Money in a DSGE framework with an application to the euro zone

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Layout

- Introduction
  - Money and New Keynesian models
  - DSGE analysis
  - Selected papers
- The model
  - Non-separable utility function
  - Solving the model
  - Calibration
- Results
  - Impulse response functions
  - Comments
  - Conclusion

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 !

Money and separable utilities

- 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.
- In order to assign a bigger role to money, we need an other specification of household's preferences. That's why we use a **non-separable** money in the utility function.

DSGE simulation

- During the past few years, dynamic stochastic general equilibrium (DSGE) models have become an increasingly important part of the analytical toolbox used by central banks and other economic policymaking institutions.
- For central banks, macroeconomic models play an important role in monetary and economic policy analysis. There are two major areas in which they are used: the forecasting of aggregate economic developments and, through simulations, to help improve the assessment of the effects of certain events.
- We use a New Keynesian DSGE model to simulate the effects of some shocks on the economy and to show how money is important or not.

Selected papers

- Assenlacher-Wesche, Katrin and Stefan Gerlach, 2006b, Understanding the link between money growth and inflation in the Euro area, *CEPR Discussion Paper* #5683.
- Fourçans, André and Radu Vranceanu, 2006, The ECB monetary policy : Choices and challenges, *Journal of Policy Modelling*, 29, 2, pp.181-194.
- Galí, Jordi, 2008, Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework, *Princeton University Press*.
- Smets, Frank and Raf Wouters, 2003, An Estimated Dynamic Stochastic General Equilibrium Model for the Euro Area, *Journal of the European Economic Association*, September 2003, 1(5):1123–1175.
- Woodford, Michael, *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, 2003.

New Keynesian framework

The model consist of households that supply labor, purchase goods for consumption, and hold money and bonds, and firms that hire labor and produce and sell differentiated products in monopolistically competitive goods markets (Dixit and Stiglitz, 1977). We do not run afoul the Lucas Critique because we derive our macroeconomic system from microeconomic optimization. Economic agents of 3 types :

- Households maximize the expected present value of utility.
- Firms maximize profits.
- Central bank controls the nominal rate of interest.

Money in the Utility

A non-separable utility function

- 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.
- The CES utility function is:

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

- Our budget constraint is:

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

- We use a very simple production function, without capital:

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

Solving the model

- By using Lagrangian method in order to optimize the utility function with respect to budget constraint, we obtain three optimal conditions which we log-linearize.
- We add an ad-hoc Taylor type rule equation to complete our model.
- Finally, we have 4 equations of 4 unknown variables for our economy: output gap, inflation rate, money stock and nominal interest rate.

Log-linearized around the steady state

- $\hat{\pi}_t = \kappa_{\pi,+1} E_t\left[\hat{\pi}_{t+1}\right] + \kappa_{\pi,-1}\hat{\pi}_{t-1} + \kappa_x \Delta\hat{x}_t + \kappa_m \Delta\hat{m}_t + z_t^{\pi}$
- $\hat{x}_t = E_t\left[\hat{x}_{t+1}\right] - \kappa_r\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right]\right) + \kappa_{mp}\left(E_t\left[\Delta\hat{m}_{t+1}\right] - E_t\left[\hat{\pi}_{t+1}\right]\right) + z_t^x$
- $\hat{m}_t = \hat{m}_{t-1} + \hat{\pi}_t + \Delta\hat{x}_t - \kappa_i \Delta\hat{\imath}_t + z_t^m$
- $\hat{\imath}_t = (1-\lambda_i)\left(\lambda_\pi\hat{\pi}_t + \lambda_x\hat{x}_t\right) + \lambda_i\hat{\imath}_{t-1} + z_t^i$

The lowercase (ˆ) denote the log-linearized (around the steady state) form of the original aggregated variables.

Calibrated model

The values listed below, produced by estimating a model for Euro area data, are used to simulate the preference shock. We estimate parameters by the General Method of Moments (GMM).

