The Macroeconomic Consequences of EMU: International Evidence from a DSGE Model

Jürgen Jerger and Oke Röhe

University of Regensburg
Institute for East European Studies (OEI), Regensburg

Bratislava, June 17, 2010

Roadmap

- Introduction
- Model
- Symmetric Equilibrium
- Solution and Estimation
- Data
- Results
- Stability Tests
- Conclusion

Motivation

- Despite current turmoils – and the lack of credibility of the stability and growth pact: the record after 10 years of European Monetary Union (EMU) looks (looked?) quite favorable (European Commission 2008)
- It is, however, difficult to pin down the channels through which monetary unification in general and EMU in particular indeed works
- (10 years of data is still a problem for many econometric techniques)

Motivation

- Related strands of research analyse ...
  - implications of a common currency for other economic institutions like regulation or wage setting (e.g. von Hagen 1999, Fratzscher and Stracca 2009);
  - (changes of) different transmission channels of monetary policy, usually by employing some variety of a (structural) VAR model (e.g. Angeloni and Ehrmann 2006, Jarocinski 2008);
  - convergence across countries due to monetary union (Beck and Weber 2005, Ongena and Popov 2009);
  - dynamic stochastic general equilibrium (DSGE) models to characterize the Euro area or the economies in this region (e.g. Milani 2009, Reis 2009).

Questions

- Did the behavior of monetary policy change in Germany, France and Spain after the inception of EMU?
- Are the data consistent with the hypothesis that monetary policy converged to the pre-EMU behavior of the German Bundesbank?
- Does a DSGE model support the notion of efficiency gains in terms of lower adjustment cost of prices due to the Euro?

Important papers

- Ireland, Peter N. (2003): Endogenous Money or Sticky Prices?, *Journal of Monetary Economics* 50: 1623-1648.
- Ireland, Peter N. (2004): A Method for Taking Models to the Data, *Journal of Economic Dynamics and Control* 28: 1205-1226.
- Andrés, Javier, J. David Lopéz-Salido and Javier Vallés (2006): Money in an Estimated Business Cycle Model of the Euro Area, *Economic Journal* 511: 457-477.

General Framework

Closed-economy New Keynesian setting featuring

- a representative household,
- a representative finished goods-producing firm,
- a continuum of intermediate goods-producing firms indexed by $i \in [0, 1]$ and
- a monetary policy authority.

Household I

- Household enters period t holding money M_{t-1}, bonds B_{t-1} and capital K_{t-1}; the latter is rented to the intermediate goods sector
- There is a lump sum transfer T_t from the monetary authority at the beginning of period t
- Household receives $W_t h_t$ units of labor income; $K_t Q_t$ in capital income; and a nominal dividend D_t from the intermediate goods producing firm
- In order to transform invested units of the final good into capital the household faces quadratic capital adjustment cost (Abel and Blanchard 1983) given by

$$\frac{\phi_K}{2}\left(\frac{K_{t+1}}{gK_t}-1\right)^2 K_t,$$

with $\phi_K \geq 0$.

Household II

- The capital accumulation process is given by $K_{t+1} = (1-\delta)K_t + x_t I_t$, with $0 < \delta < 1$.
- Following Greenwood, Hercowitz and Huffman (1988) x_t represents a shock to the efficiency of investment. This shock is specified as

$$\ln(x_t) = \rho_x \ln(x_{t-1}) + \varepsilon_{xt},$$

with $0 < \rho_x < 1$ and $\varepsilon_{xt} \sim N(0, \sigma_x^2)$.
- Budget constraint

$$\frac{M_{t-1} + T_t + B_{t-1} + W_t h_t + Q_t K_t + D_t}{P_t} \geq C_t + I_t + \frac{\phi_K}{2}\left(\frac{K_{t+1}}{gK_t} - 1\right)^2 K_t + \frac{B_t/r_t + M_t}{P_t}.$$

