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Determinants of sovereign yield spreads in the Eurozone: A Bayesian approach

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A B S T R A C T

We analyze the determinants of sovereign yields spreads of EMU member states applying Bayesian Model Averaging (BMA) to annual panel data from 1999 to 2009. BMA is well-suited in cases of small samples and high model uncertainty. This seems to be the case in modeling sovereign yield spreads in the Eurozone since the literature reports heterogeneous results with respect to significant explanatory variables. We are testing a number of variables reported to be significant in the literature and find that the most likely country specific drivers of yield spreads are fiscal variables such as budget balance and government debt, as well as external sector variables, such as terms of trade, trade balance and openness. Global financing conditions, indicated by the US interest rate, and market sentiments, indicated by corporate bond spreads, are likely to influence sovereign yield spreads.

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1. Introduction

The paper aims to provide answers to the question of what drives sovereign yield spreads of EMU countries' government bonds, which is an important issue in the current political debate about the further development and even the survival of the Euro and the Eurozone. We analyze potential determinants of sovereign yield spreads of EMU member states (to German bond yields) observed on secondary bond markets. These yield spreads result from several reasons. Apart from default risk, the yield spreads are influenced by liquidity risk and market sentiments toward investments in risky bonds. We examine the relation between spreads and several variables related to these causes using

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Bayesian Model Averaging (BMA). We particularly focus on the default risk component and test a variety of variables related to this issue, however, we also control for the other issues. Identifying the determinants of sovereign yield spreads is an important research question because it helps to understand which factors determine countries' capital costs. For example, we can analyze whether interest rates paid for borrowing capital depend on countries' fiscal discipline, (certain drivers of the) competitiveness of the economy, global financing conditions or even market sentiments.

A broad and interesting literature exists that deals with determinants of sovereign bond yield spreads. However, the results of these studies are rather heterogeneous, i.e. different papers report different variables as the main drivers of spreads.[1] This may be due to differences in econometric models, country samples, observation periods and variables considered. Edwards (1986), Eichengreen and Mody (1998), Kamin and von Kleist (1999), and Min (1998), e.g., consider *primary* (market) spreads of several *developing countries*, i.e. spreads observed when bonds are issued. Arora and Cerisola (2001) perform individual regressions for time series of *secondary market spreads* of observed countries, whereas Cantor and Packer (1996) consider cross-section data. Examples of papers that employ panel data on developing countries' secondary market yield spreads are: Baldacci et al. (2008), Dailami et al. (2005), Hilscher and Nosbusch (2010), and Rowland and Torres (2004).

While the studies mentioned so far exemplify the bulk literature where the determinants of yield spreads for developing countries are estimated, several papers consider the spreads for *developed countries*. Bernoth et al. (2006) provide a detailed literature review of OECD countries in general and Gale and Orszag (2002) of the US in particular. Examples for other papers dealing with the US are Gale and Orszag (2004), Laubach (2003), and Poterba and Rueben (1999). OECD countries are considered, e.g., in Alesina et al. (1992), and Ardagna et al. (2004).

A number of papers analyze yield spreads of *EU government bonds*. They report some similar but also some very different results. Bernoth et al. (2006) report debt to GDP, deficit to GDP, debt service to revenues, US corporate bond spreads, a EMU dummy, the short-term US rate, as well as liquidity and maturity of the issue as significant. Schuknecht et al. (2009) identify debt to GDP, fiscal balance to GDP, US corporate bond spreads, region dummies, liquidity and maturity of the issue and the short-term US rate as significant determinants of sovereign yield spreads. Schuknecht et al. (2009) confirm these results, but in addition, they find crises and turmoil dummies to be significant. Whereas these papers consider spreads observed for single bond issues, others, such as Codogno et al. (2003), Lemmen and Goodhart (1999), and Manganelli and Wolswijk (2007), use data for a benchmark curve that is related to a fixed maturity, usually a time to maturity of 10 years is considered. Lemmen and Goodhart (1999) report the debt to GDP ratio, capacity to acquire taxes, inflation, and inflation variability to be significant spread drivers. Codogno et al. (2003) only find debt to GDP ratio, US swap spread and US corporate bond spreads significant. Manganelli and Wolswijk (2007) only report ratings and short-term interest rates as significant spread drivers. The literature reviewed so far provides interesting insights into drivers of yield spreads. However, the results are rather heterogeneous, not only for different samples, but even for rather similar samples, such as the Eurozone countries, which a comparison of results from Lemmen and Goodhart (1999) with those of Bernoth et al. (2006), for example, shows. To some extent, these differences may be a result of different observation periods.[2] Another reason could be, however, that papers in the literature also differ considerably with respect to tested variables.

The fact that there is no consensus about the key determinants of sovereign yield spreads may be seen as indication for high uncertainty about the "true" empirical model. One appropriate approach to deal with this model uncertainty is Bayesian Model Averaging (BMA). It explicitly accounts for the high model uncertainty by considering (approximately) the entire model space, i.e. any possible combination of regressors out of a given set of potential determinants. In classical statistics, by contrast, the

[1] The considered sample and results with respect to significant determinants of the papers discussed here are presented in detail in Table A-1 and A-2 in the appendix.

[2] In fact, an interesting new strand of the literature analyzes changes in the influence of explaining variables over time. Bernoth and Erdogan (2010) provide an overview on this literature and tackle the issue by applying a semi-parametric time-varying coefficient model.

conclusions are based on just one model (or a small sample of models). Often only a small set of potentially explaining variables is even tested (see the discussion above) or smaller models out of a comprehensive sample are selected using heuristics. However, model selection is problematic given the size of the potential model space and, what is more, information from almost all possible models is neglected. Even testing the full model does not solve this issue due to the multi-co-linearity problem, which in particular implies that we may reject variables by mistake. This is particularly an issue for small samples as it is the case in the EMU sample. By considering the entire model space BMA is supposed to provide more solid information about the determinants of spreads than classical regressions.

BMA is applied successfully to various other topics. Examples are economic growth (see, e.g., Eicher et al., 2007; Fernandez et al., 2001b; Masanjala and Papageorgiou, 2008, Sala-i-Martin et al., 2004), monetary policy (see, e.g., Hineline, 2007, and Milani, 2008), the relationship between consumption and wealth (see, e.g., Koop et al., 2008), and pricing of stocks (see, e.g., Avramov, 2002, and Cremers, 2002) or hedge funds (see Vrontos et al., 2008). We contribute to the literature by applying BMA to the issue of sovereign yield spreads in the member states of the Eurozone. We test a number of hypotheses on causes of these spreads and include related variables reported to be significant in the literature in our analysis.