- $\hat{\pi}_t = 0.59 E_t \left[\hat{\pi}_{t+1}\right] + 0.41 \hat{\pi}_{t-1} + 0.05 \Delta \hat{x}_t + 0.10 \Delta \hat{m}_t + z_t^{\pi}$
- $\hat{x}_t = E_t \left[\hat{x}_{t+1}\right] - 0.03 \left(\hat{\imath}_t - E_t \left[\hat{\pi}_{t+1}\right]\right) + 0.0005 \left(E_t \left[\Delta \hat{m}_{t+1}\right] - E_t \left[\hat{\pi}_{t+1}\right]\right) + z_t^{x}$
- $\hat{m}_t = \hat{m}_{t-1} + \hat{\pi}_t + \Delta \hat{x}_t - 0.98 \Delta \hat{\imath}_t + z_t^{m}$
- $\hat{\imath}_t = 1.77 \hat{\pi}_t + 0.98 \hat{x}_t + 0.67 \hat{\imath}_{t-1} + z_t^{i}$

Calibration

$$\hat{\pi}_t = \kappa_{\pi,+1} E_t \left[\hat{\pi}_{t+1}\right] + \kappa_{\pi,-1} \hat{\pi}_{t-1} + \kappa_x \Delta \hat{x}_t + \kappa_m \Delta \hat{m}_t + z_t^{\pi}$$

	Coefficient	Standard Error	Student Test	p-value
$\kappa_{\pi,+1}$	**0.587443**	0.219194	2.680011	0.0079
$\kappa_{\pi,-1}$	**0.410781**	0.215235	1.908523	0.0575
κ_x	**0.050209**	0.032446	1.547481	0.1230
κ_m	**0.098725**	0.059806	1.650765	0.1001

Determinant residual covariance	0.04	J-statistic	0.02
R^2	0.68	Prob(F-statistic)	0.44
Adjusted R^2	0.67	S.D. dependent var	0.38
S.E. of regression	0.21	Sum squared resid	11.62
Mean dependent var	1.07	Observations	252

Estimation Method: Generalized Method of Moments (GMM); Sample: january 1987 to december 2007;

Instruments: $\hat{x}_{t-3}$, $\hat{m}_{t-3}$, $\hat{x}_{t-6}$, $\hat{m}_{t-6}$, $\hat{x}_{t-12}$, $\hat{m}_{t-12}$.

Calibration

$$\hat{x}_t = E_t\left[\hat{x}_{t+1}\right] - \kappa_r\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right]\right) + \kappa_{mp}\left(E_t\left[\Delta\hat{m}_{t+1}\right] - E_t\left[\hat{\pi}_{t+1}\right]\right) + z_t^x$$

	Coefficient	Standard Error	Student Test	p-value
κ_r	**−0.025938**	0.007700	−3.368425	0.0009
κ_{mp}	**0.000490**	$9.80E-05$	5.002005	0.0000

Determinant residual covariance	0.97	J-statistic	0.04
R^2	*NS*	Prob(F-statistic)	0.34
Adjusted R^2	*NS*	S.D. dependent var	0.60
S.E. of regression	0.99	Sum squared resid	230.67
Mean dependent var	0.02	Observations	236

Estimation Method: Generalized Method of Moments; Sample: april 1988 to november 2007; Kernel: Quadratic, Bandwidth: Andrews (25.28), No prewhitening; Linear estimation after one-step weighting matrix. Instruments: $\hat{\pi}_{t-11}$, $\hat{m}_{t-11}$, $\hat{\imath}_{t-11}$, $\hat{\pi}_{t-12}$, $\hat{m}_{t-12}$, $\hat{\imath}_{t-12}$, $\hat{\pi}_{t-11}$, $\hat{m}_{t-13}$, $\hat{\imath}_{t-13}$, $\hat{\pi}_{t-14}$, $\hat{m}_{t-14}$, $\hat{\imath}_{t-14}$, $\hat{\pi}_{t-15}$, $\hat{m}_{t-15}$, $\hat{\imath}_{t-15}$.

