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"ASSET CORRELATIONS AND MACROECONOMIC FUNDAMENTALS"

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Asset Correlations and Macroeconomic Fundamentals

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The margin between the price of crude oil and one or more of its refined products, known as the crack spread, is a key risk measure in the energy trading industry. Effective forecasts of crack spread returns require modelling the co-movements of crude oil and refined product prices. To this end, in this paper we re-examine the relationship between parameter instability in energy commodity returns correlations and macroeconomic fundamentals using a new correlation component model dubbed the Regime Switching DCC-MIDAS, which distinguishes regime switches in the short and long-run correlations. Breaks in the secular component are associated with low-frequency macroeconomic fundamentals, while short-run correlations are characterized by abrupt breaks linked to market constraints. Our results reveal the benefits of our specification for Value-at-Risk and portfolio optimization in terms of forecasting performance at medium and long horizons and in times of intense market instability, such as the recent pandemic crisis.

Introduction

Our aim in this study is to investigate the role of breaks in modelling energy commodity correlations and their relationship with macroeconomic fundamentals. Optimal portfolio allocation, derivatives pricing and hedging strategies require modelling the co-movements of energy returns to quantify aggregate risk. Energy commodity markets are characterized by complex co-movements and structural changes. A key risk measure used in these markets is the crack spread, *i.e.*, the difference between the crude oil price, that is, the cost input, and the prices of gasoline and heating oil that represent the revenue stream. In the refining industry, the crack spread is interpreted as the profit margin of the refining process: its variations contain information on marginal production costs, reflect changes in the cost structure, and offer a proxy of the industry's daily profitability. Naturally, refiners are short on physical crude oil and long on physical refined products. As a result, they aim to lock in the spread to protect their profit margin by going long crude oil and short refined products using derivative contracts.

We propose a new correlation model, the Regime Switching DCC-MIDAS (RSDCC-MIDAS), which distinguishes between the long and short-run correlation components and investigates whether they are subject to different types of breaks, driven by different fundamentals. Short-run correlations are subject to abrupt breaks, linked to market constraints, while long-run correlation regime switches are driven by a smooth transition function that depends on a weighted sum of low-frequency macroeconomic indicators. The use of the MIDAS filter (Ghysels *et al.*, 2006) enables us to work with data at different frequencies.

Our results provide consistent evidence that, in the short run, correlations are affected by demand and supply fundamentals linked to operational aspects of the markets; in the long run, their changes reflect the stance of the economy. Our findings substantiate the relevance of macroeconomic variables as drivers of crack spread dynamics. In terms of forecasting, our new model outperforms several competitors at medium and long-term horizons and in periods of market turbulence, from both statistical and risk management perspectives, and confirm that accurate forecasting of energy commodity correlations must take into account the presence of structural breaks in their dynamics.

Forecasting Assessments

We examine and compare the forecasting performance of different models of commodity return correlations at various horizons. We consider the short horizons of 1, 5 and 22 days ahead as they are mostly relevant for financial investors, and the 65 and 130-day ahead long horizons which are key in risk management, for example, for refiners who reassess their crack spread configuration. To compare model-based correlation forecasts with ex-post realizations, we use several loss functions which are robust to the covariance matrix proxy (Bauwens *et al.*, 2016).

In the comparison, we use several competing models including regime switching correlation models, correlation models with macroeconomic factors and no breaks, and correlation models with breaks of the same type in the components. The first case is interesting as it provides a non-component reference for evaluating the importance of breaks. The second is relevant when assessing the forecasting benefits of component models and of the explicitly included macroeconomic factors. Finally, the third one is of interest when evaluating the implications of allowing breaks of the same type in time-varying components. We implement a fixed rolling-window scheme, *i.e.*, we re-estimate the model parameters every month (*i.e.*, 22 days) subject to a window of previously observed data whose size corresponds to the number of available observations when making the first predictions, and we conduct the evaluation from 11 June 2013 to the end of the sample, 1 June 2023, (out-of-sample period: 1697 observations). As metrics for the forecasting performance comparison, we use the:

Global Minimum Variance Portfolio

In portfolio management, a superior model produces optimal portfolios with the lowest variance realizations. Using out-of-sample covariance forecasts from the set of competing models, we consider the global minimum variance portfolio and the portfolio with minimum variance under the constraint of achieving a target expected return.

Value-at-Risk (VaR)

We are interested in the ability of the models to predict the left tail (short position) and the right tail (long position) of the distribution of the returns. Being able to correctly assess the VaR is central to business, as they aim to ensure that their income stream is realized with all other overheads covered as well with minimal risk of disruption.

