Interest rates dynamics: Contribution of macroeconomic information in four European markets

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Interest rates dynamics

- Predictive ability in the term structure of interest rates dynamic models;
- Using data from German, English, Spanish and Portuguese public debts, the inflation rate and the annual variation of the industrial production index;
- Results obtained, for the period from January 1990 to December 2012, indicate that the consideration of macroeconomic factors has a positive contribution to the improvement of forecasts for different countries and maturities.

Interest rates dynamics

Dynamic Models
Vasicel (1977), Cox et. al (1985), Duffie and Kan (1996), Ang and Piazzesi (2003)

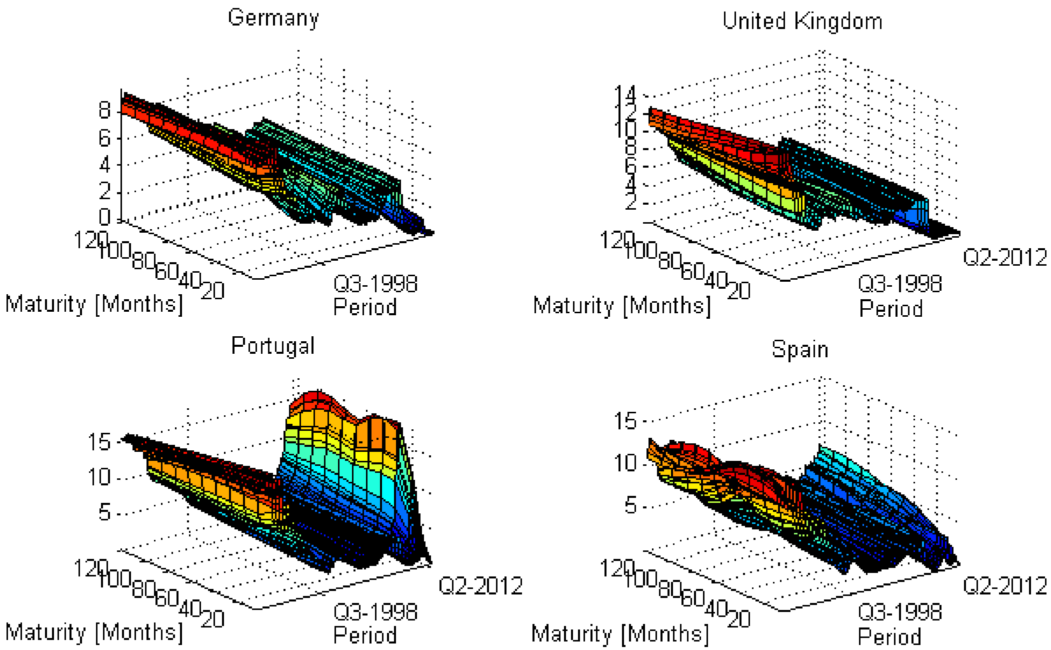
Statistic Models
McCulloch (1971, 1975), Nelson and Siegel (1987), Svensson (1994)

With of macroeconomic variables
Ang and Piazzesi (2003), Diebold at. al (2006), Christensen et. al. (2011)

Data and Methodology

- Public debt interest rates of four European countries: Germany, United Kingdom, Spain and Portugal
- Period: from January 1990 to December 2012
- Monthly observations
- Maturities of 3, 6, 9, 12, 24, 36, 48, 60, 72, 84, 96, 108 and 120 months
- For unobserved maturities, we used the non-parametric interpolation procedure proposed by McCulloch (1971, 1975)
- Macroeconomic variables: consumer price index (CPI) and industrial production index, total industry excluding construction (ICI).

Term structure of Interest Rates



Results

- Adjustment quality
- Out-Off-Sample Predictive Ability
- Contribution of Macroeconomic Variables
- Temporal Evolution of Errors Analysis

Results - adjustment analysis

Estimation and adjustment quality:

- Dynamic Nelson and Siegel model (DNS)
- Affine Dynamic Nelson and Siegel model (ADNS)

- Estimation for the period January 1990 to December 2012, assuming autoregressive specifications of first order, AR(1), and vector autoregressive specifications of first order, VAR(1).

Results - adjustment analysis

Estimation of the DNS-AR(1)

Germany							
	Lt-1	St-1	Ct-1	μ	q	λ	LogL
Lt	0.9912	-	-	0.0507	0.0025	0.051	-14499.1
St	0	0.9134	-	-0.0199	0.0022		
Ct	0	0	0.8904	-0.0101	0.0023		
United Kingdom							
	Lt-1	St-1	Ct-1	μ	q	λ	LogL
Lt	0.9991	0	0	0.0627	0.0022	0.073	-14748.5
St	0	0.9868	0	-0.0197	0.0024		
Ct	0	0	0.9803	-0.0126	0.0024		
Portugal							
	Lt-1	St-1	Ct-1	μ	q	λ	LogL
Lt	0.9988	0	0	0.0597	0.0023	0.06	-12417.1
St	0	0.943	0	-0.0213	0.0025		
Ct	0	0	0.8923	-0.0124	0.003		
Spain							
	Lt-1	St-1	Ct-1	μ	q	λ	LogL
Lt	0.9872	0	0	0.0597	0.0023	0.065	-12825.6
St	0	0.9371	0	-0.0212	0.002		
Ct	0	0	0.896	-0.0126	0.0028		

Table 1 present the transition matrix A, the media vector μ and the q matrix.