Household III

- Stream of expected utility given by

$$E\sum_{t=0}^{\infty}\beta^t\{a_t[\gamma/(\gamma-1)]\ln[C_t^{(\gamma-1)/\gamma}+e_t^{1/\gamma}(M_t/P_t)^{(\gamma-1)/\gamma}]+\eta\ln(1-h_t)\},$$

  where $0<\beta<1$ and $\eta>0$
- Preference shock:

$$\ln(a_t)=\rho_a\ln(a_{t-1})+\varepsilon_{at},$$

  where $0<\rho_a<1$ and $\varepsilon_{at}\sim N(0,\sigma_a^2)$ denotes an IS shock (McCallum and Nelson 1999) and
- Money demand shock:

$$\ln(e_t)=(1-\rho_e)\ln(e)+\rho_e\ln(e_{t-1})+\varepsilon_{et},$$

  where $0<\rho_e<1$,$e>0$ and $\varepsilon_{et}\sim N(0,\sigma_e^2)$

Finished Goods-Producing Firm

- Y_t is produced perfectly competitive according to

$$\left[\int_0^1 Y_t(i)^{(\theta-1)/\theta} di\right]^{\theta/(\theta-1)} \geq Y_t,$$

with $\theta > 1$

- $\Rightarrow$ demand function for intermediate goods

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\theta} Y_t,$$

where $P_t = \left[\int_0^1 P_t(i)^{1-\theta} di\right]^{1/(1-\theta)}$.

Intermediate Goods-Producing Firms I

- Monopolistic competition; CRS technology

$$K_t(i)^{\alpha}[g^t z_t h_t(i)]^{1-\alpha} \geq Y_t(i),$$

with $1 > \alpha > 0$.

- Technology:

$$\ln(z_t) = (1-\rho_z)\ln(z) + \rho_z \ln(z_{t-1}) + \varepsilon_{zt},$$

with $1 > \rho_z > 0$, $z > 0$ and $\varepsilon_{zt} \sim N(0, \sigma_z^2)$.

- Each firm faces convex price adjustment costs (Rotemberg 1982):

$$\frac{\phi_P}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t,$$

where $\phi_P \geq 0$

Intermediate Goods-Producing Firms II

- Note: due to (non-linear) adjustment costs, the firm's decision problem becomes dynamic
- Each firm chooses $h_t(i), K_t(i), Y_t(i)$ and $P_t(i)$ to maximize its total market value $E \sum_{t=0}^{\infty} \beta^t \lambda_t [D_t(i)/P_t]$, where λ_t measures the period t marginal utility to the representative household provided by an additional dollar of profits that are distributed to the household as dividends.
- Dividends are defined by

$$\frac{D_t(i)}{P_t} = \left[\frac{P_t(i)}{P_t}\right] Y_t(i) - \frac{W_t h_t(i) + Q_t K_t(i)}{P_t} - \frac{\phi_P}{2} \left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t.$$

Central Bank

- Monetary policy is represented by a generalized Taylor (1993) rule

$$\omega_r \ln(r_t/r) = \omega_\mu \ln(\mu_t/\mu) + \omega_\pi \ln(\pi_t/\pi) + \omega_y \ln(y_t/y) + \ln(\upsilon_t).$$

- This specification encompasses monetary policies that are conducted by steering interest rates r_t, gross money growth $\mu_t = M_t/M_{t-1}$ or any (linear) combination thereof
- These monetary policy instruments may respond to deviations of gross inflation $\pi_t = P_t/P_{t-1}$ and detrended output $y_t = Y_t/g^t$ from their steady-state values
- Monetary policy shock:

$$\ln(\upsilon_t) = \rho_\upsilon \ln(\upsilon_{t-1}) + \varepsilon_{\upsilon t},$$

with $0 < \rho_\upsilon < 1$ and $\varepsilon_{\upsilon t} \sim N(0, \sigma_\upsilon^2)$.