In the next section we overview the BMA approach. In Section 3, we formulate the hypothesis with respect to causation of yield spreads tested in our empirical analysis and discuss the variables used to indicate these hypotheses. Section 4 deals with the setting of our empirical analysis and discusses the results. Section 5 concludes.

2. Bayesian Model Averaging (BMA) in a nutshell

The literature based on a classical regression framework provides interesting results and insights into the causes of yield spreads. We complement this literature by applying Bayesian Model Averaging (BMA). In relation to classical regressions, BMA has some advantages as well as some disadvantages. So, one could state that there is no silver bullet to tackle the issue, but applying BMA enables us to provide additional and in some sense broader information and avoids some drawbacks of classical regressions, which comes at the cost of accepting the assumptions and drawbacks of BMA. To some extent we test the results provided so far since we include various variables which have been included in several papers but have not been tested jointly.

The Bayesian approach interprets the concept of probability as a measure of the state of knowledge. Thereby it is acknowledged that there exists uncertainty about the 'true' empirical model, whereby the term model refers to a possible combination of variables determining the dependent variable. In a linear regression framework as given by Eq. (1) with a given set of k variables that are potentially determinants of the dependent variable 2^k different combinations, i.e. models, are possible. BMA determines the most likely models by considering the whole model space, given by all possible combination of potential determinants of the dependent variable. What is more, it helps to identify the variables which are most likely to determine the dependent variable by estimating the probability of inclusion (in the true model) for each regressor.

One could argue that this problem could be solved by simply estimating the full model containing all possible independent variables. However, in the application of regression models often the problem arises that the results are not robust to alternative model specifications. This means deleting (or including) specific variables turns others to be significant (insignificant), an issue related to co-linearity between the regressors. This is a severe problem, in particular, if the sample is small and the number of observations is low compared to the number of regressors. Researches following a non Bayesian approach deal with this problem by applying several schemes for model selection (see Sala-i-Martin, 1997). These approaches have rather weak statistical foundation since the classical frequent econometrics does not treat models itself as uncertain.

The BMA approach, by contrast, is more comprehensive since information from the entire model space is included in the model selection procedure, which has a sound statistical foundation. Instead of a single model, a ranking of the best models is provided. It depends on the posterior probability of each model, i.e. the probability that a model with given specifications fits the data the best.

Based on the probability of inclusion (in the true model) the importance of single regressors can be evaluated and ranked as well. Here a second major advantage of BMA applies: The information about single regressors is based on information about the entire model space in contrast to the results for one single model considered in frequent statistics. Thus, instead of the measures used in classical statistics, alternative measures are used to judge the quality of a regressor. In particular, we consider the (marginal posterior) probability of inclusion. Its calculation and the BMA methodology is explained in more detail in the following.

We consider the following OLS setting:[3]

$$y = \alpha\iota + X_j\beta_j + \sigma\varepsilon, \tag{1}$$

where y denotes the vector of the observations of the dependent variable, α the regression constant (multiplied with a vector of ones ι) and X the n x k matrix of the k independent variables and n observations, $\beta_j \in \Re^{k_j} (0 \le k_j \le k)$ denotes the regression coefficients and $\sigma \in \Re_+$ is a scale parameter. The vector of the residuals, ε, is assumed to have a multivariate normal distribution, with mean μ and covariance matrix Σ. Alternatively to the full model, which includes all potentially explaining variables, Eq. (1) can also be used to describe regressions for any subset j of all k potential explaining variables that are taken into consideration. For k potential independent variables 2^k models can be formulated.

The Bayesian view of probability as a measure of the state of knowledge implies a step wise updating of the probability measures in Bayesian techniques. In each step a-priori information is included in the estimation. Also the application of BMA requires the specification of prior distributions. This can be seen as point of criticism for several reasons. Of course, the assumptions concerning the prior distribution influence the outcome of the estimation which means that the results do not follow solely from the data.[4] In addition such prior information must be available, which often is not the case.

However, even if no a-priori information is available or the researcher does not want to include a-priori information, BMA can be applied. In this case, so-called non informative priors have to be used. In this paper, we adopt a prior structure developed by Fernandez, Ley and Steel (FLS henceforth) (2001a).[5] Here a g-prior (proposed by Zellner, 1986) structure is used, which can be represented by the product of:

$$p(\alpha, \sigma) \propto \sigma^{-1} \tag{2}$$

and

$$p(\beta_j|\alpha, \sigma, M_j) = f_N^{k_j}\left(\beta_j|0, \sigma^2\left(gX_j'X_j\right)^{-1}\right). \tag{3}$$

$f_N^q(w|m, V)$ represents the density function of a q-dimensional Gaussian distribution of w, with mean m and covariance matrix V, and M_j is the model with a subset of j regressors. Since the mean is assumed to be zero we include no a-priori information regarding the sign of the considered explaining variables, i.e. whether the direction of influence is positive or negative. By performing empirical simulations regarding the choice of g in Eq. (3), FLS (2001a) find that assuming $g = 1/\max\{n, k^2\}$ yields robust results.

We also have to specify a-priori information about the probability of inclusion which is related to the a-priori distribution over the model space:

$$P(M_j) = p_j, j = 1, \ldots, 2^k, with \quad pj > 0 \quad and \quad \sum_{j=1}^{2^k} p_j = 1 \tag{4}$$

A natural choice in this respect seems to be the uniform distribution over the model space. To put it simple, the a-priori probability of including a potential candidate variable in the model is 50%. This

[3] Our description of BMA is oriented on Fernandez et al. (2001b).
[4] For further discussion of the impact of prior distributions on the outcomes see Kass and Raftery (1995), and George (1999).
[5] See also FLS 2001b for a detailed discussion of the influence of their non informative priors on the results.

means, we assume the same probability for inclusion as for exclusion and we assume to be equally uncertain about the inclusion of any of the potential explaining variables.