Model and Data

To identify the role of structural breaks in short and long-run correlations, we consider a component model which distinguishes between the unconditional and the conditional correlations. The model allows reversion to a time-varying average of correlations, rather than a fixed one. Thanks to this decomposition, we are able to allow for different kinds of breaks in correlation components. The short-run correlations follow a Markov switching process, which is abrupt and not linked to observables, while the breaks in the long-run correlations are driven by the weighted average of the macroeconomic variables via a smooth transition function. The degree of smoothness of such transition is estimated from the data. The number of states in the correlation components is not assumed to be known *a priori* but it is determined empirically from the data.

Our data comprise settlement prices of front-month (1-month ahead) continuous contracts of Crude Oil (CO) (NYMEX Light Sweet Crude), NY Harbor ULSD (HO) and RBOB gasoline available from the CME Group for the period from 20 October 2005 to 1 June 2023, *i.e.*, a total of 4334 valid observations. Returns are calculated by taking the first-order differences of the closing log-prices for each series. As macroeconomic indicator, we use the GDP quarterly growth rates, generating a daily/quarterly frequency mix, and the industrial production (IP) monthly growth rate, generating a daily/monthly mix (Engle *et al*. 2013). Data are obtained from the Bureau for Economic Analysis (BEA) of the U.S. Department of Commerce. The period of interest includes the pandemic and several periods of high market turbulence, allowing us to test the validity of our forecasting approach in various economic conditions and to assess wheather the dynamics of both correlation components are consistent with the presence of structural breaks.

Results

Our results suggest that what distinguishes our model is its ability to describe the long-term dynamic correlation by exploiting the smooth, macroeconomic-driven transition in the low frequencies. Forecasts from the model differ significantly at the long horizon from those based on regime switching models reverting to a constant mean. At the short and medium horizons, the advantage of our model framework is that it associates high-frequency correlation dynamics with the typical abrupt pattern of short-run breaks, while preserving the component structure.

Results from the minimum variance portfolio analysis provide notable evidence of hedging benefits from models with breaks in the long and short-run components of correlations. Table 1 on the next page reports the standard deviations of the forecasted portfolios' return time series and the different models' ranks. Results for the constrained portfolios are presented in the second column. We can see that the five bestperforming models belong to the component model class, and our model, the RSDCC-MIDAS, achieves the lowest global minimum variance portfolio with a standard deviation of 1.0301. This improves at the 1% significance level over the first best benchmark. Our model tracks more closely the correlations over the period. The rise of correlations at the end of 2008 persists for the RSDCC-MIDAS, while the other model reverts to a lower level, underestimating the correlations in the more volatile period, thus yielding less appreciable gain from the portfolio diversification.

Table 1: Global minimum variance (standard deviations)

	Unconstrained		Constrained	
	Std. deviation	Rank	Std. deviation	Rank
Benchmark models				
CCC	1.3215	(16)	1.14936	(16)
DCC(1)	1.2134	(15)	1.12439	(15)
DCC(2)	1.1926	(14)	1.1168	(13)
DCC-MIDAS(2)	1.0855	(10)	1.11440	(11)
MS-DCC	1.1005	(13)	1.11441	(12)
Tested models				
DCC-MIDAS(1)	1.0800	(7)	1.1158	(8)
mDCC	1.0918	(11)	1.1135	(10)
mGDCC	1.0834	(9)	1.1150	(7)
treeDCC	1.0956	(12)	1.13073	(14)
treeDCC-MIDAS(1)	1.0805	(8)	1.1160	(9)
treeDCC-MIDAS(2)	1.0774	(2)	1.1001	(5)
DCC-MIDAS-X	1.0785	(5)	1.0988	(4)
DCC-MIDAS-C	1.0798	(6)	1.1054	(6)
DCC-MIDAS-XC	1.0781	(4)	1.0901	(3)
RSDCC-MIDAS(1)	1.0778	(3)	1.0875	(2)
RSDCC-MIDAS(2)	**1.0711****	(1)	**1.0821***	(1)

To assess the VaR performance, we forecast the one-quarter ahead VaR for each model at the 5%, 2.5% and 1% levels and assess their accuracy via statistical back-testing using the conditional coverage test of Christoffersen (1998). Table 2 on the next page reports the *p*-values of the test, with highlighted values corresponding to rejecting the null hypothesis at the 5% significance level. Rejection of the null implies that the model does not adequately forecast the VaR. The table shows that in the case of traditional, non-component models such as the Dynamic Conditional Correlation (DCC) and the Dynamic Conditional Correlation with breaks (MS-DCC), the null hypothesis is rejected for both positions. On the other hand, our model passes all tests with occasional rejection at the most extreme quantiles, confirming that it adequately forecasts VaR at all levels.

