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Estimation and empirical performance of non-scalar dynamic conditional correlation models

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ABSTRACT

A method capable of estimating richly parametrized versions of the dynamic conditional correlation (DCC) model that go beyond the standard scalar case is presented. The algorithm is based on the maximization of a Gaussian quasi-likelihood using a Bregman-proximal trust-region method that handles the various non-linear stationarity and positivity constraints that arise in this context. The general matrix Hadamard DCC model with full rank, rank equal to two and, additionally, two different rank one matrix specifications are considered. In the last mentioned case, the elements of the vectors that determine the rank one parameter matrices are either arbitrary or parsimoniously defined using the Almon lag function. Actual stock returns data in dimensions up to thirty are used in order to carry out performance comparisons according to several in- and out-of-sample criteria. Empirical results show that the use of richly parametrized models adds value with respect to the conventional scalar case.

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1. Introduction

The choice of the dynamic conditional correlation (DCC) model has become very common in the multivariate GARCH applied literature, where the goal is often to fit the dynamics of time-varying conditional variances and correlations of asset returns and to forecast their future values. The DCC family was developed in Engle (2002) and Tse and Tsui (2002) as a generalization of the constant conditional correlation (CCC) model of Bollerslev (1990). The main advantage of DCC models is the availability of a two-step estimation procedure which, combined with correlation targeting, makes their use feasible even when the number of assets is high. It is worth noting that even though in the original paper Engle (2002) a general matrix Hadamard-type model parameterization is proposed, it is almost exclusively the scalar prescription that is used in applications. This simplified version of the model imposes the same correlation dynamics to all the pairs of assets that are considered which, for sizable dimensions, may constitute an excessively restrictive homogeneity assumption.

The main contribution of this paper is to provide adequate estimation tools for several non-scalar richly parametrized DCC models and to empirically evaluate how they perform with respect to each other and to the scalar model. The non-scalar models that are considered are the general matrix Hadamard-type model and four more parsimonious particular

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cases thereof. The main conclusions are that the estimation of these models is practically feasible in moderate dimensions (up to thirty), and that two of the non-scalar models considered are worth using in practice.

This study is restricted to DCC models in which only an approximate correlation targeting as suggested by Engle (2002) is possible. This is a widespread approach that aims at reducing the number of parameters in the likelihood maximization by replacing the constant term matrix of the quasi-correlation process by a moment estimate. This approach is controversial in the DCC context since the approximate targeting procedure is statistically inconsistent (see Caporin and McAleer, 2012 for an extensive review). This issue has motivated the introduction by Aielli (2013) of a corrected DCC (cDCC) model that carefully addresses it, but the price to pay is that estimation is more convoluted. Despite the substantial theoretical interest of the cDCC model, it is not considered in this work since existing empirical findings and simulation results in Aielli (2013) reveal that the performance of the cDCC and DCC models does not differ much in practice for typical financial series.

The need to go beyond the scalar DCC prescription has been partly addressed in Hafner and Franses (2009) and Cappiello et al. (2006). In these papers, a so-called diagonal DCC model that allows for asset-specific heterogeneity in the correlation structure is used. This extension specifies the parameter matrix associated to the lagged innovations as a rank one matrix, and the same applies to the parameter matrix of the lagged quasi-correlation term although that one is also kept as a scalar parameter in Hafner and Franses (2009). The results in those papers provide empirical evidence supporting that these richer DCC models exhibit improved performance with respect to the scalar model. Another relevant paper in the same direction is that of Noureldin et al. (2014) who introduce (among others) a model, called Rotated DCC (RDCC), which uses similar specifications as in the two previously cited papers, after applying an estimated orthogonal transformation to the devolatized returns, and illustrate that it yields increased performance when compared to existing models like, for instance, the OGARCH model of Alexander (1998). The contribution of this paper with respect to these mentioned works is that other non-scalar and more richly parametrized models are proposed and estimated.

The results in Hafner and Franses (2009) and Cappiello et al. (2006) lead us to believe that non-scalar DCC models with asset specific dynamics in the correlation structure, like the one associated to the original matrix Hadamard-type parameterization of Engle (2002), can yield a superior performance in practical applications when compared with the widespread scalar DCC model. This conjecture can only be verified when effective estimation procedures are available for the richer models, the absence of which explains in part statements in the literature (see for example Billio et al., 2006 or Chapter 7 of Engle, 2009) about the lack of empirical interest of these more general models. Two difficulties in this respect arise: the first one is the quadratic dependence of the number of parameters on the model dimension and the second is the need to impose at the time of estimation the nonlinear constraints that ensure the positivity and the stationarity of the dynamic conditional correlation process.

Our attention hence turns first to the optimization techniques that can be used for the estimation of non-scalar DCC models and, more specifically, to the approach proposed by Chrétien and Ortega (2014) based on the use of Bregman divergences, that we take as our starting point. That paper successfully applies this approach to the estimation of the heavily parametrized VEC-GARCH model subjected to stationarity and positivity constraints. We extend this optimization method to the DCC models and develop explicit estimation tools for a variety of non-scalar DCC specifications originating from the general Hadamard-type DCC prescription in Engle (2002). Even though the DCC family has a much smaller parameter space than VEC, the use of the Bregman divergences approach is extremely advantageous in the treatment of the DCC highly nonlinear optimization constraints. The paper is therefore organized around the three topics that we describe in the following paragraphs.

DCC model specifications: The considered models are the Hadamard DCC family for which the two parameter matrices of the lagged innovations and lagged quasi-correlation terms are symmetric with full rank, as well as four other subfamilies where these matrices have smaller ranks. More specifically, in one case the rank is set equal to two, and in three other cases it is equal to one. The first of these three "rank one" cases is equivalent to the diagonal DCC model considered also in Hafner and Franses (2009) and Cappiello et al. (2006), where the parameter matrices are built as outer products of vectors of size the number n of assets that are being modeled. The other two "rank one" models are new and called Almon DCC and Almon shuffle DCC. In these models, the elements of the vectors that generate the rank deficient parameter matrices are defined using an Almon function (see Almon, 1965). Thus, like in the scalar model, the number of parameters that need to be estimated does not depend on the dimension n but the correlation dynamics differs for all pairs of assets. The Almon DCC models are therefore more flexible than the scalar DCC model, while determined by a comparable number of parameters. Section 2 is devoted to presenting the general setup for DCC models, to describing in detail the different parameterizations under study, as well as the constraints that are imposed on each of them in order to ensure the stationarity of the process and the positive definiteness of the resulting conditional correlation matrices.

DCC model estimation: This is the subject of Section 3, which presents the main ideas behind the optimization algorithm chosen for the estimation. Bregman divergences are used in order to handle the model constraints, following the scheme proposed in Chrétien and Ortega (2014). This approach is very popular in the context of machine learning (see for instance Dhillon and Tropp, 2007 and Kulis et al., 2009a). In our situation, it is particularly advantageous because it allows for the treatment of the nonlinear optimization constraints that the problem is exposed to without resorting to Lagrange duality or other techniques that demand the solution of supplementary optimization problems. Section 3 contains a comprehensive description of the ingredients necessary to implement this optimization algorithm for each of the DCC models.

DCC specifications performance assessment: The possibility of estimating non-scalar DCC models with the tools just mentioned, allows us to empirically study their performance and, ultimately, to assess the need for those models in the processing

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