The assessment of a specific quantity of interest, lets say a potential regressor, in the BMA approach is based on the general idea that information of all possible models is considered by averaging the results obtained for specific models with a posterior probability greater than zero. Thereby, these model probabilities are used as weights. The following formula is used:

$$P_{\Delta|y} = \sum_{j=1}^{2^k} P_{\Delta|y,M_j} P(M_j|y) \tag{5}$$

The probability, $P_{\Delta|y}$, of a certain quantity, Δ, let's say some regressor out of the set of potential regressors, results from calculating the weighted average of the specific likelihoods of inclusion, $P_{\Delta|y,M_j}$, in each of the 2^k potential models, M_j, given the specific model and the data. As weights, we use the posterior probabilities, $P(M_j|y)$, of the considered models, M_j, given the data. This model probability follows from dividing the likelihood of this specific model by the sum of the likelihood of all models in the model space:

$$P(M_j|y) = \frac{\ell_y(M_j)p_j}{\sum_{h=1}^{2^k} \ell(M_h)p_h}, \tag{6}$$

where $\ell_y(M_j)$ is the marginal likelihood of model M_j, which follows by:

$$\ell_y(M_j) = \int p(y|\alpha,\beta_j,\sigma,M_j)p(\alpha,\sigma)p(\beta_j|\alpha,\sigma,M_j)d\alpha d\beta_j d\sigma. \tag{7}$$

Here, $p(y|\alpha,\beta_j,\sigma,M_j)$ represents the probability of a model, and $p(\alpha,\sigma)$ and $p(\beta_j|\alpha,\sigma,M_j)$ are the priors described in (2) and (3) respectively.

In applying BMA we estimate any possible model, and calculate, on the one hand, the corresponding likelihood values and, on the other, the probability values of each regressor that is part of the model. In a second step, we assess the "quality" of each model, i.e. estimate the model probability according to Eq. (6). In the third step, we estimate the posterior probability of each regressor using Eq. (5).

In a similar way, one can infer information on other quantities of interest. The average value of the regression coefficient β_i related to a regressor, x_i, for example, can be calculated by averaging all coefficients estimated for specific models and using the respective model probabilities as weights. The sign of the average regressor is of special interest since it hints the direction of influence.

Even with modern computers, it is hard or even impossible to estimate all 2^k potential models if the number of regressors is large. Thus, in practical applications the model space is searched approximately. We do this by applying the MC^3-Sampler (Markov Chain Monte Carlo Model Composition) of Madigan and York (1995).

3. Hypotheses and variables

In this section, we discuss our hypotheses on determinants of sovereign yield spreads and the variables used to test the significance of these hypotheses in the case of the EMU member states in recent years. The hypotheses and the variables used may be seen as overlap of findings in the literature, i.e. we include variables that were found to be significant in other papers.

An important determinant of sovereign yield spreads found to be significant in several important studies is the countries' *budget balance in relation to GDP*. It plays the most prominent role (mostly in terms of deficit to GDP) in public discussion and is named in the Maastricht Treaty as important stability criterion that EMU countries are required to fulfill. A negative budget balance (deficit) is supposed to lead to higher market perception of default risk and, thus, to higher yield spreads, e.g., since it points to problems in financing the government's budget by taxes, which in turn may result from a weak tax system or a weak state of the economy.

Another important variable found to be significant in a multitude of papers and also named as stability criterion in the Maastricht Treaty is *total government debt (to GDP)*. This variable reflects the hypothesis that higher indebtedness increases *ceteris paribus* the default risk and therefore yield spreads. This is the case because higher indebtedness means the country must spend more funds for debt servicing. For higher debt service payments the requirements on ability and willingness to pay are higher, and thus a default is more likely.

Besides the total amount of outstanding debt, the interest rate costs also may have an influence on spreads. We use the *average interest rate* paid on all outstanding debt as an indicator for interest rate costs. It is not to be confused with the bond yields observed on secondary markets. This average interest rate results from the contractual conditions (loan interest and coupon payments) when debt, i.e. loans or bonds, are issued. Higher interest rate costs are supposed to lead to higher market perception of default risk and spreads because they make debt service more costly, as well as increasing the burden of the debt for the economy.

While the variables related to the debt situation describe the payment obligations the government has to fulfill, in addition the government's ability to meet these obligations is of crucial importance for yield spreads. There are several hypotheses and variables in regards to the government's ability to meet debt service requirements. First, the overall state of the economy can be important. The most important indicator used here is the *growth of GDP*, which is supposed to have a negative influence on spreads. For growing economies it is *ceteris paribus* easier to fulfill given payment obligations than for stagnating economies. Even early theoretical contributions on the sustainability of countries' debts (see, e.g., Domar, 1944, 1950) point to the relation between the growth rate of GDP and the growth rate of debt. From a theoretical point of view, the burden of the debt, even if the debt is constantly growing, is not problematic as long as the debt grows at a slower rate than the GDP.

In addition to the overall state of the economy, the external sector is also significant in several studies. To capture this issue, we use variables related to external trade. On the one hand, we employ the *trade balance to GDP*, i.e. the difference between exports and imports over GDP, and on the other hand, we include the country's openness, i.e., the sum of exports and imports over GDP. These variables may influence sovereign yield spreads and the market perception of default risk in several ways. For example, a higher trade balance is supposed to lead to lower default risk because it helps to collect funds for debt servicing and, more generally speaking, because it may serve as an indication for high competitiveness of the economy. Therefore we would expect a negative sign for the trade balance. However, a positive sign for the trade balance is also plausible. This can be explained as follows: The *balance of payment identity* implies that the "real side" of the balance of payments, i.e. trade balance or, more generally, the current account, more or less mirrors the capital account[6] a current account deficit is related to net capital imports, whereas a current account surplus occurs jointly with net capital exports (if we neglect changes in foreign exchange reserves, whose numbers are in fact negligible for developed countries). Net capital exports can indicate facts that are supposed to increase default risk, such as a country's inability to borrow abroad (e.g., because high default risk causes lenders to be unwilling to provide loans) or net outflow of capital because of capital flight. Since net capital exports imply a current account surplus it is therefore possible that a current account surplus can also be a negative signal. This explains that the current account or the trade balance can have a positive sign, i.e. a higher/positive current account (and the corresponding negative capital account) increases the spreads and the market perception of default risk. A positive sign of the trade balance (justified by these arguments) would be more closely related to short term or liquidity issues, whereas a negative sign (justified above) is related to long-term or solvency arguments.