Table 2: VaR *p*-values

Model	Long positions			Short positions		
	5%	2.5%	1%	5%	2.5%	1%
CCC	**0.00**	**0.00**	**0.00**	**0.01**	**0.01**	**0.02**
DCC(1)	**0.01**	**0.02**	**0.01**	**0.03**	**0.02**	**0.01**
DCC(2)	**0.03**	**0.01**	**0.04**	**0.03**	**0.04**	**0.01**
DCC-MIDAS(1)	0.11	**0.04**	**0.04**	**0.02**	**0.02**	0.12
DCC-MIDAS(2)	0.13	0.11	**0.04**	0.11	**0.03**	**0.03**
mDCC	**0.00**	**0.02**	0.12	**0.03**	**0.03**	**0.03**
mGDCC	**0.00**	0.13	**0.04**	0.11	**0.03**	0.10
MS-DCC	**0.00**	**0.02**	**0.04**	**0.03**	**0.03**	0.10
treeDCC	**0.00**	**0.02**	**0.04**	**0.03**	**0.03**	**0.03**
treeDCC-MIDAS(1)	**0.00**	0.11	**0.04**	**0.03**	**0.03**	**0.03**
treeDCC-MIDAS(2)	0.14	0.12	0.12	0.11	0.06	**0.04**
DCC-MIDAS-X	0.14	0.12	0.12	0.11	0.07	**0.04**
DCC-MIDAS-C	0.14	0.12	**0.01**	0.11	0.07	**0.04**
DCC-MIDAS-XC	0.14	0.12	0.12	0.11	0.0	**0.04**
RSDCC-MIDAS(1)	0.40	0.27	**0.04**	0.49	0.13	0.36
RSDCC-MIDAS(2)	0.59	0.40	0.40	0.49	0.76	0.47

Conclusions

In this paper, we introduce a new flexible correlation component model that combines abrupt, Markov breaks in short-run correlations, driven by market-specific adjustments, with smooth regime switches in long-run correlations. The model specification is related to the established use of macroeconomic variables in long-run correlation forecasting but innovates on current approaches by using the weighted average of the macroeconomic indicator as the transition variable of structural changes in long-run correlations.

We use our model to forecast crack spread short and long-run correlations given their importance to agents trading crude oil or any of its two main refined products, and particularly so to those who trade crack spreads. Refiners are the primary stakeholders, as they are inherently exposed to both risks from crude oil and product prices and seek to protect their refining (profit) margin. We observe an improvement in in-sample fit and interpretability with respect to economic conditions, confirming the relevance of macroeconomic variables as drivers of crack spread dynamics. What is most encouraging is the model's ability to deliver accurate forecasts over medium and long horizons of interest to refiners, as well as in periods of high turbulence. We test the sensitivity of our results to the forecasting sample by considering sub-samples of homogenous crack spread volatility dynamics.

We assess our model's ability to accurately forecast global minimum variance portfolios and the VaR of short and long positions. Our findings indicate that models without breaks are always rejected in favor of component models with structural breaks in the full sample and in turbulent market periods. These findings are mainly attributable to the model's flexibility in incorporating different structural changes. This is important for planning refining operations, such as the configuration changeover that occurs in the autumn and spring at U.S. refineries. However, it is not only refiners who can benefit from our findings. Crack spreads can be used by other parties who may have exposures to both the crude and refined sides of the market, notably independent commodity trading companies that put energy at the heart of their portfolios.

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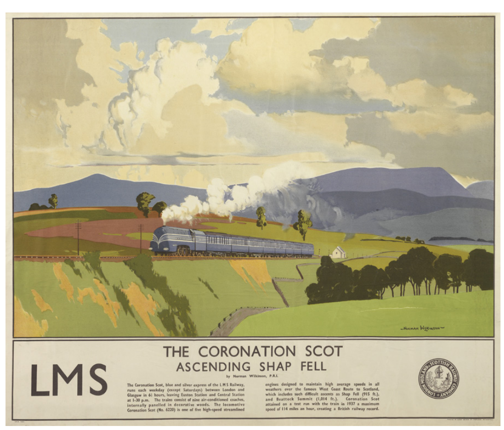
The Winter 2023 *CID* cover image is cropped from the poster for the London Midland & Scottish (LMS) Railway: The Coronation Scot Ascending Shap Fell. Artist: Norman Wilkinson, R.I., about 1937.



Text beneath reads: "The Coronation Scot, blue and silver express of the LMS Railway, runs each weekday (except Saturdays) between London and Glasgow in 6½ hrs, leaving Euston Station and Central Station at 1.30 p.m. The trains consist of nine air conditioned coaches, internally paneled in decorative wood. The locomotive, Coronation Scot (No. 6220) is one of the five high-speed streamlined engines designed to maintain high average speeds in all weathers over the famous west-coast route to Scotland, which includes such difficult ascents as Shap Fell (915 ft.) and Beattock Summit (1,014 ft.). Coronation Scot attained on a test run with the train in 1937 a maximum speed of 114 miles an hour, creating a British railway record."

On the left side of the text are the letters "LMS" with the company crest on the other side. Printed by Staffords. Credit © National Railway Museum/Science Museum Group (U.K.). ■

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