Results - adjustment analysis

Estimation of the DNS-VAR(1)

Germany									
	Lt-1	St-1	Ct-1	µ	qL	q_S	q_C	λ	LogL
Lt	0.9859	0.0048	0.0086	0.0951	0.0028	-	-	0.052	-14492.1
St	-0.0077	0.9279	0.0595	0.0444	0.0023	0.00203	-		
Ct	0.0415	0.0512	0.9265	0.3365	0.0026	0.00284	0.00271		
United Kingdom									
	Lt-1	St-1	Ct-1	µ	qL	q_S	q_C	λ	LogL
Lt	0.9997	0.0046	0.0015	0.0646	0.0021	-	-	0.072	-14750.5
St	0.0005	0.969	0.0653	-0.0209	0.002	0.0023	-		
Ct	-0.0067	-0.0864	0.9741	-0.0123	0.0021	0.0022	0.0024		
Portugal									
	Lt-1	St-1	Ct-1	µ	qL	q_S	q_C	λ	LogL
Lt	0.9973	0.0095	0.0094	0.0578	0.003	-	-	0.0672	-12407.3
St	0.0094	0.9261	0.0102	-0.0223	0.0024	0.0018	-		
Ct	0.0104	0.0137	0.9033	-0.0057	0.0049	0.0029	0.0021		
Spain									
	Lt-1	St-1	Ct-1	µ	qL	q_S	q_C	λ	LogL
Lt	0.9862	0.0561	0.0116	0.0635	0.0022	-	-	0.069	-12807.3
St	0.0025	0.9074	0.0495	-0.0275	0.0025	0.0027	-		
Ct	0.0873	-0.0459	0.8947	-0.018	0.0035	0.003	0.0028		

Table 2 present the transition matrix A, the media vector µ and the q matrix.

Results - adjustment analysis

Estimation of the ADNS-AR(1)

Germany									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.1259	-	-	0.061	σ_L	0.005	0	0	0.0681
K_S	-	0.2305	-	-0.0185	σ_S	0	0.0062	0	
K_C	-	-	1.0623	-0.0115	σ_C	0	0	0.0059	
United Kingdom									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.1152	-	-	0.0881	σ_L	0.005	0	0	0.07
K_S	-	0.2726	-	-0.0174	σ_S	0	0.0062	0	
K_C	-	-	1.1602	-0.0092	σ_C	0	0	0.0059	
Portugal									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.0725	-	-	0.0713	σ_L	0.0025	0	0	0.056
K_S	-	0.2605	-	-0.0283	σ_S	0	0.01	0	
K_C	-	-	0.9964	-0.0031	σ_C	0	0	0.0038	
Spain									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.1508	-	-	0.066	σ_L	0.0031	0	0	0.0671
K_S	-	0.1386	-	-0.0252	σ_S	0	0.0063	0	
K_C	-	-	0.876	-0.014	σ_C	0	0	0.0102	

Table 3 presents the estimated parameters for the Kp matrix, θ vector and diagonal diffusion matrix Σ for ADNS model.

Results - adjustment analysis

Estimation of the ADNS-VAR(1)

Germany									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.02765	1.6931	-1.1819	0.0521	σ_L	0.0028			0.057
K_S	-0.491	0.6457	-0.6817	-0.0179	σ_S	0.002	0.0021		
K_C	-0.7436	0.9196	1.2368	-0.0073	σ_C	0.0023	0.0025	0.0027	
United Kingdom									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.1093	-0.2833	0.207	0.0625	σ_L	0.0018			0.083
K_S	-0.0103	0.2979	0.4087	-0.0398	σ_S	0.0022	0.002		
K_C	0.2557	0.0524	1.3231	-0.008	σ_C	0.0024	0.0027	0.003	
Portugal									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.1933	-0.4819	0.1497	0.0972	σ_L	0			0.0565
K_S	0.13	0.2383	-0.8557	0.0115	σ_S	0.0028	0.0028		
K_C	0.3553	1.9332	1.3287	-0.0064	σ_C	0.0026	0.0027	0.0038	
Spain									
K	K_L	K_S	K_C	θ	Σ	σ_L	σ_S	σ_C	λ
K_L	0.1633	-0.2318	0.1097	0.0735	σ_L	0			0.067
K_S	0.1408	0.2873	-0.7507	-0.0375	σ_S	0.0042	0.0025		
K_C	0.2378	1.0335	1.1743	-0.038	σ_C	0.0037	0.0032	0.0027	

Table 4 presents the estimated parameters for the Kp matrix, θ vector and diagonal diffusion matrix Σ for ADNS model.