With respect to *openness*, competing explanations for the influence on yield spreads are conceivable, which can even lead to opposite directions of influence. The *first* approach is related to the issue of *unwillingness to pay*, which is, according to an influential strand of theoretical literature (see Eaton et al., 1986, or Eaton and Fernandez, 1995), an important issue in countries' default risk, since

[6] Since current account and capital account are theoretically more or less a linear combination (if we neglect some other sub-balance of the balance of payment, which have a minor influence numerically) and are practically highly correlated, it does not make sense to include both in the estimation, not even in BMA.

enforcement problems play an important role in causing default risk when sovereign states are borrowers. According to the willingness-to-pay-literature, countries that do not fulfill their payment obligations are "punished" by disruptions of trade (which offers an explanation about why countries pay their debt at all). More open countries suffer more from these punishments and are, therefore, more willing to pay. Thus, based on this theory, more openness leads to lower default risk and spreads. A negative influence of openness on spreads can *secondly* also result because countries that are more open are better able to deal with crises. A *third* and contradicting hypothesis relies on some kind of "spill-over" argument: Economies that are more open are also more prone to variations and shocks in the world economy, and they, in particular, tend to "import" crises from the rest of the world. This increases their default risk and yield spreads in times of crisis.

A third variable related to the external sector that we use in the analysis is the *change in the terms of trade index*. An increase (decrease) of the terms of trade means that (average) export prices in relation to (average) import prices increase (decrease). A change in terms of trade may result from a change in the exchange rate, on the one hand, and from a change of average (export) market prices paid for goods and services of the respective country, on the other. Since all EMU countries, which constitute our sample, use the Euro as the domestic currency, all the differences between countries solely result from changes in their export prices. An increase of terms of trade may decrease default risk and, thus, yield spreads since it favors the economy and makes it easier to collect funds for debt servicing: countries pay relatively less for their imports in relation to their earnings for exports. This holds true especially if the increase results from changes in market prices. If an increase in terms of trade would result, by contrast, from an increase in the exchange rate, it may lead to a loss in competitiveness and, hence, to a higher default risk.

Inflation was also found to be a significant determinant of spreads in the literature. Although all EMU member states face the same monetary policy made by the European Central Bank (ECB), the inflation may have a (different) influence on spreads and market perception of default risk. Irrespective of the common monetary policy, the inflation shows considerable differences between countries. Inflation influences economic activity and may have an influence on default risk in several ways. Higher inflation rates, i.e. increasing price differentials, for example, lead c.p. to a loss in competiveness (for pegged currencies or even a common currency), which increases the default risk.[7] In the case of EMU member states the influence of inflation on the economy may be even more important because it may be hard(er) for governments to deal with and achieve the optimal level of inflation without independent monetary policy, whereby one size (monetary policy/interest rate) usually does not fit all (countries). On the other hand, for some countries that were troubled with high inflation in the past, it may be easier to achieve low inflation rates being member of a monetary union. Besides inflation, we include *variation of inflation*, which was also found to be important in the literature (see, e.g., Lemmen and Goodhart, 1999). A high variation of inflation imposes additional costs and disruptions on the economy and may make debt service more difficult.

Finally, we consider the *capital formation to GDP* as a potential country specific determinant of the market perception of default risk and yield spreads. By including this variable, we aim to test whether the use of funds has an influence on default risk. Higher capital formation is supposed to decrease default risk because it should c.p. lead to higher productivity and higher economic growth in the future. Thus, a higher future ability to make debt service payments is to be expected which should decrease the default risk.

In addition to variables related to the market perception of countries' default risk discussed so far, the market *liquidity* also may influence sovereign yield spreads. The influence of liquidity for EMU bond markets is controversial in the literature. Some emphasize the importance of liquidity, while others find it to be insignificant. Several indicators are used in the literature. For single bond issues, one can observe bid-ask-spreads and the face value of outstanding debt. On an aggregated level for the country, the entire outstanding debt can serve as an indicator for the depth of the country's bond market. We include two aggregated measures: on the one hand, the country's *total outstanding debt* and, on the

[7] The loss of competitiveness because of inflation differentials without the possibility to devaluate (because of a joint currency) can be seen – among others – as explanation for the crisis in Greece after 2009.

other, countries' *debt in relation to the overall debt of all EMU countries*, the latter in order to relate the countries market size to the EMU market size. Because of a lack of data, we do not include bid-ask-spreads. However, several studies, as, e.g., Ejsing and Sihvonen (2009), and Korajczyk and Sadka (2008), show that bid-ask-spreads and other liquidity measures are closely related.

Besides these country specific variables, some variables related to global conditions are also reported to be significant in the literature. We include the risk-less *US interest rate*, which is considered in a variety of papers. Its influence is intensively debated in the literature. The US rate reflects the international financing conditions and global financing costs and is, thus, supposed to determine market perception of default risk and spreads. A higher US rate should increase the spreads.

Another important global driver of spreads discussed and considered in the literature is the influence of market sentiments, i.e. the propensity to invest in risky bonds. Several papers consider the *spread for risky US corporate bonds over US treasuries*. It is assumed that high corporate spreads indicate that market participants are less willing to invest in risky bonds and pay lower bond prices, i.e. require higher yields for holding risky bonds. Thus, higher corporate bond spreads are supposed to lead to higher sovereign yield spreads. In order to examine market sentiments toward risk, we include the spread of BBB rated bonds over US treasuries.

4. Analyzing the determinants of sovereign yield spreads by BMA

4.1. The setting

Our sample comprises the 10 countries that apart from Germany and Luxembourg constitute the EMU.[8] Germany is excluded since we use German bond yields to calculate the bond spreads for other countries, whereas Luxembourg is not considered because of lacking data. The observation period starts in 1999 when the EMU was founded and exchange rate risk between the considered countries and Germany disappeared, which means that spreads are not biased by exchange rate risk.[9] The observation period ends in 2009 because of data availability. We consider annual data since we are interested in fundamental and long-term determinants of spreads and the market perception of default risk, whereas data in higher frequency is supposed to be more influenced by short-term influences. In addition, a number of the explaining economic variables is available in annual frequency only.

