North American Journal of Economics and Finance 42 (2017) 461–472

Contents lists available at ScienceDirect

North American Journal of Economics and Finance

journal homepage: www.elsevier.com/locate/ecofin

Measuring systemic risk of the US banking sector in time-frequency domain

Petr Teply *, Ivana Kvapilikova

Department of Banking and Insurance, Faculty of Finance and Accounting, University of Economics in Prague, Winston Churchill Sq. 4, 130 67 Prague, Czech Republic

ARTICLE INFO

Article history:
Received 16 April 2017
Received in revised form 9 August 2017
Accepted 14 August 2017

Keywords:
Bank
Conditional value at risk (CoVaR)
DCC GARCH
Tail dependence
US banks
Wavelet analysis
Wavelet Conditional Value at Risk (WCoVaR)

ABSTRACT

To estimate short-term, medium-term, and long-term financial connectedness, we propose a frequency-based approach and measure the contribution of individual financial institutions to overall systemic risk. We derive Wavelet Conditional Value at Risk (WCoVaR) – a robust market-based measure of systemic risk across financial cycles of differing length. We evaluate the systemic importance of financial institutions based on their stock returns and use wavelet framework to analyze returns in a time-frequency domain. Empirical analysis on US banking sector data between 2004 and 2013 demonstrates that wavelet decomposition can improve the forecast power of the CoVaR measure. We use panel regression to explain systemic importance of individual banks, using their objectively measurable characteristics and conclude that size, volatility and value-at-risk are the most robust determinants of systemic risk.

1. Introduction

Accurate and timely measurement of systemic risk is a starting point towards designing a macroeconomic policy aimed at promoting market discipline and strengthening the stability of the financial system. Sources of systemic risk are usually investigated on aggregate level rather than at different time frequencies as documented by Bisias, Flood, Lo, and Stavros (2012). As a result, some sources of this risk might remain hidden when several fundamental properties of connectedness are overlooked. It is therefore essential to identify and measure the drivers of this risk over the short, medium and long term separately. To capture this, we develop a market-based approach and use Conditional Value at Risk (CoVaR) to estimate the sensitivity of individual financial institutions to overall systemic risk.

The fall of Lehman Brothers in 2008 serves as a testament to tail interdependence across global financial institutions as losses spread across institutions, threatening the whole financial system. Since then, the need for tools to detect systemic risk has been much highlighted and has been of interest to academic researchers (Acharya, Engle, & Richardson, 2012; Acharya, Pedersen, Philippon, & Richardson, 2010; Black, Correa, Huang, & Zhou, 2016), national stability regulators (BCBS, 2009; Borio, 2011), and policy makers (U.S. Congress, 2010). The recent 2007–2009 global crisis provides ample evidence that widespread failure of financial institutions imposes an externality on the rest of the economy, requiring adoption of a system-wide macroprudential approach to bank regulation (Borio, 2011). It is important to identify systemic events at

* Corresponding author.
E-mail addresses: petr.teply@vse.cz (P. Teply), ivana.kvapilikova@gmail.com (I. Kvapilikova).

http://dx.doi.org/10.1016/j.najef.2017.08.007
1062-9408/

early stages to empower regulators to take requisite steps that can effectively lower the probability of a systemic crisis or minimize its potential consequences (IMF, 2009).

Since the global financial crisis, several models measuring systemic risk have been proposed to increase the predictability of systemic risks and empirically tested. Acharya (2009) analyze contribution of a financial institution to systemic risk when the system is in the left tail of its profit/loss distribution. Adrian and Brunnermeier (2014) presents a CoVaR model and measure co-movement and contagion in financial series. However, Löffler and Raupach (2016) argue that CoVaR can imply a lower systemic risk contribution if a bank increases its idiosyncratic risk provided that an institution has a large weight in the system. Mainik and Schaanning (2014) suggest a modification of CoVaR in order to improve its dependence consistency. Adrian and Brunnermeier (2014) suggest using forward CoVaR based on economic and accounting figures rather than returns for regulatory purposes. In this paper, we attempt to moderate undesirable sensitivities to idiosyncratic risk resulting from a linear model of the market by estimating a non-linear model of returns.