$$\hat{m}_t = \hat{m}_{t-1} + \hat{\pi}_t + \Delta\hat{x}_t - \kappa_i \Delta\hat{\imath}_t + z_t^m$$

	Coefficient	Standard Error	Student Test	p-value
κ_i	$-$**0.975873**	0.185315	-5.266013	0.0000

Determinant residual covariance	6.24	J-statistic	0.02
R^2	*NS*	Prob(F-statistic)	0.07
Adjusted R^2	*NS*	S.D. dependent var	1.40
S.E. of regression	2.50	Sum squared resid	149.16
Mean dependent var	1.90	Observations	239

Estimation Method: Generalized Method of Moments; Sample: january 1988 to november 2007; Kernel:

Quadratic, Bandwidth: Andrews (53.10), No prewhitening; Linear estimation after one-step weighting matrix.

Instruments: $\hat{\imath}_{t-1}$, $\hat{\imath}_{t-3}$, $\hat{\imath}_{t-6}$, $\hat{\imath}_{t-9}$, $\hat{\imath}_{t-12}$.

$$\hat{\imath}_t = (1-\lambda_i)(\lambda_\pi \hat{\pi}_t + \lambda_x \hat{x}_t) + \lambda_i \hat{\imath}_{t-1} + z_t^i$$

	Coefficient	Standard Error	Student Test	p-value
$(1-\lambda_i)\lambda_\pi$	**1.777883**	0.176837	10.05379	0.0000
$(1-\lambda_i)\lambda_x$	**0.978120**	0.048315	20.24480	0.0000
λ_i	**0.665076**	0.035634	18.66425	0.0000

Determinant residual covariance	0.91	J-statistic	0.03
R^2	0.89	Prob(F-statistic)	0.22
Adjusted R^2	0.89	S.D. dependent var	2.90
S.E. of regression	0.96	Sum squared resid	230.24
Mean dependent var	5.91	Observations	251

Estimation Method: Generalized Method of Moments; Sample: january 1988 to november 2008; Kernel: Quadratic, Bandwidth: Andrews (32.89), No prewhitening; Linear estimation after one-step weighting matrix.

Instruments: $\hat{\pi}_{t-1}$, $\hat{x}_{t-1}$, $\hat{\pi}_{t-2}$, $\hat{x}_{t-2}$, $\hat{\pi}_{t-3}$, $\hat{x}_{t-3}$, $\hat{\pi}_{t-4}$, $\hat{x}_{t-4}$, $\hat{\pi}_{t-5}$, $\hat{x}_{t-5}$, $\hat{\pi}_{t-6}$, $\hat{x}_{t-6}$.

DSGE simulation

- The impulse response functions in the diagrams below illustrate how the economy adjusts.
- They show how the disturbance causes each variable to move away from its steady state (zero line) and how it reverts back to it.