Regarding the time structure of the data, we apply two approaches, both of which are used in the literature. In our baseline estimation, we relate the dependent variable on simultaneously observed explaining variables, i.e. we relate (explaining) economic variables, which are end of the year values for a specific year, to spreads observed at the end of the same year. This approach of using instantaneous observation is very common in the literature, especially in the literature on data for EMU or (other) developed countries. In addition, we run regressions with lagged independent variables, i.e. we regress (explaining) economic variables on average spreads observed in the next year. This approach is also common in the literature, especially in the literature for emerging market countries. This approach provides an early warning system because the results can be used to forecast sovereign spreads and, in a wider sense, the market perception of future default risk. In addition, the results can be considered as a robustness check.

There is another point where the literature follows different approaches. One strand of the literature relates the explaining variables to the observation of the "anchor" country (in our case Germany), i.e. the country that provides the bonds used to calculate the spread by subtracting the yield of the analyzed country by the yield of the anchor country. In this strand of literature, also the explaining variables observed for the analyzed countries are differenced by the observations of the anchor country Germany. This approach relies on the insight that the anchor country is also not completely free of default risk, and differencing with German data takes this into account. A second approach denies such changes and uses the "original" data observed for the analyzed countries. This approach implicitly assumes that the benchmark country is risk free, or at least that its interest rate is the best

[8] These are Austria, Belgium, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal, and Spain.
[9] For Greece we consider data from 2001 onwards when the country became member of the EMU.

Table 1
Description of variables.

No.	Variable	Definition	Source
0	Bond yield spread (dependent variable)	Redemption yield on sovereign bonds of the considered country minus redemption yield on German sovereign bonds, both taken from the yield curve for a fixed 10-year maturity	DATASTREAM
1	Budget balance to GDP	Budget Balance to GDP	Economist Intelligence Unit
2	Total government debt to GDP	Total government debt as percentage of GDP	IMF World Economic Outlook
3	Average interest rate	Interest as percent of gross public debt of preceding year	Annual Macroeconomic Database of the European Commission
4	GDP growth	Real GDP at 2005 prices (annual growth)	OECD Economic Outlook
5	Inflation	Inflation as annual change in CPI	IMF World Economic Outlook
6	Inflation variation	Instantaneous volatility, i.e. quadratic deviation of inflation from long-term (10 year) mean	Own calculations based on IMF World Economic Outlook
7	Capital formation	Gross fixed capital formation divided by GDP	Annual Macroeconomic Database of the European Commission
8	Trade balance	Exports minus Imports over GDP in US Dollar	IMF International Financial Statistics
9	Openness	Exports plus Imports over GDP in US Dollar	IMF International Financial Statistics
10	Terms of Trade growth	Terms of Trade Index (1990 = 100) (annual growth)	Economist Intelligence Unit
Liquidity indicators			
11	Total debt	Total government debt	IMF World Economic Outlook
12	Total debt to EMU debt	Total government debt as percentage of Total EMU government debt	Own calculations based on IMF World Economic Outlook
Global conditions			
13	US interest rate	Bond yield from US treasury yield curve for one-year maturity	DATASTREAM
14	Market sentiment	BBB rated US corporate bond spread to US treasuries	DATASTREAM

approximation for a risk-less interest rate (which in reality does not exist), and differencing with German variables, in this case, does more bad than good. Of course there is no silver bullet; both sides have their pros and cons. To be consistent with the major part of the literature on EMU countries, we run the estimations with differenced data as our baseline estimation. As a robustness check we provide the results of estimations with original data.

In addition to the results for the entire period 1999–2009, we provide separate results for estimations that rely on the pre-crisis period 1999–2007.[10] This provides evidence regarding the question of whether or not our results hold true in tranquil times as well, or if our results are driven by the crisis period. It can be seen as further robustness check and is appropriate when discussing the relation to older studies that only consider data observed before the crisis started.

We include the 14 explaining variables described in the last section. A detailed description of the data, including data sources, can be found in Table 1. In addition we include country dummies to account for unobserved heterogeneity between countries. Thus, our estimations correspond to fixed effects panel estimation in classical statistics.

4.2. The baseline results: non-lagged estimations for the entire period 1999–2009

We apply BMA to identify the major determinants of sovereign yield spreads. Whereas the main measure to assess the importance in classical statistics is the *p*-value that describes the significance level

[10] We do not apply our analysis on the crisis period since the number of observations is to low, we do not have enough degrees of freedom since additionally to the 14 regressors we require degrees of freedom for the fixed effects country dummies (see below).

for each regressor for the specific model, in BMA the probability of inclusion calculated by Eq. (5), as described in Section 2, is used to assess the quality of a regressor. As explained, this measure combines information obtained by considering the entire model space instead of that from a single model. The probability is the weighted average of probability values (which determine the significance levels) for single models, whereby the model probabilities are used as weights in averaging. Similarly, we take the average of the coefficients obtained for a specific regressor in the single models that contains this regressor to obtain an average coefficient; i.e. we calculate the weighted average using the model probabilities as weights. Here the sign of the average coefficient is especially important because it gives us the direction of influence. The results are reported in Table 2, the columns marked with PI display the respective Probabilities of Inclusion and the columns market with DI show the Direction of influence.

First we discuss our baseline results (see Column 3 and 4 in Table 2), i.e. the findings obtained for non-lagged estimations where the explaining variables observed for the analyzed countries are differenced by the respective observations for Germany. Our results confirm some important findings of the literature, cause doubt in others and provide mixed evidence for a third group of variables. A high likelihood value of 100% is obtained for *budget balance to GDP*. The sign of the average coefficient is, as expected, negative. A lower budget balance, i.e. a higher deficit (which is mostly observed), increases yield spreads. This confirms findings of important contributions in the literature (see, e.g., for EU countries Bernoth et al., 2006; Lemmen and Goodhart, 1999; Schuknecht et al., 2009, 2010) where this variable was also found to be an important driver of spreads.

A second variable that shows a high probability of inclusion of about 100% is the *change in the terms of trade*. This variable was so far, in particular, found to be significant for developing countries (see, e.g., Baldacci et al., 2008). Our results indicate that this variable seems to be important for EMU countries as well, whereby better terms of trade decrease yield spreads.

Also for the other external variables, *trade balance and openness*, we find high likelihood values of 80% respective 73%. The negative sign for openness indicates that higher openness implies lower spreads, which supports the theoretical implications explained in Section 3, i.e. either the importance of the willingness-to-pay-argument or the fact that more open countries are better able to deal with crises.