Results - adjustment analysis

Root mean squared error for Germany, United Kingdom, Portugal and Spain

						Maturity							
Germany	3	6	9	12	24	36	48	60	72	84	96	108	120
DNS-AR(1)	0.2863	0.179	0.1277	0.1087	0.0784	0.0991	0.1187	0.1141	0.0905	0.057	0.0288	0.0504	0.0884
DNS-VAR(1)	0.0672	0.0812	0.1144	0.1287	0.0825	0.0255	0.0471	0.0534	0.0394	0.023	0.0451	0.0809	0.1215
ADNS-AR(1)	0.0908	0.0428	0.0755	0.0914	0.0641	0.0553	0.08000	0.0806	0.0613	0.0342	0.0367	0.0699	0.1086
ADNS-VAR(1)	0.0619	0.0535	0.0878	0.1037	0.0631	0.0321	0.0614	0.0653	0.0476	0.023	0.0369	0.0739	0.1152
United Kingdom	3	6	9	12	24	36	48	60	72	84	96	108	120
DNS-AR(1)	0.2578	0.1508	0.0929	0.0863	0.0749	0.0975	0.1491	0.1831	0.1906	0.1387	0.0686	0.1173	0.2201
DNS-VAR(1)	0.1200	0.0824	0.1200	0.1420	0.1109	0.0577	0.1073	0.1477	0.1604	0.1135	0.0648	0.1374	0.2388
ADNS-AR(1)	0.1597	0.0784	0.0987	0.1252	0.1044	0.0800	0.1276	0.1646	0.1746	0.1275	0.0766	0.1343	0.2335
ADNS-VAR(1)	0.1223	0.0957	0.133	0.1539	0.1222	0.0633	0.1067	0.1453	0.1571	0.1100	0.0674	0.1437	0.2448
Portugal	3	6	9	12	24	36	48	60	72	84	96	108	120
DNS-AR(1)	0.2247	0.1596	0.1302	0.111	0.1497	0.1753	0.2393	0.2819	0.2555	0.2772	0.1704	0.0964	0.2453
DNS-VAR(1)	0.2556	0.2036	0.1098	0.0890	0.2081	0.1411	0.1409	0.1689	0.1514	0.1837	0.1650	0.1983	0.3251
ADNS-AR(1)	0.1576	0.0350	0.0853	0.1174	0.1830	0.1195	0.1689	0.2045	0.1959	0.2282	0.1447	0.1288	0.3017
ADNS-VAR(1)	0.1296	0.0436	0.1221	0.1577	0.2021	0.1243	0.1735	0.2224	0.1919	0.2031	0.1739	0.2026	0.3650
Spain	3	6	9	12	24	36	48	60	72	84	96	108	120
DNS-AR(1)	0.3217	0.1985	0.1968	0.2154	0.2511	0.3442	0.4378	0.3623	0.2464	0.2084	0.1535	0.115	0.3567
DNS-VAR(1)	0.1388	0.0796	0.1423	0.1744	0.116	0.2507	0.385	0.3307	0.2465	0.2232	0.1659	0.1056	0.3379
ADNS-AR(1)	0.1385	0.0794	0.1424	0.1745	0.1159	0.2505	0.3848	0.3306	0.2465	0.2233	0.1659	0.1057	0.3379
ADNS-VAR(1)	0.1895	0.0796	0.1296	0.1716	0.1054	0.2119	0.3558	0.3128	0.2407	0.2214	0.1672	0.1103	0.3437

Table 5 shows the RMSE for the estimation of Diebold-Li models with autoregressive first-order process DNS-AR(1), with vector autoregressive first-order process, DNS-VAR(1), and also for the affine models ADNS-AR(1) and ADNS-VAR(1).

Results - adjustment analysis

- The degree of adjustment between the observed rates and estimated rates **is generally high** for the different models.

- The estimation results shows that **none of the models analyzed** seems to be **clearly superior** to the others in terms of adjustment.

- The adjustment analysis allows us to state that, as regards the temporal dimension, DNS and ADNS models, have a **good adjustment** in **market stability phases**, however, in periods of high volatility the adjustment quality decreases considerably.

Results – out off sample predictive ability

- The data set was divided into **two subsets**:
  - an initial, January 1990 to December 2002 used for the initial estimation
  - and a second subset, January 2003 to December 2012, used for forecasting
- Methodology based on the rolling windows method with 120 observations
- Prediction horizons set: h = 1, 3, 6, 9, 12, 15 and 18 months
- For the 13 maturities estimated (3, 6, 9, 12, 24, 36, 48, 60, 72, 84, 96, 108 and 120 months) was determined the RMSE as well as the ratio RMSE and RMSE of the random walk model (RW).

