



# Dependence in credit default swap and equity markets: Dynamic copula with Markov-switching



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## ABSTRACT

Theoretical credit risk models à la Merton (1974) predict a non-linear negative link between the default likelihood and asset value of a firm. This motivates us to propose a flexible empirical Markov-switching bivariate copula that allows for distinct time-varying dependence between credit default swap (CDS) spreads and equity prices in “crisis” and “tranquil” periods. The model identifies high-dependence regimes that coincide with the recent credit crunch and the European sovereign debt crises, and is supported by in-sample goodness-of-fit criteria relative to nested copula models that impose within-regime constant dependence or no regime-switching. Value-at-Risk forecasts that aim to set day-ahead trading limits for the hedging of CDS-equity portfolios reveal the economic relevance of the model from the viewpoints of both regulatory and asymmetric piecewise linear loss functions.

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## 1. Introduction

The appropriate modeling of the dependence structure of credit portfolios and systematic risk factors is important for risk managers in setting trading limits and for traders in hedging the market risk of their credit positions and in pricing credit derivatives. In particular, the use of models that acknowledge shifts in the relationships between financial institutions' credit exposures and the underlying equity market can be beneficial for the design of more adequate regulatory frameworks and for the reduction of systemic risks under stressed market conditions. Merton's (1974) theory suggests the existence of a link between credit derivative prices and equity prices. Firm-value structural models originating from Merton's theoretical framework rest on the fundamental asset value process; that is, a

firm's default likelihood and the price of its debt are functions of the firm's asset value and the level of debt. As both the asset value and its volatility are latent, the implementation of structural credit risk models for publicly-traded firms relies on the observable equity return and a volatility proxy, while the credit default swap (CDS) spread can be taken as a measure of the firm default risk.

It can be argued that CDS spreads provide more reliable signals on the default riskiness of corporate borrowers than bond spreads, as bond prices are often distorted by tax and liquidity issues. The perception of the CDS premium as a rather “direct” measure of the default risk, together with the rapid development of the CDS market, have spurred an enthusiastic debate over the determinants of CDS spreads, and in particular, their sensitivity to structural factors such as equity returns and volatility, macrovariables, firm-specific balance sheet information and credit ratings.<sup>1</sup> Norden and Weber (2009) investigate

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<sup>1</sup> CDS contracts are designed to protect bondholders against a default of the reference entity in a way similar to traditional insurance policies.

the link between changes in CDS spreads and stock returns, while Blanco, Brennan, and Marsh (2005), Madan and Unal (2000), and Zhang, Zhou, and Zhu (2009) also consider the stock return volatility. Ericsson, Jacobs, and Oviedo-Helfenberger (2004) find that the volatility and leverage alone explain a substantial proportion of the variation in CDS premia. Yu (2006) is the first to document shifts between “turbulent” and “calm” regimes in the dynamics of CDS spreads. A common denominator of the above studies is the fact that they focus on the determinants of single-name CDS spreads. The launch of broad-based CDS indices in 2001 by JP Morgan and Morgan Stanley marks a new era in credit derivatives trading by offering increases in liquidity, tradeability and transparency; unlike single-name CDSs that are traded over the counter, CDS indices are highly standardized and are traded actively in the open market. However, the research into the dependence structure dynamics between CDS index spreads and equity market indicators is still sparse. Bystrom (2008) finds that stock returns and the stock market volatility are able to explain most of the variation in iTraxx CDS spreads. Using Markov-switching regressions, Alexander and Kaech (2008) show that the determinants of CDS index spreads are regime-specific; the implied volatility is related strongly to CDS spreads in the high volatility regime, while stock returns play a bigger role in the tranquil regime.

