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Testing heterogeneity within the euro area

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Abstract

This note estimates several constrained versions of an optimization-based multi-country model to test the sources of heterogeneity within the euro area. We show that the main source is the asymmetry of shocks affecting the economies and that the heterogeneity of behaviors does not seem to be of empirical relevance for the euro area.

Keywords: Euro area; Heterogeneity; Bayesian econometrics; Multi-country model

JEL classification: C51; C52; F4

1. Introduction

In the last few years, the policy discussion has focused on heterogeneity of economic performances across countries in the euro area. While some studies suggest that business cycles have converged to a large extent over the past decades (see the contributions in Angeloni et al., 2003), several recent studies focus on the differences between euro-area countries across several dimensions and obtain rather mixed evidence.

A first source of heterogeneity, that may be named *structural heterogeneity*, corresponds to differences in preferences, technology, and constraints of private agents across countries or, more generally, in the propagation mechanism of shocks within the economy (*e.g.* Campa and González Mìnguez, 2004). A second component of heterogeneity is the asymmetry in the conduct of country-specific policies and may be named *policy heterogeneity*. It includes monetary policy (until 1999), fiscal policy and regulation (*e.g.* Demertzis and Hugues Hallett, 1998). A last source of heterogeneity relies on the asymmetry of shocks across countries, or *stochastic heterogeneity* (*e.g.* Verhoef, 2003).

The objective of this note is to investigate the various sources of heterogeneity across euro-area countries within an *optimization-based framework*. We first model and estimate the joint dynamics of the major economies in the euro area assuming full heterogeneity (*i.e.* allowing parameters to differ from one country to the other). Then, we consider the various sources of heterogeneity described above and compare the performances of the competing hypotheses.

2. The stylized multi-country model

The euro area is modelled as the aggregate of several economies.[1] For each country, we formulate a stylized open-economy sticky-price model derived from the "New Open Economy Macroeconomics" literature, which has a sufficiently rich dynamics to fit actual data fairly well. The main ingredients of the multi-country model (MCM) are: (i) habit formation in the households' preferences, (ii) Calvo pricing with indexation of non-optimized prices, (iii) differences in preferences and technologies across countries, (iv) imperfectly correlated

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[1] Since commercial links are much stronger between countries within the area than with countries outside the area, we neglect trade with the rest of the world.

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domestic and foreign shocks, (v) taste bias towards home-produced goods, (vi) deviation from purchasing power parity, (vii) perfect risk sharing assumption. Log-linearization of this model around the steady state implies the following equations for the home block[2]:

$$c_t = \frac{\gamma}{1+\gamma}c_{t-1} + \frac{1}{1+\gamma}\mathbb{E}_t c_{t+1} - \frac{(1-\gamma)}{(1+\gamma)\sigma}(i_t - \mathbb{E}_t\pi_{H,t+1}) + \frac{(1-\gamma)(1-\omega)}{(1+\gamma)\sigma}\mathbb{E}_t\tau_{t+1} + \frac{(1-\rho_p)(1-\gamma)}{(1+\gamma)\sigma}\varepsilon_{p,t} \quad (1)$$

$$\pi_{H,t} = \frac{\xi}{1+\xi\beta}\pi_{H,t-1} + \frac{\beta}{1+\xi\beta}\mathbb{E}_t\pi_{H,t+1} + \frac{(1-\beta\alpha)(1-\alpha)}{(1+\beta\xi)\alpha} \times \left[\frac{\sigma(c_t - \gamma c_{t-1})}{1-\gamma} + \varphi y_t + (1-\omega)\tau_t - (1+\varphi)\varepsilon_{a,t}\right] \quad (2)$$

$$\tau_t = \frac{1}{\omega-\omega^*}\left[\frac{\sigma(c_t-\gamma c_{t-1})}{1-\gamma} - \frac{\sigma^*(c_t^* - \gamma^* c_{t-1}^*)}{1-\gamma^*} + \varepsilon_{p,t}^* - \varepsilon_{p,t}\right] \quad (3)$$

$$y_t = (\omega s)c_t + (1-\omega s)c_t^* + \theta\tau_t \quad (4)$$

$$i_t = \psi_i i_{t-1} + (1-\psi_i)\left[\psi_\pi \pi_{H,t} + \psi_y(y_t - y_t^n)\right] + \varepsilon_{i,t} \quad (5)$$

where $\mathbb{E}_t\{.\}$ denotes the expectation operator conditional on time t information. Eq. (1) is the IS curve where c_t denotes the home consumption, $\pi_{H,t}$ is the home inflation, i_t is the nominal interest rate, and τ_t is home terms of trade. Eq. (2) is the forward-looking New Phillips curve where inflation varies according to real marginal cost and is indexed to past inflation. Eq. (3) defines the terms of trade. Eq. (4) represents the goods market clearing in the home country, where y_t is the aggregate output. Eq. (5) represents a monetary policy rule, in which the interest rate is set in an inertial manner to respond to inflation and the output gap (the deviation of aggregate output to its flexible-price equilibrium value, y_t^n).