Results – out off sample predictive ability

Root mean squared error, Germany

							Maturity						
A) RW	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	0.23	0.216	0.209	0.207	0.227	0.235	0.231	0.224	0.217	0.211	0.208	0.204	0.203
h=3	0.475	0.476	0.479	0.482	0.493	0.484	0.461	0.437	0.414	0.395	0.38	0.366	0.357
h=6	0.775	0.78	0.783	0.786	0.772	0.74	0.702	0.665	0.629	0.598	0.573	0.551	0.534
h=9	1.002	1.001	0.998	0.993	0.935	0.875	0.821	0.773	0.73	0.693	0.661	0.636	0.616
h=12	1.217	1.211	1.201	1.186	1.077	0.983	0.912	0.856	0.809	0.769	0.735	0.708	0.686
h=15	1.419	1.41	1.396	1.375	1.231	1.109	1.021	0.955	0.902	0.859	0.825	0.797	0.775
h=18	1.6	1.591	1.576	1.554	1.395	1.251	1.143	1.062	0.999	0.949	0.909	0.878	0.853
B) DNS-AR(1)	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	0.273	0.218	0.209	0.213	0.225	0.247	0.27	0.271	0.252	0.227	0.208	0.207	0.224
h=3	0.507	0.477	0.474	0.476	0.486	0.49	0.489	0.474	0.444	0.41	0.38	0.359	0.35
h=6	0.801	0.78	0.775	0.774	0.763	0.746	0.727	0.699	0.66	0.616	0.574	0.538	0.512
h=9	1.029	1	0.985	0.975	0.924	0.884	0.851	0.813	0.766	0.714	0.662	0.618	0.581
h=12	1.245	1.209	1.184	1.162	1.064	0.996	0.948	0.902	0.849	0.792	0.736	0.686	0.643
h=15	1.445	1.406	1.376	1.347	1.217	1.124	1.061	1.005	0.945	0.884	0.824	0.771	0.724
h=18	1.621	1.586	1.556	1.526	1.379	1.264	1.183	1.112	1.043	0.974	0.907	0.848	0.797
C) DNS-VAR(1)	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	0.25	0.215	0.219	0.226	0.231	0.242	0.261	0.262	0.245	0.222	0.207	0.208	0.228
h=3	0.495	0.477	0.479	0.484	0.491	0.489	0.485	0.468	0.439	0.407	0.377	0.358	0.351
h=6	0.794	0.78	0.78	0.781	0.767	0.746	0.724	0.695	0.655	0.612	0.57	0.536	0.51
h=9	1.018	0.996	0.985	0.976	0.925	0.882	0.847	0.808	0.76	0.709	0.658	0.614	0.577
h=12	1.232	1.201	1.18	1.161	1.064	0.993	0.943	0.896	0.843	0.786	0.73	0.681	0.638
h=15	1.433	1.399	1.372	1.346	1.217	1.121	1.056	0.999	0.939	0.878	0.818	0.765	0.718
h=18	1.613	1.582	1.556	1.528	1.382	1.264	1.179	1.107	1.037	0.968	0.901	0.842	0.79

Table 6 presents in three panels the RMSE for Germany, for out-of-sample forecasts of RW model (Panel A), Latent Factor Model DNS-AR(1) (Panel B) and Latent Factor Model DNS-VAR(1) (Panel C). In all cases, the forecasts were made for the period between 01: 2003 and 12:2012. The forecasts were made for the maturities of 3, 6, 9, 12, 24, 36, 48, 60, 72, 84, 96, 108 and 120 months, and for forecast horizons of 1 to 18 months (h=1, h=3, h=6, h=9, h=12, h= 15 and h=18).

Results – out off sample predictive ability

Root mean squared error ratio for DNS-AR and DNS-VAR models, Germany

						Maturity							
A) RMSE[DNS-AR(1)]/RMSE[RW]													
	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	1.189	1.01	1.003	1.028	0.994*	1.05	1.167	1.208	1.161	1.072	1.002	1.012	1.105
h=3	1.066	1.002	0.989*	0.988*	0.986*	1.013	1.06	1.083	1.073	1.039	1	0.979*	0.982*
h=6	1.034	1	0.989*	0.986*	0.988*	1.007	1.036	1.052	1.049	1.029	1.002	0.977*	0.959*
h=9	1.028	0.999*	0.987*	0.982*	0.989*	1.01	1.037	1.052	1.049	1.03	1.002	0.971*	0.943*
h=12	1.023	0.998*	0.986*	0.980*	0.988*	1.012	1.039	1.054	1.05	1.03	1.001	0.968*	0.937*
h=15	1.018	0.997*	0.986*	0.980*	0.989*	1.013	1.04	1.053	1.048	1.029	0.999*	0.966*	0.934*
h=18	1.013	0.997*	0.987*	0.982*	0.989*	1.011	1.035	1.047	1.044	1.026	0.998*	0.966*	0.934*
B) RMSE[DNS-VAR(1)]/RMSE[RW]													
	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	1.088	0.997*	1.05	1.095	1.017	1.027	1.128	1.169	1.127	1.049	0.993*	1.018	1.123
h=3	1.042	1.001	1.000*	1.003	0.995*	1.01	1.05	1.071	1.061	1.03	0.994*	0.977*	0.983*
h=6	1.025	1.001	0.995*	0.994*	0.993*	1.007	1.032	1.045	1.042	1.022	0.996*	0.972*	0.956*
h=9	1.017	0.994*	0.986*	0.983*	0.990*	1.008	1.032	1.045	1.042	1.023	0.994*	0.964*	0.937*
h=12	1.012	0.992*	0.982*	0.978*	0.988*	1.009	1.034	1.047	1.042	1.023	0.993*	0.961*	0.930*
h=15	1.01	0.992*	0.983*	0.979*	0.988*	1.011	1.035	1.047	1.041	1.021	0.992*	0.959*	0.927*
h=18	1.008	0.995*	0.987*	0.983*	0.991*	1.01	1.032	1.043	1.038	1.02	0.991*	0.959*	0.927*