Brownlees and Engle (2012) rank systemic importance using the SRISK index, based on firms' size, leverage and equity loss. IMF (2009) presents a Systemic Risk-adjusted Liquidity (SRL) model which links a firm's assets and liabilities mismatch. Black et al. (2016) use Distress Insurance Premium (DIP) model to measure systemic contribution of individual banks to systemic risk. Klinger and Teply (2014) demonstrate how agent-based models can be used to conduct stress tests of the banking system, while Klinger and Teply (2016) construct an agent-based network model of an artificial financial system to analyze the effects of state support on systemic stability. Bisias et al. (2012) present a comprehensive overview of methodologies used in systemic risk models.

Our study is motivated by higher systemic risk of the US banking sector after the Lehman Brother's collapse in 2008. However, relative infrequency of occurrence of systemic shocks restricts the development of useful empirical and statistical intuition for financial crises. Current approaches vary from tail measures based on the concept of value at risk (VaR) and expected shortfall, to elaborate network-based models. There is an ongoing discussion on the strengths and weaknesses of different models. Models are often sensitive to the frequency of observations chosen and the sampling rule employed. We use the wavelet method to solve this problem. Wavelet transform applied to financial data generates time-frequency representation of the original time series, which allows us to study both long-term and short-term relationships. The riskometers can therefore be adjusted to capture variability on the frequencies which are relevant to research. Wavelets were introduced for financial series analysis by Ramsey and Zhang (1997), who used them to decompose a time series of tick-by-tick observations of exchange rates. Our paper successfully applies this theory to empirical data and facilitates the development of a robust measure of systemic risk at different time horizons. It is justified to assume that agents operate on different investment horizons since they follow their preferences as consumption-based asset pricing models indicate (Bansal & Yaron, 2004; Ortu, Tamoni, & Tebaldi, 2013). Moreover, Diebold and Yilmaz (2009, 2011) show that variance decompositions from approximating models can be used for empirical analysis of connectedness.

Through this work, we propose a new measurement technique to evaluate financial data at different frequencies. The used wavelet methods allowed us to extract frequency information from time series while maintaining the time localization of fluctuations and shocks. Such approach is intuitively sound since financial markets are populated by traders with diverse trading horizons who induce fluctuations and create cycles of differing lengths. Multiresolution analysis (MRA) enabled us to work with data sampled at the highest possible frequency and then filter it to isolate different time scales. Literature on wavelet application to risk models is still scarce and mostly concentrated around validation of the CAPM model. Wavelet methods have been used in the past by researchers to estimate the beta risk measure and verify the CAPM hypothesis by performing an analysis on different investment horizons (Gençay, Selçuk, & Whitcher, 2005; Rhaeim, Ammou, & Mabrouk, 2007). Wavelet tools served Fernandez (2006), to analyze VaR of Chilean stocks; Khalfaoui (2015), to decompose volatility spillovers; Rua and Nunes (2009), to measure correlation between international stock market returns on different scales by the wavelet squared coherence coefficient; Vacha and Barunik (2012), to study co-movement of energy commodities.

We use wavelet methods to contribute to ongoing research with a revised measure of systemic risk. As we are primarily interested in long-term relationships which pose a potential risk of a crisis and a financial contagion, we benefit by extracting patterns created by longer cycles. The properties of the new riskometer WCoVaR are inspected using a panel regression on financial characteristics of institutions collected over the 2004–2013 period. The results of our analysis help in identifying the most robust determinants of systemic risk which can be considered by policymakers and regulators.

The remainder of this paper is organized as follows. Section 2 outlines the methodology, the mathematical framework of ΔCoVaR estimation, conditional volatility modelling and the wavelet transform. Section 3 presents the empirical analysis together with its results and Section 4 concludes the paper.

2. Methodology

2.1. Wavelet approach

Wavelet methods comprise innovative approaches to time series analysis allowing one to extract frequency information from time series (Percival & Walden, 2000). This approach originated from Fourier analysis which represents a series in terms of the frequencies it contains, but loses the time information altogether. To recover it, the Fourier transform can be