**Sectoral dependence and contagion in the BRICS grouping: an application of the R-vine copulas**

# **Chapter 1 Introduction**

## **Background and problem statement**

The minimum variance portfolio introduced by Markowitz (1952) had a major effect on how portfolio allocation is considered. The main pivot in ideology was that a portfolio should not only maximize future individual asset returns, but also minimize the correlations between said assets. Several prominent methods are based on the principle of correlation of assets. For example, a simplified approach is proposed by Elton, Gruber, & Padberg (1976) which attempts to describe the correlation structure using either a single index model or by assuming that all pairwise correlations are the same. More advanced techniques that dampen unusually large estimates for correlations have also been considered by Ledoit & Wolf (2004).

Other studies propose that portfolio allocation should depend on whether the economy is in a tranquil or turmoil market regime. For example, multiple market regimes have been represented by asset returns that follow bimodal distributions (Buckley, Saunders, & Seco, 2008). The authors of the latter paper generalize the minimum-variance portfolio of Markowitz (1952) so that the returns of assets can follow a Gaussian mixture distribution.

In addition, still in the context of rebalancing portfolios, studies attempted to uncover whether correlations of asset returns increase during turmoil market regimes. For example, Ang & Bekaert (2002) develop a regime-switching process that considers the increase in correlation of assets during turmoil periods. The same authors found that following such a strategy dominates other static strategies in the out-of-sample testing period (Andrew Ang, 2004). This lead to a variety of authors studying the increase in correlation during turmoil market conditions (see for example Campbell, Koedijk, & Kofman (2002), Graflund & Nilsson (2002) and Pelletier (2006)). Thus, these studies determine their asset allocation strategy by distinguishing between contagion, a surge in correlation during turmoil market regimes, and interdependence, whereby the correlation during tranquil and turmoil market regimes are not significantly different.

While literature abounds in distinguishing between contagion and interdependence, there is however, no consensus in terms of the methodology to be used to distinguish between the two concepts. Early papers only focussed on changes in the correlation structures between assets if there is a shock in one of the markets (King & Wadhwani, 1990). A prominent paper of Forbes & Rigonon (2002) in turn proved that the correlation estimate is biased since it depends on the variance of both markets. Forbes & Rigonon (2002) and others (see Boyer, Gibson, & Loretan (1999) and Loretan & English (2000)) continue to study unbiased estimators of the correlation structure but Corsetti, Pericoli, & Sbracia (2005) proves that these estimators have too stringent assumptions. Other authors like Horen, Jager, & Klaassen (2006) focussed on multiple regression techniques whilst others like Billio, Duca, & Pelizzon (2005) and Ye, Luo, & Liu (2017) considered regime switching models and quantile regression, respectively. Generalized Auto Regressive Conditional Heteroscedasticity (GARCH) type models have also been considered by Bonga-Bonga (2018) and Akhtaruzzaman & Shamsuddin (2018). By leaning more on extreme value theory, Longin & Solnik (2001) test for contagion by testing for significant correlation in the case of extreme returns. Furthermore, other authors have considered incorporating the copula methodology to measure contagion (Costinot, Roncalli, & Teiletche, 2000). When this methodology is used, it allows the practitioner to determine changes in linear and non-linear correlation structures. This is important since linear relationships assume that a change in one asset corresponds to a constant change in the other. On the other hand, non-linear relationships allow the relationship between the variables to change as their values change. By incorporating the R-Vine copula methodology, it allows one to find the optimal correlation structure as well (Cubillos-Rocha, Gomez-Gonzalez, & Melo-Velandia, 2019).

This study aims to add to this line of literature by proposing a new methodology to distinguish between contagion and interdependence. Contagion is in general defined as the extent of transmission of shocks during a financial crisis from one market to another. Hence, two assets will experience contagion if one can find significant correlation in the negative tails of their joint distributions, i.e. during turmoil regimes. This study adds to this line of reasoning by also testing the significance of the correlation in the positive tails of the joint distributions, i.e. during tranquil, prosperous regimes. If significant correlations can be found in the negative and positive tails, we argue that the markets are experiencing interdependence rather than contagion. This will be done by estimating the joint distributions using the R-Vine Copula methodology introduced by Joe (1997) and testing the Tail Dependence Coefficients introduced by Longin & Solnik (2001) for significant correlations in the tails of the joint distributions.

The developed methodology to distinguish between contagion and interdependence is presented by considering the Financial, Industrial and Resource sectors of the BRICS countries, i.e. Brazil, Russia, India, China and South Africa, since it consists of 5 major emerging economies that provide 23.2% of the world GDP as of April 2018 (IMF, 2018). Also, since developed markets tend to have lower costs of capital whilst emerging markets provide a higher return on capital (Henry, 2007), this set of countries should be of heightened interest to investors considering international portfolio diversification. The sectors are chosen to represent the main sources of growth for these countries and to focus on the effect of the continuous effort to align their stances on regional, financial and economic challenges (Info BRICS, 2019).