For the *other country specific* variables related to market perception of countries' default risk and solvency, the posterior probability of inclusion is lower than the a-priori probability of 50%. For the

Table 2
Results of BMA.

No	Variable	Baseline		Lagged		Pre-crisis	
		PI	DI	PI	DI	PI	DI
Country specific yield spread drivers							
1	Budget balance to GDP	**100.0**	–	**100.0**	–	**95.8**	–
2	Total government debt to GDP	27.6	+	5.4	+	**88.6**	+
3	Average interest rate	41.1	+	9.9	+	4.6	+
4	GDP growth	4.1	+	8.3	+	22.5	–
5	Inflation	6.1	–	5.7	–	9.6	+
6	Inflation variation	17.7	+	6.7	+	5.6	+
7	Capital formation	5.2	+	4.3	+	39.6	+
8	Trade balance	**80.0**	+	5.8	+	**70.2**	–
9	Openness	**73.1**	–	4.3	–	18.6	–
10	Terms of Trade growth	**100.0**	–	**99.9**	–	4.9	–
Liquidity indicators							
11	Total government debt	25.8	–	8.8	–	7.2	–
12	Total government debt to total government debt of all EMU countries	22.6	–	15.3	–	50.5	–
Global conditions							
13	Global capital costs: US interest rate	4.5	+	3.8	+	**99.9**	+
14	Market sentiment: BBB rated US corporate bond spread to US treasuries	**99.0**	+	7.1	+	23.8	–

Explanation: Baseline: Explaining variables are differenced by observations for Germany. Variables are not lagged. Sample: 1999–2009 Lagged: Explaining variables are differenced by German observations. Variables are lagged by one year. Sample: 1999–2009 Pre-crisis: Explaining variables are differenced by observations for Germany Variables are not lagged. Sample: 1999–2007PI means Probability of Inclusion and DI means Direction of Influence.

average interest rates, i.e. the implicit interest rate costs of all outstanding debt, the probability of 40.1 is close to the posterior probability. This means the influence does not seem to be not negligible but also not overwhelming. Furthermore, for the debt level, which was found to be significant in several studies, a probability of 27.6% can be interpreted as rather mixed evidence (See, however, also the discussion of results for the pre-crisis period in the Subsection 4.4).

For some other variables, we find very low inclusion probabilities. This holds true, e.g., for economic growth, which means that the current development of GDP is not particularly related to sovereign yield spreads, if we control for other variables. Likewise for capital formation we find a low inclusion probability. This may result because investments and capital formation influence default risk in the long-run, but the market perception of default risk and spreads are rather driven by short- or medium-term influences, whereas the long-run perspective is of minor importance. Another explanation could be that the amount of investments (in relation to GDP) is less important than the quality of investment projects and the reasonable use of funds, which is not measured by this variable. Also, inflation and inflation variation are not found to be important drivers of yield spreads. (Interestingly, the influence of the variation is higher than that of the inflation itself.) The low impact of inflation can be seen as evidence that the inflation has low importance for yield spreads and market perception of default risk in the Eurozone, perhaps because inflation was relatively low for all countries in the sample in the last decade (compared, e.g., to developing countries), which in turn may result from the membership in the EMU. This indicates further that under the viewpoint of (minimizing) default risk, the common monetary policy is seen by the bond market participants rather as a minor problem or even to reduce default risk.

Besides the default risk related variables discussed so far, *liquidity* may also influence yield spreads. However, both indicators, the total outstanding (government) debt of the considered countries and the relation between this debt and the entire debt of all EMU countries, show rather mixed results with inclusion probabilities of 25.8 and 22.6, respectively.[11] The rather low influence is in line with some contributions considering similar samples. The low influence can be explained by the fact that although we observe substantial differences in outstanding debt, all EMU countries have substantial amounts of outstanding debt largely financed by issuing government bonds. Hence, for all countries sufficient market depth may exist and the "marginal utility of liquidity" is decreasing, i.e. the additional positive influence of a (further) increase of liquidity following from increasing market size is relatively low.

In addition to country specific determinants, the spreads may depend on *global conditions*, as explained in Section 3. One of the most important variables in this respect in the literature is the *US rate*, which is used in many papers as indicator for financing conditions and financing costs. However, its influence is debated: some authors find significant influence, whereas others do not. Since the probability of inclusion of about 4.5 is low, our baseline results indicates a minor influence. However, for the pre-crisis period, we obtain different results (as discussed in Subsection 4.4).

Another driver of sovereign yield spreads could be the market sentiment, for which we use the *spread of BBB-rated US corporate* bonds over US treasuries as indicator, as it is done in several other papers. A high inclusion probability of about 99% indicates that market sentiment seems to play an important role indeed. The positive sign of the average coefficient shows that an increasing corporate bond spread, which is interpreted as indicator for lower propensity to invest in risky bonds, increase the observed sovereign yield spreads.

As a robustness check we include the results for estimations where the explaining variables are used without differencing them by the influence of Germany. The results are reported in Table A-3 in the appendix. It can be seen that the major findings are similar to those obtained with differenced explaining variables discussed so far: budget balance and terms-of-trade growth as well as US corporate spreads have high inclusion probabilities, whereas the results for the other variables are below the a-priori probabilities. This means that trade balance and openness are not important according to this setting.

[11] One could expect (at least in classical regressions) that skipping one of the variables would increase the importance of the second one. In order to analyze whether this is the case here, we ran alternative BMA estimations, where only one of the liquidity indicators was included. This, however, did not increase the inclusion probability significantly. This result can be expected since the inclusion of broad information from the entire model space eases the multi-co-linearity issue in BMA.

4.3. Results for estimations with lagged independent variables

As explained in Subsection 4.1 we run additional estimations with lagged variables. The results can be used to infer an early warning system, i.e. the best model or the variables with the highest inclusion probabilities can be used to forecast sovereign defaults. Additionally, the results of the lagged estimations may help to discuss the robustness of our results; if the same variables are also identified as important spread drivers in the lagged estimation, we can interprete this as confirmation of the results reported above.[12]

The results are shown in Column 5 and 6 of Table 2. The most likely country specific drivers of sovereign yield spreads – budget balance and terms of trade – also have a high probability of inclusion in the lagged estimations. A higher budget balance (lower deficit) and higher terms of trade in one period decrease the spreads in the following period, i.e. both variables can be used as predictors for future spreads and indicators for future market assessment of country risk. The other variables, as trade balance, openness and market sentiments, that are likely to influence yield spreads in the same period show rather low inclusion probabilities in the lagged estimations. This means, an influence in the same period is very likely, but these variables do not react in advance of spreads and, thus, cannot be used as early warning signals.