Table 7 presents in two panels the RMSE ratio for Germany, for out-of-sample forecasts, for the autoregressive of first order process AR (1) in latent factors model (DNS) (Panel A) and for the vector autoregressive of first order process VAR (1) in latent factors model (DNS) (Panel B). The values marked with the symbol * correspond to the forecast horizons (h) and maturities for which the models show a superior performance. The forecasts in all cases presented were made for the period between 01:2003 and 12:2012. The forecasts were made for the maturities of 3, 6, 9, 12, 24, 36, 48, 60, 72, 84, 96, 108 and 120 months and for forecast horizons of 1 to 18 months (h=1, h=3, h=6, h=9, h=12, h=15 and h=18).

Results – out off sample predictive ability

- In general, the results obtained for the forecasts out of sample, indicate a superiority of the and VAR (1) models relative to the AR (1) model.

- The VAR model (1) performs well in terms of forecasting, however, is not systematically superior to RW model in all maturities.

- In our case, grouping the performance indicators for short-term maturities (3 to 12 months), medium term (24 to 60 months) and long term (72 to 120 months) we note that as the forecasting horizon increases, the relative performance of VAR (1) models also increases.

Results – contribution of macroeconomic variables

- In order to assess the impact of the introduction of macroeconomic variables in the dynamic models, we added to the state vector of the first order VAR(1) model two macroeconomic variables, representing:

  - inflation rate π_t
  - annual change in the industrial production index $\Delta\ IPI_t$

Results – contribution of macroeconomic variables

Root mean squared error of DNS-VAR models with Macroeconomic Factors, Germany

							Maturity						
DNS-VAR(1)													
	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	0.247	0.21	0.214	0.222	0.231	0.237	0.25	0.249	0.232	0.213	0.204	0.212	0.236
h=3	0.483	0.46	0.46	0.464	0.475	0.474	0.468	0.451	0.423	0.392	0.366	0.351	0.347
h=6	0.777	0.759	0.755	0.755	0.743	0.724	0.702	0.673	0.634	0.592	0.553	0.521	0.498
h=9	1.001	0.975	0.962	0.952	0.901	0.858	0.823	0.784	0.737	0.686	0.637	0.595	0.56
h=12	1.215	1.182	1.159	1.139	1.04	0.968	0.918	0.871	0.819	0.763	0.708	0.66	0.619
h=15	1.416	1.381	1.353	1.325	1.193	1.096	1.031	0.973	0.914	0.853	0.794	0.742	0.697
h=18	1.596	1.565	1.538	1.51	1.362	1.241	1.155	1.081	1.011	0.941	0.875	0.817	0.766

Table 8 presents the RMSE for Germany, for the out-of-sample forecasts of the vector autoregressive of first order process VAR (1) for the latent factors model (DNS) with macroeconomic variables. In all cases presented the forecasts were carried out for the period from 1:2003 to 12:2012. The forecasts were made for the maturities of 3, 6, 9, 12, 24, 36, 48, 60, 72, 84, 96 108 and 120 months, and for forecast horizons of 1 to 18 months (h=1, h=3, h=6, h=9, h=12, h=15 and h=18).

Results – contribution of macroeconomic variables

Root mean squared error ratio of the DNS-VAR model with Macroeconomic Factors, Germany

							Maturity						
RMSE[DNS-VAR(1)]/RMSE[RW]													
	3	6	9	12	24	36	48	60	72	84	96	108	120
h=1	1.077	0.974*	1.026	1.075	1.019	1.007	1.081	1.109	1.07	1.008	0.981*	1.037	1.165
h=3	1.016	0.966*	0.961*	0.963*	0.963*	0.979*	1.014	1.032	1.022	0.994*	0.965*	0.957*	0.974*
h=6	1.003	0.973*	0.964*	0.961*	0.963*	0.977*	1.001	1.013	1.009	0.990*	0.965*	0.945*	0.932*
h=9	1.000*	0.974*	0.963*	0.959*	0.964*	0.980*	1.002	1.014	1.01	0.991*	0.963*	0.935*	0.910*
h=12	0.998*	0.976*	0.965*	0.960*	0.966*	0.985*	1.007	1.018	1.012	0.992*	0.963*	0.931*	0.901*
h=15	0.998*	0.979*	0.969*	0.964*	0.969*	0.989*	1.01	1.02	1.013	0.993*	0.963*	0.931*	0.900*
h=18	0.998*	0.984*	0.976*	0.972*	0.976*	0.992*	1.01	1.019	1.012	0.992*	0.963*	0.931*	0.899*

Table 9 shows the RMSE ratio for Germany, for the out-of-sample predictions of the vector autoregressive first order VAR (1) for latent factors model (DNS) and macroeconomic variables. The values marked with the symbol * correspond to the forecast horizons (h) and maturities for which the models perform better. The predictions in all cases were carried out for the period from 1:2003 to 12:2012. The forecasts were made for the maturities of 3, 6, 9, 12, 24, 36, 48, 60, 72, 84, 96, 108 and 120 months, and for forecast horizons of 1 to 18 months (h=1, h=3, h=6, h=9, h=12, h=15 and h=18).