Symmetric Equilibrium

- The model is characterized by a set of nonlinear difference equations, namely the first-order conditions for the three agents' problems, the laws of motion for the five exogenous shocks and the monetary policy rule.
- Two additional steps are required to close the model:
    - Symmetry: $P_t(i) = P_t$, $Y_t(i) = Y_t$, $h_t(i) = h_t$, $K_t(i) = K_t$ and $D_t(i) = D_t$ for all $i \in [0, 1]$.
    - Market clearing: $M_t = M_{t-1} + T_t$ and $B_t = B_{t-1} = 0$ must hold for all $t = 0, 1, 2....$

Solution

- Due to the nonlinearity of the model, there s no closed-form solution ⇒ log-linearize the system around the steady state and then apply Blanchard and Kahn (1980) to solve linear difference models under rational expectations
- State space representation of the form:

$$\begin{aligned} \mathbf{s_t} &= \mathbf{A}\mathbf{s_{t-1}} + \mathbf{B}\varepsilon_{\mathbf{t}} \\ \mathbf{f_t} &= \mathbf{C}\mathbf{s_t}. \end{aligned}$$

Estimation

- The matrices **A**, **B**, and **C** contain (functions of) the 'deep' as well as the policy rule parameters of the model.
- These parameters are estimated using maximum likelihood.
- Following Hamilton (1994) or Canova (2007), the likelihood function of a state space model can be expressed in terms of one-step-ahead forecast errors of the observables, conditional on the initial observations, and of their recursive variance, both of which are obtained using the Kalman filter.

Data

- To estimate the structural parameters of the model we use French, German and Spanish quarterly (seasonally adjusted) data for consumption, investment, money balances, inflation and the interest rate from 1980q1 to 1998q4 and 1980q1 to 2008q3, respectively.
- Following Ireland (2003), we use linearly detrended time series for (logs of) consumption, investment and M3.
- Despite its relative simplicity, the model contains a considerable number of parameters that are difficult to estimate precisely on only five time series. Hence, a number of parameters not central to the aim of our investigation is fixed prior to estimation, namely η, θ, δ and α.

Selected Results

	France		Germany		Spain	
Parameter	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error
ϕ_P	18.0112	5.3625	19.9115	8.3694	54.0482	22.4337
ϕ_K	25.9372	1.9953	21.7369	3.2108	18.7675	2.9162
ω_r	2.0503	0.2241	2.2517	0.2900	1.3221	0.1640
ω_μ	0.5733	0.1498	0.6468	0.1336	0.9282	0.1547
ω_π	1.8480	0.2326	3.0386	0.3601	0.5674	0.2324
ω_y	-0.2119	0.0434	0.0235	0.0179	-0.0846	0.0209
$\|L\|$	1351.1586		1309.3003		1288.8190	

Table: Maximum Likelihood Estimates: 1980-1998.

Selected Results

	France		Germany		Spain	
Parameter	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error
ϕ_P	16.4569	3.7043	7.6166	3.4101	23.9138	7.1255
ϕ_K	24.1030	0.8750	21.3831	2.7162	13.4216	1.7388
ω_r	2.1694	0.2209	1.8002	0.1930	1.2694	0.1545
ω_μ	0.4661	0.1108	0.3819	0.0797	0.5268	0.1328
ω_π	2.4653	0.2094	2.6668	0.2171	0.9186	0.2710
ω_y	-0.3305	0.0575	0.0284	0.0138	-0.0713	0.0216
$\lvert L \rvert$	2132.5877		1995.1746		1964.1076	

Table: Maximum Likelihood Estimates: 1980-2008.

Selected Results

- To interpret the results, we compare the estimated coefficients
  - across countries $j \in \{\text{France}, \text{Germany}, \text{Spain}\}$ for a given sample $k \in \{1, 2\}$, where $k = 1$ indicates the short sample until 1998 and $k = 2$ the full sample and
  - across samples k for a given country j.
- For cross-country comparison, we employ the Andrews and Fair (1988) Wald test $W = \frac{(a_{jk} - a_{-jk})^2}{\sigma^2_{a_{jk}} + \sigma^2_{a_{-jk}}}$, where $j \neq -j$. W follows a $\chi^2(1)$ distribution under the null of $a_{jk} = a_{-jk}$.
- To compare across samples we use a simple t-test in order to test whether the estimate from the full sample is significantly different. Formally, we use $\frac{|a_{j2} - a_{j1}|}{\sigma_{a_{j2}}}$.