DSGE simulation of a Money stock shock

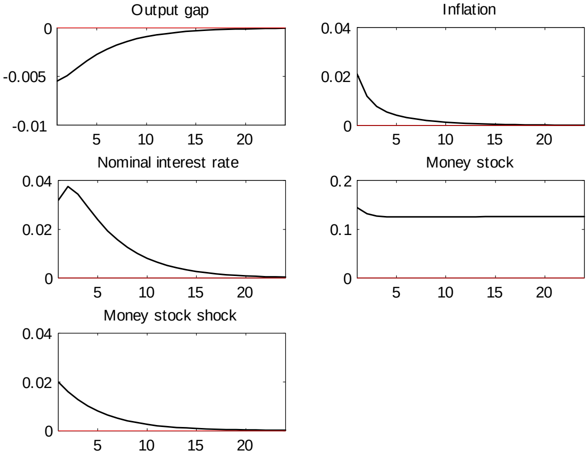

Figure 1: Money stock shock

DSGE simulation of an Inflation shock

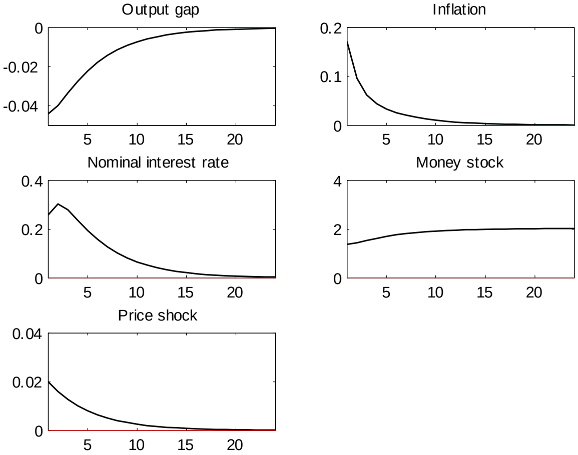

Figure 2: Inflation shock

DSGE simulation Output gap shock

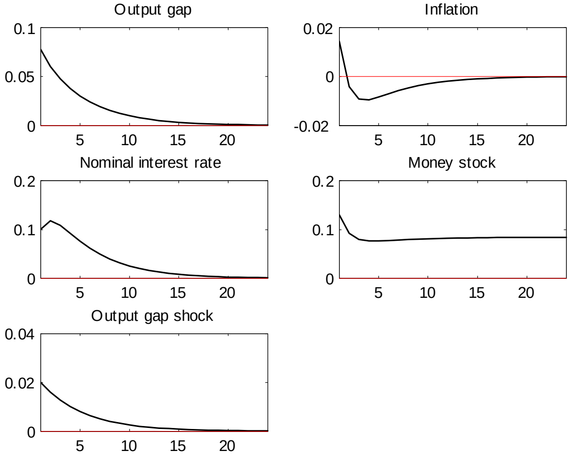

Figure 4: Output gap shock

DSGE simulation of a Preference shock (structural shock)

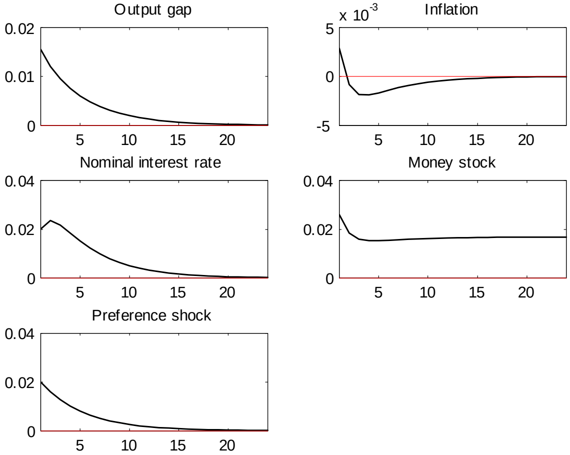

Figure 6: Preference shock

Interpretation

- The baseline model presented by Casares (2006) shows, for an inflation shock in a model calibrated for the Euro area, an impulse response function more smoothed for the nominal interest rate.
- Moreover, the reaction of interest rate in our model is faster than the baseline model. In a monthly report of the Deutsche Bundesbank (Eurosystem, 2008), the preference shock in a DSGE model calibrated for the German economy (close to the Euro area economy) doesn't show any peak for the nominal interest rate while our model with money highlight a significant peak in the nominal interest rate (for a preference shock).

Conclusion and further research

- Similarly, for an interest rate shock, the falling in the inflation rate doesn't show any peak in Bhattacharjee and Thoenissen (2007) while in our model, it does.
- The main property of our model is to magnify shocks and the curvature of variables after a shock.
- By considering monetary aggregates, central bank could react more strongly to such shocks. Introduction of money could incite monetary authority to react more quickly.
- For further research, we intend to build a more complete model (with sticky wages, capital, investment and government spending) and to estimate parameters by DSGE method. It would be interesting to modelize current crisis issues and monetary actions by the way of such a model.