While all of the aforementioned empirical studies implicitly rely on the conventional Pearson’s correlation  $\rho$  as a (linear) dependence measure, the firm structural models inspired by Merton (1974) suggest that the marginal effect of a fall in equity value is not constant (as linear approaches would predict), but instead is driven by firm fundamentals such as leverage. Using an extension of Merton’s model with the realized volatility and jumps, Zhang et al. (2009) provide evidence that the strength of the relationship between credit risk and equity value depends on the firm’s credit rating. Empirical studies have suggested consistently that the credit spread predictions obtained from Merton-type structural credit risk models underestimate historical credit spreads; e.g., Jones, Mason, and Rosenfeld (1984) and Eom, Helwege, and Huang (2004). This may stem in part from the fact that the actual dependence structure of debt with equity has complex features that linear correlation models fail to capture. Recent work supports this conjecture. Hull, Nelken, and White (2004) show that the theoretical CDS spreads implied from Merton’s model using equity value and volatility as inputs are related non-linearly to historical CDS spreads. Using adaptive non-parametric regressions,

Giammarino and Barrieu (2009) provide evidence that the relationship between iTraxx Europe CDS index returns and two systematic factors, Euro Stoxx 50 returns and changes in the VStoxx 50 volatility index, suffered structural changes between 2004 and 2008.

Our paper extends recent research on the non-linear relationship between credit spreads and tradeable systematic risk factors by adopting copulae which represent a very versatile framework for the estimation of multivariate distributions. The main appeal of the copula framework is that it facilitates modeling the marginal distributions and the dependence separately, allowing a variety of dependence structures to be captured with more flexibility and parsimony than in competing frameworks (e.g., multivariate GARCH). Patton (2006) introduces conditional or *dynamic* copulae for capturing time-varying dependence structures, which represent an important improvement upon *static* copulae. The dynamic copula framework is extended by Christoffersen, Errunza, Jacobs, and Langlois (2012) to accommodate asymmetries and trends in the time-varying cross-market dependence. Far less attention has been paid to the possibility of regime-switching (RS) effects; to the best of our knowledge, the only empirical investigations that consider such things are those by Cholete, Heinen, and Valdesogo (2009), Okimoto (2008) and Rodriguez (2007) for international equity markets, Garcia and Tsafack (2011) for bond and equity markets, and Stöber and Czado (2013) for foreign exchange markets. Existing RS copula models have the limitation that they assume a constant within-regime dependence, given that a latent economic or financial state could linger for years.

This paper makes both methodological and empirical contributions to the literature. On the former, we propose flexible *Markov-switching dynamic* (autoregressive) copulae which capture asymmetry in the form of either high (‘crisis’) dependence or low (‘tranquil’) dependence. Our models generalize the existing Markov-switching static copulae by allowing for distinct mean-reversion in the dependence within each regime. We seek to provide empirical insights into the dependence structure between credit and equity markets; specifically, we jointly model the European credit market (proxied by the iTraxx CDS index) and the underlying systematic equity return factor (proxied by the Stoxx index in the aggregate European stock market), and two sectors that were at the ‘epicenter’ of the late 2000s financial crisis: automotive and subordinated financial. We carry out an in-sample statistical comparison of various copula models and draw inferences on cross-market dependence at the center and tails of the bivariate distribution. Given that CDS indices have become a very important instrument for risk hedging and arbitrage trading, and therefore a key component of institutional investors’ portfolios, we assess the relevance of the proposed Markov-switching dynamic copulae in the context of CDS-equity portfolios from a risk management perspective. The economic merits of the competing copula are assessed through a Value at Risk (VaR) forecasting exercise for setting daily trading limits for CDS-equity portfolios. These portfolios can be rationalized in light of the theoretical (i.e., the model of Merton, 1974) and well-documented negative dependence between corporate credit default risk

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However, the CDS market has been criticized for providing a false sense of security to debt holders that contributed to the 2008 financial crisis and the Greek debt crisis. In response to this critique, the 2009 Dodd-Frank Act required the Commodity Futures Trading Commission (CFTC) to regulate swaps. In the European sovereign bond market, the Collective Action Clause (CAC), which allows the majority of bondholders to agree to a debt restructuring, was introduced in order to provide an additional layer of protection for bonds issued by Eurozone members. In practice, the CAC introduces a degree of uncertainty as to the size of the payout to CDS holders, since the payout will decrease if the post-restructuring bond value falls. This extra dimension of risk is discussed in a *Wall Street Journal* article by Charles Forelle (see <http://www.wsj.com/articles>).

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