4.4. Results for the pre-crisis period 1999–2007

Our observation period comprises the relatively tranquil period of 1999–2007 as well as the time of the financial crisis 2008–2009. This leads to the question of how far our results are driven by the crisis period and whether we would obtain similar results in tranquil times. Thus, we consider the pre-crisis period 1999–2007 in separate estimations. Such an analysis is especially appealing since an interesting new literature emerges that is concerned with changes in the influence of explaining variables. A discussion of this literature can be found in Bernoth and Erdogan (2010), who contribute to this literature by applying a semi-parametric time-varying coefficient model. However, considering a pre-crisis subsample is also appropriate when discussing the relation to somewhat older papers, which rely on samples that end before the crisis started.

Column 7 and 8 of Table 2 report the results for the period from 1999 to 2007. For a number of variables we obtain similar results as with the estimations results for the entire sample. Especially the *budget balance* is still important in the pre-crisis sample. For the variables related to *inflation, economic growth, capital formation and interest costs* the inclusion probabilities are rather low also in the pre-crisis period. Whereas for interest rates cost and inflation variation the probabilities are lower in the pre-crisis period the results for the capital formation and growth are somewhat higher. However, the posterior inclusion probabilities are still clearly lower than the a-priori probabilities of 50%.

Also some external sector variables, such as *terms of trade* and *trade balance*, are important drivers of yield spreads in the pre-crisis period, too. In contrast to the trade balance and terms of trade, the impact of *openness* is relatively low in the pre-crisis period. The fact that openness is important with a positive sign in the entire period and not very important in tranquil periods may be interpreted as particular support of the hypothesis that open countries are better able to deal with crisis.[13] It indicates that the "spill-over hypothesis" discussed above is not important in our sample, i.e. supposed negative influences from the world economy on more open countries are seemingly unimportant our out-balanced from the first influence.

Another important finding is that the *debt level in relation to GDP*, has a high probability of about 88.6% in the pre-crisis period. This result is in line with previous literature, where this variable was also found to be significant in several other studies (often the samples do not include the crisis period). Our

[12] However, the opposite does not hold, i.e. it does not necessarily mean that the influence on spreads is questionable if some variables found to be significant in non-lagged estimations are not significant in lagged estimations.

[13] In some sense it contradicts the willingness-to-pay-argument, which implies the same (negative) direction of influence on spreads. According to the willingness-to-pay theory we would expect this negative influence, however, not only in crises times but also in other periods. This interpretation should be handled with care, however.

results indicate that the *level of indebtedness* in fact does play a role for sovereign yield spreads and the market perception of country default risk in EMU countries in addition to budget deficits and the resulting *changes in debt*. Whereas the level seems to be considered as important by market participants, especially in tranquil times, budget deficits and the (dramatic) changes in debt not only play a major role in crisis times, but are also significant in the entire time span.

The results for the *liquidity indicators* are rather mixed even in the pre-crisis period. Here the default risk was low. Hence, one could suppose that the influence of liquidity is more important in this period relative to default risk. However, the probability observed for total debt of 7.2 is even lower in the pre-crisis period than in the crisis period, whereas the total debt to EMU debt is about 50%, i.e. still not significantly higher than the a-priori probability.

For global influences, we find differences between the pre-crisis period and the entire sample period. While the *US rate* shows a low probability of inclusion for the entire sample, it has a high probability of inclusion in the pre-crisis period. In times of low default risk, the global financing conditions have an influence on sovereign yield spreads, whereas in times of high default risk, the influence of countries' solvency (drivers) on yield spreads dominates the influence of financing conditions, whose influence is altered to be negligible.

For the influence of changes in *market sentiments* on EMU government bond spreads (indicated by BBB US corporate bond spreads over US treasuries), we observe the opposite. In the tranquil pre-crisis period, the evidence for their influence on yield spreads is not overwhelming, whereas in the crisis period, changes in market sentiments seem to be a very important driver of sovereign yield spreads. This may result since the changes in the pre-crisis period are rather small, whereas the crisis leads to considerable changes in market sentiments.

5. Conclusion

Considerable default risk of several EMU member states is an important issue because it causes financial turmoil in the Eurozone, imposes high costs for all member states, and is even a threat for the future existence of the EMU. Especially the market perception of default risk is important, and high interest rates for government bonds are a major problem for a number of EMU member states. An interesting strand of the empirical literature analyzes this issue by regressing several potentially explaining variables on government bond yield spreads. These papers provide interesting insights into the determinants of sovereign yield spreads in general and into the nature and causes of country default risk in particular. However, the results are heterogeneous, even in papers that focus on EU countries, which points to some degree of model uncertainty.

We contribute to this literature by tackling the issue with Bayesian Model Averaging (BMA), which has been successfully applied in other cases, but not in regards to the issue of EMU sovereign yield spreads. BMA is an elegant approach to test a variety of potentially explaining variables and to deal with model uncertainty. It uses information from the entire model space and not only a single model (or some selected models), as it is the case in classical regressions, to identify the best models and assess the quality of potential regressors. In this sense, BMA provides additional and broader information. Therefore our paper complements the existing literature. We apply BMA in several settings and consider different time spans in order to carefully analyze the issue and provide robust results. We confirm some important findings of the literature, disprove others and provide mixed evidence for some.