Results – contribution of macroeconomic variables

- The results obtained point to an improvement in the forecast ability for the dynamic Nelson and Siegel model after the incorporation of macroeconomic variables.

- As can be seen by the RMSE for most of the maturities and forecast horizons, macroeconomic information contributes positively to the predictive ability of the model, in the case of Germany (Table 8), UK, Spain and Portugal.

- The positive contribution of the inclusion of macroeconomic data is also reflected in an improvement of the RMSE of the models compared to the RMSE of the random walk model.

Results – contribution of macroeconomic variables

- Even if, in many cases, the RW model continue to provide a superior foresight, the model VAR(1) considering the two mentioned macroeconomic factors, performs better for short maturities in the United Kingdom, and short maturities as well as for long maturities in the case of Germany, Spain and Portugal.

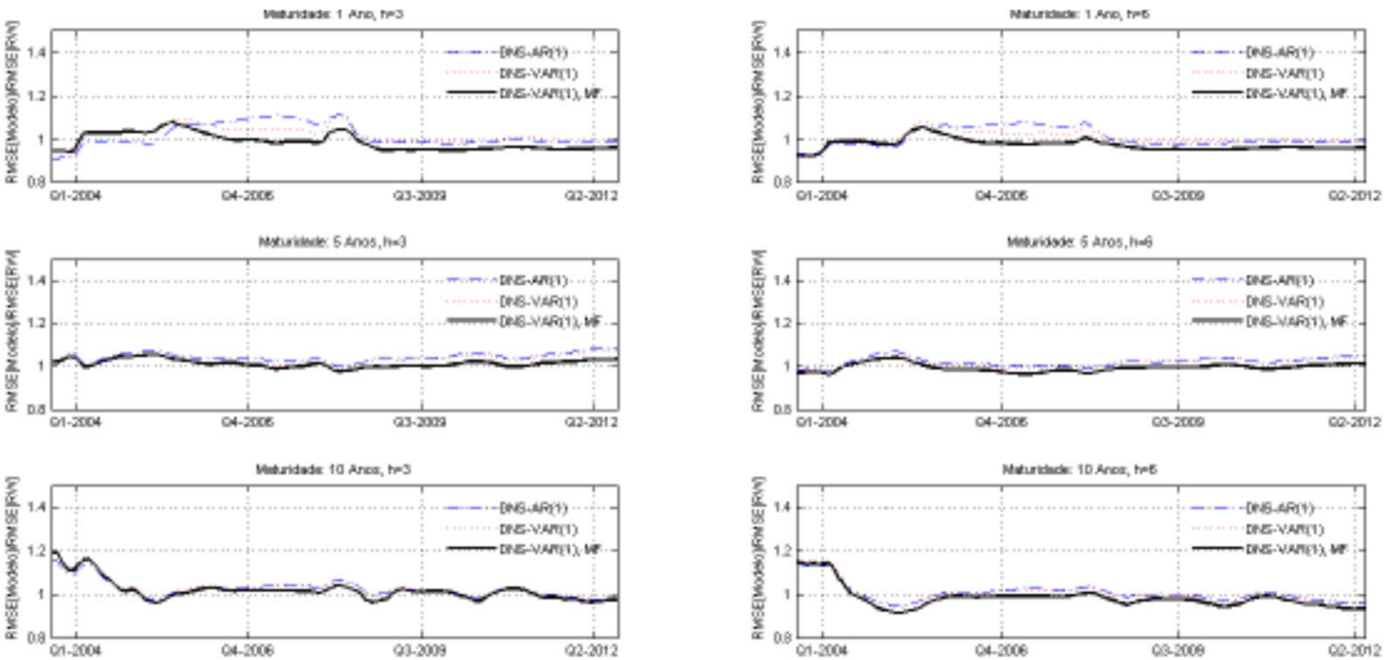
- These results reinforce the current assumption in literature that the incorporation of macroeconomic information has a clear contribution to the improvement of forecasting ability.

Results – temporal evolution of errors analysis

- In order to analyze the evolution of the model's performance compared to models that do not include macroeconomic data, we study the evolution of the RMSE for the latent factors models (DNS) compared to the RMSE of the random walk model for the autoregressive of first order process (DNS-AR(1)), the vector autoregressive of first order process (DNS-VAR(1)) and the autoregressive of first order process, incorporating macroeconomic factors (DNS-VAR(1)MF).
- The data are for the period from January 2003 to December 2012, and for maturities of 1, 5 and 10 years and forecasting horizons 3 and 6 months.