$\varepsilon_{p,t}$, $\varepsilon_{a,t}$, and $\varepsilon_{i,t}$ are country-specific preference, productivity, and monetary policy shocks, respectively. They are assumed to follow AR(1) processes: $\varepsilon_{\varsigma,t}=\rho_\varsigma\varepsilon_{\varsigma,t-1}+\eta_{\varsigma,t}$, $\varsigma=p, a, i$.

Estimated parameters are defined in Table 1, while calibrated parameters are β the intertemporal discount factor, ω the weight of the home-country goods in the consumption of home-country household, s the home steady-state consumption/output ratio, and θ which is a composite parameter depending on ω, ω^* and s.

3. Empirical analysis

We adopt a Bayesian full information approach to estimate variants of the MCM. This method is helpful to compare models that are non-nested and takes explicit account of all uncertainty surrounding parameter estimates.

We take Germany, France, and Italy to represent the euro area. The sample period runs from 1970:1 to 1998:4 at a quarterly frequency. The data are drawn from OECD Business Sector Data Base. The estimation is based on four key macroeconomic variables for each country: real consumption, the inflation rate, the nominal short-term interest rate and the nominal exchange rate. Consumption is defined as real consumption expenditures, linearly detrended. Inflation is the annualized quarterly percent change in the implicit GDP deflator. The interest rate is the three-month money-market rate. Priors for common parameters have been chosen to be very close to those adopted by Smets and Wouters (2003) for the euro area. Finally, shocks in a given country are assumed to be uncorrelated, but we allow a non-zero correlation between a given shock in two countries.[3]

3.1. *Estimates of the constrained models*

Table 1 reports statistics on parameter estimates (mode and standard error) of the complete MCM and its various constrained versions.

First, we estimate the *complete* MCM. The overall picture that emerges from the first column is that the three countries display very similar parameter estimates. However, some differences are worth emphasizing regarding the habit persistence parameter (γ), the price indexation parameter (ξ) and the serial correlation of shocks. More importantly, most cross-country correlations between shocks are significantly positive, but shocks are far from being perfectly correlated across countries however, suggesting some asymmetry of shocks across countries.

Second, we estimate an MCM with *structural homogeneity* across countries. This model allows to test formally the hypothesis that private agents behave in a similar manner in the three countries. Structural parameters are found to be rather close to the complete MCM for the utility function parameters ($\gamma=0.79$, $\sigma=1.89$ and $\varphi=2.20$). Turning to the behavior of firms, our estimates reveal that the price indexation parameter is significantly below the estimates obtained for the complete MCM, while other parameters are not significantly altered. Overall, this result suggests that, between core countries of the euro area, structural heterogeneity may be neglected at a first approximation.

Third, we estimate an MCM with policy homogeneity, so that monetary policy parameters are constant across countries. The common policy rule has parameters equal to $\psi_i=0.87$, $\psi_\pi=1.43$ and $\psi_y=0$. The major change with respect to the complete MCM is that the policy rule does not respond to output gap anymore. Imposing policy homogeneity also alters some structural parameters significantly, like the habit parameter or the Calvo

[2] Foreign variables are denoted with a star. We abstract here from the symmetric foreign block. In order to simplify the notations, we present the model as a two-country model, however a complete description of the three-country model can be found in Batini et al. (2004) and Jondeau and Sahuc (2004).

[3] Additional parameters are $\beta=0.99$ and $s=0.57$ for all countries. Parameters of home bias in preferences (ω) are set in order to reflect the weight of each country in the external trade of the others: the weights of German, French, and Italian goods in the consumption of German households are (0.8; 0.11; 0.09). For French and Italian households, the weights are (0.13; 0.8; 0.07) and (0.13; 0.07; 0.8) respectively.

