion

- Under a standard risk aversion: money plays a minor role in explaining output variability (Andrès et *al.*, 2006; Ireland, 2004).
- **Under a higher risk aversion: money plays a non-negligible role in explaining output and flexible-price output fluctuations.**
- The explicit money variable does not appear to have a notable direct role in explaining inflation variability.
- The higher the risk aversion, the stronger the smoothing of the interest rate. This reflects probably the central bankers' objective not to agitate markets.
- One may infer that by **changing economic agents' perception of risks**, the last financial crisis may have increased the **role of money** in the transmission mechanisms and in output changes.

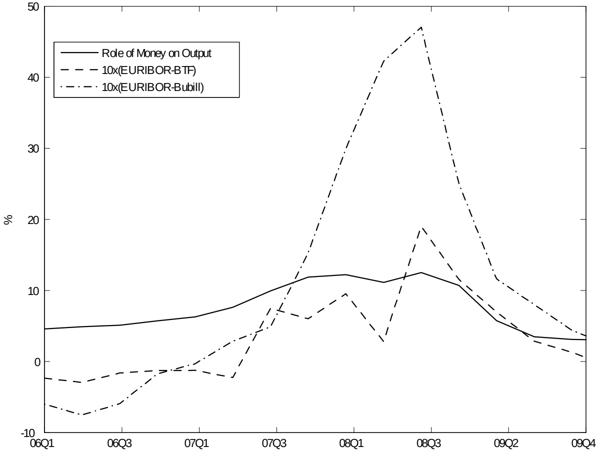
Further research

Out-of-sample forecasting errors (DSGE Forecast)



Further research

Comparison between the role of money on output and the spreads between the Bubill/BTF and the Euribor



Forthcoming in the Journal of Macroeconomics

- Same results with other datasets (detrended, demeaned).
- Taylor rule with a money variable.
- Short and long run analysis of the role of money.