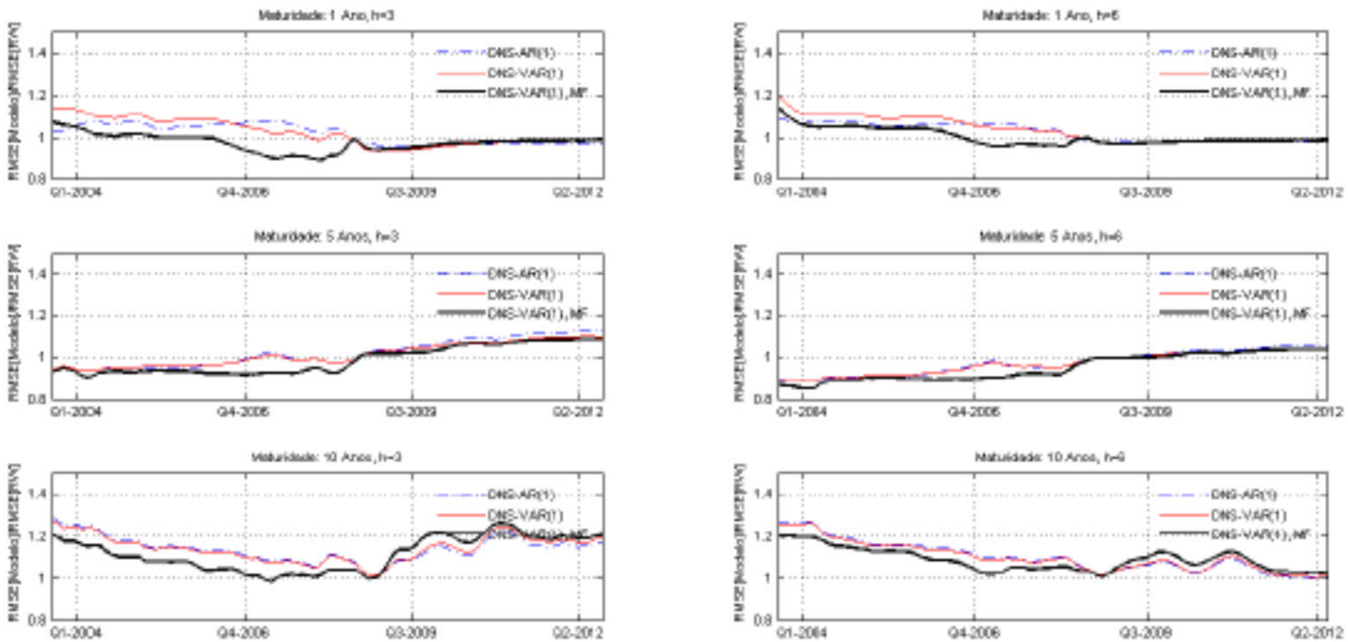
Results – temporal evolution of errors analysis

Germany – Root mean squared error ratio evolution



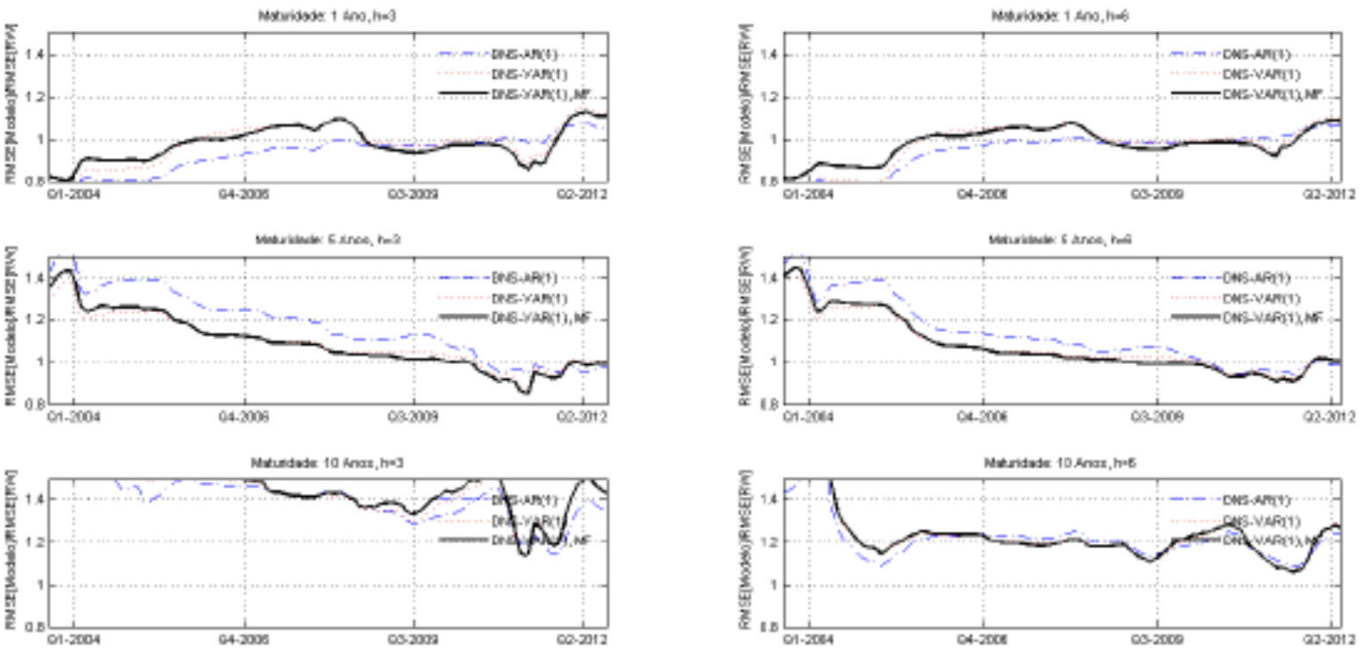
Results – temporal evolution of errors analysis