Table 1
Posterior distribution of parameter estimates under alternative hypotheses

		Complete MCM		Structural homogeneity		Policy homogeneity		Structural + policy homogeneity		Stochastic homogeneity	
		Mode	Standard deviation	Mode	Standard deviation	Mode	Standard deviation	Mode	Standard deviation	Mode	Standard deviation
Germany (country 1)											
Consumption habit	γ	0.630	0.050	0.792	0.029	0.759	0.045	0.885	0.018	0.479	0.042
Consumption elast. of subst.	σ	1.542	0.232	1.894	0.218	2.056	0.221	2.278	0.223	1.358	0.194
Labour desutility	φ	1.934	0.253	2.198	0.231	1.882	0.244	1.915	0.228	1.928	0.217
Price indexation	ξ	0.290	0.078	0.151	0.037	0.395	0.092	0.206	0.047	0.425	0.111
Calvo probability	α	0.839	0.019	0.877	0.013	0.928	0.010	0.950	0.007	0.667	0.047
Policy rule: lagged interest rate	ψ_i	0.871	0.020	0.886	0.017	0.870	0.015	0.875	0.014	0.705	0.039
Policy rule: inflation	ψ_π	1.507	0.100	1.499	0.102	1.427	0.105	1.361	0.105	1.705	0.076
Policy rule: output gap	ψ_y	0.458	0.104	0.361	0.119	0.005	0.005	0.003	0.003	0.544	0.096
Vol. preference shock	σ_p	0.048	0.008	0.093	0.014	0.091	0.017	0.191	0.031	0.059	0.010
Vol. productivity shock	σ_a	0.037	0.006	0.054	0.010	0.191	0.052	0.314	0.080	0.020	0.002
Vol. mon. policy shock (x100)	σ_i	0.244	0.020	0.233	0.019	0.213	0.015	0.210	0.013	0.455	0.033
Serial-corr. preference shock	ρ_p	0.640	0.065	0.408	0.070	0.511	0.083	0.310	0.061	0.947	0.014
Serial-corr. productivity shock	ρ_a	0.740	0.067	0.671	0.067	0.362	0.076	0.415	0.069	0.872	0.023
Serial-corr. mon. policy shock	ρ_i	0.506	0.067	0.570	0.059	0.435	0.059	0.450	0.063	0.356	0.048
France (country 2)											
Consumption habit	γ	0.688	0.045	0.792	–	0.898	0.025	0.885	–	0.453	0.039
Consumption elast. of subst.	σ	1.851	0.226	1.894	–	2.161	0.232	2.278	–	1.651	0.190
Labour desutility	φ	2.015	0.252	2.198	–	1.974	0.250	1.915	–	1.973	0.238
Price indexation	ξ	0.324	0.083	0.151	–	0.378	0.084	0.206	–	0.442	0.116
Calvo probability	α	0.822	0.017	0.877	–	0.943	0.009	0.950	–	0.648	0.039
Policy rule: lagged interest rate	ψ_i	0.820	0.027	0.825	0.027	0.870	–	0.875	–	0.688	0.041
Policy rule: inflation	ψ_π	1.517	0.101	1.497	0.099	1.427	–	1.361	–	1.487	0.078
Policy rule: output gap	ψ_y	0.482	0.102	0.303	0.118	0.005	–	0.003	–	0.383	0.099
Vol. preference shock	σ_p	0.063	0.010	0.089	0.012	0.188	0.042	0.176	0.029	0.059	–
Vol. productivity shock	σ_a	0.038	0.007	0.059	0.012	0.330	0.065	0.374	0.099	0.020	–
Vol. mon. policy shock (x100)	σ_i	0.426	0.034	0.427	0.035	0.365	0.024	0.364	0.025	0.455	–
Serial-corr. preference shock	ρ_p	0.509	0.077	0.402	0.071	0.271	0.061	0.292	0.063	0.947	–
Serial-corr. productivity shock	ρ_a	0.660	0.075	0.641	0.066	0.409	0.071	0.468	0.066	0.872	–
Serial-corr. mon. policy shock	ρ_i	0.447	0.067	0.515	0.080	0.337	0.057	0.326	0.058	0.356	–
Italy (country 3)											
Consumption habit	γ	0.777	0.029	0.792	–	0.903	0.022	0.885	–	0.695	0.031
Consumption elast. of subst.	σ	2.009	0.218	1.894	–	2.040	0.235	2.278	–	1.741	0.189
Labour desutility	φ	1.922	0.247	2.198	–	1.995	0.247	1.915	–	1.999	0.220
Price indexation	ξ	0.436	0.102	0.151	–	0.465	0.100	0.206	–	0.421	0.100
Calvo probability	α	0.794	0.022	0.877	–	0.935	0.011	0.950	–	0.646	0.034
Policy rule: lagged interest rate	ψ_i	0.906	0.014	0.902	0.018	0.870	–	0.875	–	0.814	0.028
Policy rule: inflation	ψ_π	1.497	0.094	1.466	0.101	1.427	–	1.361	–	1.642	0.082
Policy rule: output gap	ψ_y	0.522	0.091	0.226	0.087	0.005	–	0.003	–	0.538	0.111
Vol. preference shock	σ_p	0.055	0.008	0.058	0.007	0.116	0.027	0.105	0.017	0.059	–
Vol. productivity shock	σ_a	0.035	0.006	0.054	0.011	0.271	0.095	0.322	0.090	0.020	–
Vol. mon. policy shock (x100)	σ_i	0.228	0.021	0.231	0.025	0.227	0.018	0.222	0.017	0.455	–
Serial-corr. preference shock	ρ_p	0.793	0.036	0.812	0.034	0.688	0.058	0.729	0.046	0.947	–
Serial-corr. productivity shock	ρ_a	0.854	0.035	0.815	0.038	0.532	0.084	0.638	0.061	0.872	–
Serial-corr. mon. policy shock	ρ_i	0.414	0.071	0.466	0.088	0.510	0.073	0.493	0.068	0.356	–
Cross-correlations across countries											
Preference shock- 1/2	$\delta_{p\ 12}$	0.311	0.063	0.303	0.066	0.272	0.064	0.280	0.065	0.674	0.046
Preference shock- 1/3	$\delta_{p\ 13}$	0.166	0.067	0.147	0.069	0.136	0.065	0.112	0.061	0.617	0.063
Preference shock- 2/3	$\delta_{p\ 23}$	0.279	0.071	0.261	0.066	0.190	0.067	0.192	0.066	0.597	0.061
Productivity shock- 1/2	$\delta_{a\ 12}$	0.194	0.067	0.221	0.073	0.161	0.067	0.167	0.072	0.562	0.056
Productivity shock- 1/3	$\delta_{a\ 13}$	− 0.032	0.076	− 0.012	0.068	− 0.006	0.069	0.016	0.071	0.511	0.040
Productivity shock- 2/3	$\delta_{a\ 23}$	0.135	0.075	0.161	0.072	0.187	0.075	0.201	0.071	0.513	0.058
Monetary policy shock- 1/2	$\delta_{i\ 12}$	0.198	0.070	0.211	0.069	0.274	0.066	0.265	0.066	0.608	0.042
Monetary policy shock- 1/3	$\delta_{i\ 13}$	0.124	0.066	0.132	0.069	0.148	0.066	0.144	0.067	0.494	0.059
Monetary policy shock- 2/3	$\delta_{i\ 23}$	0.239	0.069	0.243	0.064	0.226	0.070	0.238	0.067	0.577	0.041