## **Research question**

Contributions to the study of contagion and interdependence by making use of copulas are presented by authors such as Hu (2006), Rodriguez (2007), Chollete, Heinen, & Valdesogo (2009) and Horta, Mendes, & Vieira (2010). These authors focus mainly on mixture copula models, regime switching copula models and testing whether there is an increase in the Kendall’s tau coefficient, a non-linear estimate of correlation, between turmoil and tranquil regimes. Other authors like Costinot, Roncalli, & Teiletche (2000), (Chan-Lau, Mathieson, & Yao (2004) and Cubillos-Rocha, Gomez-Gonzalez, & Melo-Velandia (2019) focus on integrating the copula methodology with extreme value theory.

It is against this backdrop that this study aims to add to the methodological literature by distinguishing between contagion and interdependence using R-vine copulas and Tail Dependence Coefficients (TDC). The methodology is displayed by considering the contagion and interdependence between the Financial, Resource and Industrial sectors of the BRICS economy. Contributions to the study on contagion and interdependence within the BRICS context include works by Zhang, Li and Yu (2013), Bekiros (2014), Jin and An (2016), Mensi, Hammoudeh, Nguyen et al (2016), Paul and Gideon (2017), Ji, Bouri and Roubaud (2018) and Bonga-Bonga (2018). To consider contagion on a sector level within the BRIC countries and international markets, Ahmad, Mishra and Daly (2018) study contagion between six key sectors of the BRIC countries, US and Europe. The authors show the relevance of studying contagion on a sectoral level by proving that the contagion effect is different for different sectors.

The focus of this study is then to consider a different methodology to identify contagion and interdependence as well as consider contagion on a sectoral level on the BRICS grouping. Hence, our research questions are as follows:

* Can one distinguish between contagion and interdependence by testing for significant upper and/or lower tail dependence?
* Does contagion *or* interdependence exist between sectors of the same country?
* Is there contagion *or* interdependence between the same sectors of different countries?
* Is there contagion *or* interdependence between different sectors of different countries?

## **Research methodology**

To study the contagion effects between the sectors of the BRICS countries, the study will make use of the regular vine methodology as suggested by Cubillos-Rocha, Gomez-Gonzalez and Melo-Velandia (2019), who studied exchange rate contagion between different regions of the world. The tail dependence coefficients will be considered to measure the extent of tail dependence between the different indices. Unlike other studies, this study proposes that if it is found that only the lower tail dependence coefficient is significant, then contagion is observed between the two indices. On the other hand, if the lower and upper tail dependence coefficient is significant, then interdependence rather than contagion is observed between the two indices.

Daily data over the period of January 2006 to May 2019 is used in this study. This period is chosen as to include major events from a BRICS and an international perspective. The returns are computed using indices registered on the São Paolo Stock Exchange (BOVESPA) for Brazil, Moscow Exchange (MOEX) for Russia, the National Stock Exchange of India (NSE) for India, the Shanghai Stock Exchange (SSE) for China and the Johannesburg Stock Exchange (JSE) for South Africa. A robustness check will also be performed where the sample period will be reduced to exclude the 2007-2009 US financial crisis.

## **Importance of the study**

The analysis of the relationships between different financial assets are of integral importance in portfolio optimisation. This is due to the typical goal of diversification, which is to use the relationships of different assets to minimise the risk of an investment portfolio. These relationships change when contagion is observed, thus dampening the desired effects of diversification.

Discerning between contagion and interdependence is also of significance since it may lead the investor to different investment strategies compared to the case of contagion only.

The study of contagion and interdependence is also a clear indicator of changes in relationships of financial assets post-crisis. Hence it is important for policy makers since it may allow them to mould policies in a pre-emptive fashion.

Despite the former arguments, very few studies have considered the contagion effects between the BRICS countries, let alone on a sectoral level. This study will contribute to this line of literature as well. Moreover, with the use of the regular vine copula methodology, this study will ensure that a multitude of different correlation structures are considered and non-linear relationships are accounted for.

## **Structure of the study**

The remainder of the study is structured as follows: Chapter two presents the literature review on the evolution of contagion models. Chapter three presents the econometric technique used in the study, namely, the regular vine copula methodology with the estimation and simulation of tail dependence coefficients. Chapter four presents the data and conducts the econometric estimation. Lastly, Chapter five presents the conclusion of the study and policy implications derived from the results.

(Longin & Solnik, 2001)(Markowitz, 1952)(Elton, Gruber, & Padberg, 1976)(Ledoit & Wolf, 2004)(Ang & Bekaert, 2002)(Campbell, Koedijk, & Kofman, 2002)(Graflund & Nilsson, 2002)(Pelletier, 2006)(Forbes & Rigobon, 2002)(Boyer, Gibson, & Loretan, 1999) (Loretan & English, 2000)(Corsetti, Pericoli, & Sbracia, 2005)(Horen, Jager, & Klaassen, 2006)(Billio, Duca, & Pelizzon, 2005)(Ye, Luo, & Liu, Time-varying quantile association regression model with applications to financial contagion and VaR, 2017)(Bonga-Bonga, 2018) (Akhtaruzzaman & Shamsuddin, 2018)(Hu, 2006), (Rodriguez, 2007), (Chollete, Heinen, & Valdesogo, 2009) and (Horta, Mendes, & Vieira, 2010)(Costinot, Roncalli, & Teiletche, 2000), (Chan-Lau, Mathieson, & Yao, 2004) and (Cubillos-Rocha, Gomez-Gonzalez, & Melo-Velandia, 2019)

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