By considering 10 EMU member countries in the observation period 1999–2009, we find that the most important country specific drivers of sovereign yield spreads in the Eurozone are budget balance to GDP, terms of trade, trade balance and countries' openness. Budget balance and terms of trade are also significant in lagged estimations, i.e. they could be used as early warning signals. In order to discern whether our findings are driven by the crisis period or also hold true in tranquil periods, we run separate estimations for the pre-crisis period 1999–2007. Budget balance to GDP and the trade balance are very likely to influence spreads in the pre-crisis period as well as in the entire sample period, whereas openness and terms of trade play no role in the pre-crisis period. In addition, the level of debt to GDP is a very likely driver of yield spreads in the pre-crisis period, but not in the entire period where the change of debt indicated by the budget balance is important only. The importance of these fiscal

variables indicates that financial markets watch fiscal variables indeed closely, and thus impose fiscal discipline by increasing interest yields when the fiscal situation deteriorates and the default risk increases. In contrast to these spread drivers that are related to default risk, indicators for market depth and liquidity yield rather low inclusion probabilities for both the pre-crisis sample and the entire sample. In contrast, global financing conditions, indicated by the US interest rate, and global market sentiments, indicated by spreads of US BBB corporate bond spreads, are likely to drive spreads at least in some periods.

In regards to country specific drivers of sovereign yield spreads that are supposed to be influenced by the market perception of default risk, we can conclude that fiscal variables, such as budget balance and debt level (at least in the pre-crisis period), are found to be important determinants of sovereign yield spreads in EMU countries – i.e. they decisively influence the market perception of default risk and the borrowing costs of countries. As a result, avoiding defaults – and perhaps the survival of the EMU – crucially depends on the successful budget consolidation of the member states and the reduction of debt to GDP. The success seems to be partly dependent on – hopefully – favorable conditions in the external sector, since in addition to fiscal variables, variables related to the external sector, as terms of trade, trade balance and openness, are also found to be important drivers of sovereign yield spreads.

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Appendix

Table A-1. Summary of existing literature for developing countries.

Panel A: Studies with primary bond spreads as a dependent variable for developing countries

Study	Sample	Explanatory variables with significant influence
Edwards (1986)	1976–1980 13 countries	Debt to output ratio, Gross investment ratio, Debt service ratio, Maturity
Min (1998)	1991–1995 10 countries	Debt Service Ratio, Terms of Trade, Growth rates of exports and imports, Current account balance, Ratio of debt to GDP, Ratio of reserves to GDP
Eichengreen and Mody (1998)	1991–1996 55 countries	Ratio of debt to GDP, Debt Service Ratio, Dummy for rescheduling, (10 year) risk-less US interest rate, Private placement, Israel dummy, Supranational, Public or private issuer, Currency (DM/Yen), Latin America dummy, Ratings of Institutional Investor
Kamin and von Kleist (1999)	1991–1997	Debt Service Ratio, Ratio of total debt to GDP, Ratio of reserves to imports; Ratings of S&P and Moody's, Maturity, Currency dummy (Yen, Non USD), Time dummies

Panel B: Studies with secondary bond spreads as a dependent variable for developing countries.

Study	Sample	Explanatory variables with significant influence
Cantor and Packer (1996)	September, 29, 1995 45 countries	Ratings (S&P and Moody's), External debt, Stage of economic development (according to IMF classification), Default history
Arora and Cerisola (2001)	1994–1999 11 countries	Risk-less interest rates, Debt service ratio, Ratio of total debt to GDP, Ratio of reserves to GDP, Ratio of reserves to imports
Rowland and Torres (2004)	1998–2002 16 countries	Economic growth, Ratio of debt to exports, Ratio of debt service to GDP, Ratio of reserves to GDP
Dailami, Masson and Padou (2005)	1991–2004 17 countries	Openness, Level of (total) debt, Reserves to GDP, Proportion of short-term debt, Spread of US corporate bonds, Several leading indicators of US interest rates (e.g., Producer prices, Retail sales, Capacity utilization, M2)
Baldacci, Gupta and Mati (2008)	1997–2007 30 countries	Fiscal balance, Public investment, Inflation, Political risk index, Reserves, Current account balance, Terms of trade

Table A-2. Summary of existing literature for EU countries.

Panel A: Studies with bond spreads (**for single issues**) as a dependent variable for EU countries

Study	Sample	Explanatory variables with significant influence
Bernoth, von Hagen and Schuknecht (2006)	1993–2005 14 EU countries	Debt to GDP, Deficit to GDP, Debt service to revenues, Maturity of the bond issue, Corporate bond spreads, Liquidity of the issue, EMU dummy, Short-term US rate
Schuknecht, von Hagen and Wolswijk (2009)	1991–2005 13 EU countries and sub-national governments	Public debt to GDP, Fiscal balance to GDP, Maturity of the bond issue, US Corporate bond spreads, Liquidity (size) of the issue, Region dummies, Short-term US rate
Schuknecht, von Hagen and Wolswijk (2010)	1991–2009 15 EU countries	Central government debt to GDP, Fiscal balance to GDP, Maturity of the bond issue, US Corporate bond spreads, Liquidity (size) of the issue, EMU dummy, Short-term US rate, "Turmoil" dummy, Crisis dummy

Table A-2. Summary of existing literature for EU countries continued.

Panel B: Studies with bond spreads (**obtained for benchmark curves**) as a dependent variable for EU countries

Study	Sample	Explanatory variables with significant influence
Lemmen and Goodhart (1999)	1987–1996 13 EU countries	Debt to GDP ratio, Capacity to raise taxes, Inflation, Inflation variability
Codogno, Favero and Missale (2003)	1999–2002 9 EU countries	Debt to GDP ratio, US swap spread, US corporate bond spread
Manganelli and Wolswijk (2007)	1991–2009 15 EU countries	Ratings, Short-term interest rate

Table A3: Results for Unmodified Variables-Probability of Inclusion and (Average) Direct of Influence (Sign of the Average Coefficient).

No	Variable	Probability of inclusion	Direction of influence
Country specific default risk drivers			
1	Budget balance to GDP	**97.3**	–
2	Total government debt to GDP	31.5	+
3	Average interest rate	17.2	+
4	GDP growth	9.6	–
5	Inflation	9.4	–
6	Inflation variation	5.8	+
7	Capital formation	37.3	+
8	Trade balance	10.9	–
9	Openness	11.7	–
10	Terms of Trade growth	**74.8**	–
Liquidity indicators			
11	Total government debt	12.8	+
12	Total government debt to total government debt of all EMU countries	22.1	–
Global conditions			
13	Global capital costs: US interest rate	23.7	+
14	Market sentiment: BBB rated US corporate bond spread to US treasuries	**100.0**	+

*Explaining variables are **not differenced** by observations for Germany. Variables are not lagged. Sample 1999–2009.

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