Note: For the cross-correlations, "*i*/*j*" means the correlation between countries *i* and *j*.

probability that rises to somewhat implausible values. In addition, we notice a sharp increase in the volatility of the preference and technology shocks. This result may be interpreted as the sign that the constraints imposed to the model imply a loss of adequacy to the data, so that the hypothesis of policy homogeneity has some undesirable outcomes.

When we jointly assume structural and policy homogeneity, we do not observe significant changes as compared to the model with policy homogeneity. This suggests that combining the two sets of constraints does not imply side effects that would worsen the estimation of structural parameters.

Finally, the *stochastic homogeneity* hypothesis assumes that volatility and serial-correlation parameters are equal across countries. The volatility of preference and technology shocks is not significantly affected, while the volatility of the monetary policy shock increases in Germany and France. In contrast, the preference and technology shocks are more serially correlated under stochastic homogeneity. The main change in the parameter estimates is the large increase in the correlation of shocks across countries. In addition, this hypothesis does not affect the estimation of structural parameters too markedly. Actually, the main change in the parameter estimates is the sharp decrease in the value of the habit parameter that is found to be around 0.5 in Germany and France. Also the Calvo probability decreases slightly in all countries.

3.2. Model evaluation

Now, we adopt the Bayesian econometric procedure proposed by Schorfheide (2000) to compare the performance of (non-nested) DSGE models. First, we use posterior predictive measures and posterior odds as tools to assess the absolute and relative fit of probability models. Second, we evaluate the ability of the competing models to reproduce the cross-covariance functions of the data in using a quadratic loss function. The combination of these various criteria is expected to provide a clear ranking of the structural models under consideration.