Selected Results

- For all countries and both samples, the estimates the adjustment cost parameter for capital ϕ_K and prices ϕ_P are significant.
- In the long sample, both coefficients are smaller for all countries.
- The decline in ϕ_P is significant at the 1% level in both Germany and France, whereas the decline in ϕ_K is statistically insignificant in the case of Germany; the p-values for France and Spain are 0.0383 and 0.0026, respectively.

Selected Results

- To check the plausibility of the price adjustment parameters, we apply the approach of Keen and Wang (2007) to translate the estimates of ϕ_P into an average duration of quoted prices.
- France and Germany: 7 to 8 months
- Spain: 11 to 12 months

Selected Results

- For all three countries and for both samples the reaction coefficients of the monetary policy function show a significant response of the short term nominal interest rate to deviations of money growth and inflation from their steady state values.
- Relative to France and Spain, ω_π is significantly higher in Germany.
- The fact that money growth seems to be more important for interest rate decisions in Spain might be due to the various monetary policy regimes in Spain from 1980 and 1998.
- For each of the three countries the estimates of ω_μ/ω_r and ω_π/ω_r sum up to a value greater than unity.

Stability of the Monetary Policy Reaction Function

- To identify dates of regime breaks in monetary policy behavior we employ the Quandt-Andrews breakpoint test (Andrews (1993) sup-Wald test).
- This procedure tests for one or more unknown structural breakpoints in the sample given a specified equation and a pre-specified admissible range within which the breakpoint is located.
- The basic idea is that simple Chow breakpoint tests are performed at every point within this range and then summarized into a single test statistic.

Stability of the Monetary Policy Reaction Function

- For each country, we estimate a reaction function of the form

$$\hat{r}_t = \rho_\mu \hat{\mu}_t + \rho_\pi \hat{\pi}_t + \rho_y \hat{y}_t + \varepsilon_{rt},$$

  using OLS where the hat denotes linearly detrended and demeaned variables in logs.
- The analysis is undertaken for the long sample 1980q1 to 2008q3, testing for structural breaks in the response coefficients ρ_μ and ρ_π.
- We look at two different admissible ranges, namely a 'long range' (1984q4 to 2004 q1) and a 'short range' (1989q1 to 1999q4).

Stability of the Monetary Policy Reaction Function

Country	Break identified	Max LR-F	Exp LR-F	Ave LR-F
Admissible range: 1984q4 - 2004q1				
France	2002q1	12.5312	4.7377	8.0249
		(0.0332)	(0.0106)	(0.0045)
Germany	1985q2	9.0710	2.0005	1.5627
		(0.1366)	(0.1799)	(0.5343)
Spain	1999q1	9.9564	3.6299	6.4767
		(0.0963)	(0.0321)	(0.0127)
Admissible range: 1989q1 - 1999q4				
France	1999q2	12.3640	4.7305	8.8550
		(0.0208)	(0.0098)	(0.0044)
Germany	1989q1	2.6186	0.4052	0.6854
		(0.7834)	(0.8361)	(0.8476)
Spain	1999q1	9.9564	3.9474	7.6779
		(0.0569)	(0.0218)	(0.0094)

Table: Quandt-Andrews tests for structural breaks.

Stability of the Monetary Policy Reaction Function

- In the case of Germany all three of the summary statistics measures fail to reject the null hypothesis of no structural breaks within for both ranges.
- The results for France, however, indicate a significant structural break in 2002q1 within the test sample 1984q4 to 2004q1, and 1999q2 for the 1989q1 to 1999q4 range.
- For Spain both ranges clearly (and significantly) identify the inception of EMU, i.e. 1999q1 as the date of the structural break.
- These results strongly suggest that there was no discernible difference between the policies of the German Bundesbank (up to 1998) and the ECB.

Conclusion

- The DSGE model could be successfully applied to three rather different countries, where 'success' is defined by the plausibility of the estimation results.
- Our results point to efficiency gains over time in terms of lower adjustment costs, both for the capital stock and prices.
- Furthermore, the monetary policy reaction functions estimated within the models point to a convergence in France and Spain towards the behavior of the Bundesbank.
- The latter aspect is also present in formal tests for structural breaks for single equation estimations of monetary policy reaction functions.