United Kingdom – Root mean squared error ratio evolution



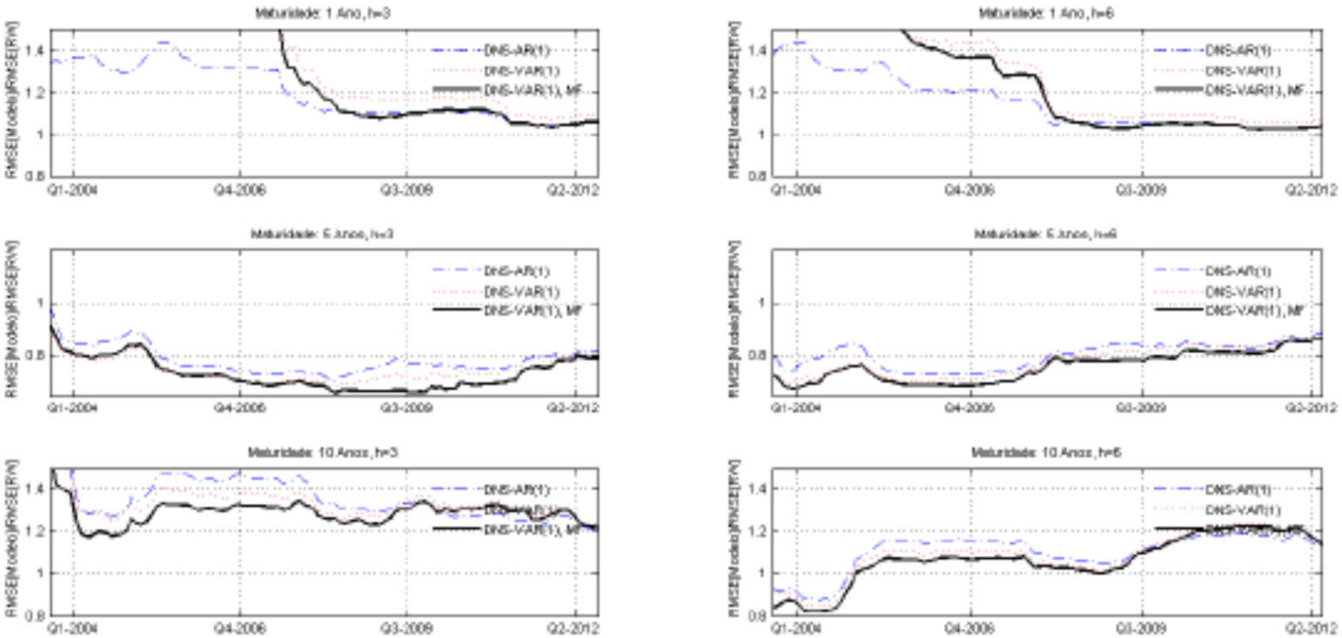
Results – temporal evolution of errors analysis

Portugal – Root mean squared error ratio evolution



Results – temporal evolution of errors analysis

Spain – Root mean squared error ratio evolution



Results – temporal evolution of errors analysis

- As we have seen by examining the Figures 2 to 5, for maturities of 1, 5 and 10 years and prediction horizons of 3 and 6 months, the performance of AR(1), VAR(1) and VAR(1)MF models varies over January 2003 to December 2012.
- The analysis of the evolution of RMSE series allows us to conclude that, in general, the inclusion of macroeconomic data in dynamic models, namely information on the inflation rate and the annual change in the industrial production index, improves its relative performance, which can be seen through the evolution of the RMSE series of the model with best performance, the dynamic model with macroeconomic variables DNS-VAR(1)MF.

Conclusion

- We find that, for the countries under study, for the period considered and for the dynamic specification of these factors, there is a superiority of the results obtained for the RW and VAR(1) models when compared whit the AR(1) model. The VAR(l) model performs well in terms of prediction, however this is not systematically higher than the RW model in all maturities.
- The inclusion of macroeconomic variables representative of inflation and the annual growth of industrial production index shows a positive contribution to the forecasts improvement, for the 4 countries analyzed, for all maturities and for all forecast horizons.
- Even if, in many cases, the RW model continue to provide a superior foresight, the model VAR(l) considering these two macroeconomic factors, performs better for short maturities in the United Kingdom and for short maturities and long maturities in the case of Germany, Spain and Portugal.