For a given structural model $\mathcal{M}_i$, a set of structural parameters Θ, a prior distribution $\Gamma(\Theta|\mathcal{M}_i)$ and a likelihood function $\mathcal{L}(X_T|\Theta,\mathcal{M}_i)$ associated to the observable variables $X_T=\{x_t\}_{t=1}^{T}$, the four main Bayesian criteria are:

(i) the marginal likelihood: $\hat{\mathcal{L}}(X_t|\mathcal{M}_i)=\int_\Theta \mathcal{L}(X_T|\Theta,\mathcal{M}_i)\times\Gamma(\Theta|\mathcal{M}_i)\mathrm{d}\Theta$,
(ii) the Bayes factor: $\mathcal{B}_{i,j}(X_T)=\hat{\mathcal{L}}(X_T|\mathcal{M}_i)/\hat{\mathcal{L}}(X_T|\mathcal{M}_j)$,
(iii) the posterior odds: $\mathcal{PO}_{i,T}=\left[\mathcal{P}_{i,0}\hat{\mathcal{L}}(X_T|\mathcal{M}_i)\right]/[\sum_{j=0}^{m}\mathcal{P}_{j,0}\times\hat{\mathcal{L}}(X_T|\mathcal{M}_j)]$, where $\mathcal{P}_{i,0}$ is the prior probability of model $\mathcal{M}_i$ (with $\sum_{j=0}^{m}\mathcal{P}_{j,0}=1$),
(iv) the quadratic loss function: $L_q(\Lambda,\hat{\Lambda}_i)=(\Lambda,\hat{\Lambda}_i)'W(\Lambda,\hat{\Lambda}_i)$, where Λ denotes the population characteristics, $\hat{\Lambda}_i$ the prediction of model $\mathcal{M}_i$ and W a positive definite weighting matrix (here, the inverse of the covariance matrix of the population characteristics Λ).

As it clearly appears in panel A of Table 2, the complete MCM does not dominate all nested models that allow some homogeneity. This result shows up in the Bayes factors that markedly favor the models with structural and policy homogeneity. The best model among DSGE models corresponds to the case of structural and policy homogeneity, whatever the criterion. On the other hand, the stochastic homogeneity hypothesis is very strongly rejected.

Panel B of Table 2 reports the loss functions evaluated for the cross-covariance functions of all observable variables computed from 1 to 20 quarters. The first row gives the value of the overall loss function and the other rows propose a decomposition by country in order to get a better diagnosis on the ability of the competing models to reproduce the characteristics of the various economies. The model that performs worst is the model with stochastic homogeneity, since it is simply unable to reproduce the cross-covariance functions of the VAR model. Among the other models, the complete MCM does not perform very well. Since this is the less constrained model, this finding suggests that its additional degrees of freedom do not help in reproducing the characteristics of the data. Whereas no improvement is obtained in assuming structural homogeneity, in case of policy homogeneity, one observes a clear improvement, which mainly comes from German cross-covariances and

Table 2
Model evaluation

	Complete MCM	Structural homogeneity	Policy homogeneity	Structural+policy homogeneity	Stochastic homogeneity	VAR(1) model
Panel A: Posterior model probabilities						
Marginal likelihood	3971.93	3985.00	3993.33	4017.55	3819.39	4088.99
Bayes factor	1	473923	2.0E+09	6.5.E+19	5.6.E-67	6.9.E+50
Posterior odds	1.5E-51	6.9E-46	2.9E-42	9.4E-32	8.2E-118	1
Panel B: Loss function based on cross-covariance functions						
Overall	14.79	14.82	12.44	10.61	1661.44	N/A
Germany	3.12	3.46	2.03	1.29	515.91	N/A
France	2.63	2.76	2.66	2.28	77.82	N/A
Italy	0.93	0.58	0.85	0.51	17.75	N/A
Cross-countries	8.11	8.02	6.89	6.53	1049.97	N/A

Note: In panel A, we assign equal prior to the models under consideration. The reference model is a VAR(1). In panel B, the population cross-covariance functions are given by the VAR(1) model.

from the interactions of shocks across countries. The best results are once again obtained for the model with both structural and policy homogeneity, since it yields the lowest loss function for each country.

4. Conclusion

This note investigates the sources of heterogeneity within the euro area. We show that heterogeneity within the euro area mainly comes from stochastic heterogeneity. Our joint modeling of the three economies allows us to be more precise on the source of heterogeneity. Indeed although preference and technology shocks have very similar properties, they are only very weakly correlated across countries. A consequence is that business cycle fluctuations are not likely to be synchronized within the euro area, even between core countries.

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