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Managing financial risk in Chinese stock markets: Option pricing and modeling under a multivariate threshold autoregression

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ABSTRACT

The Shanghai Stock Exchange and the Shenzhen Stock Exchange have grown remarkably since their inception 20 years ago. Many of the investors in these two markets are asset management firms or pension funds, some of which may offer guaranteed returns to their clients. To these investors, modeling and managing the risk associated with their equity investments are highly important. In this paper, we use a multivariate threshold autoregressive (TAR) process to model the non-linear relationship between the two markets. This model may help fund managers better plan or execute their risk management decisions, as it captures the difference in investment return behavior when one market significantly out- or under-performs the other. We also contribute a risk-neutral version of the multivariate TAR model to the literature. This contribution permits one to price exotic options written on multiple stock indexes, and consequently helps fund managers calculate the cost of an option-based risk management strategy for funds involving the two Chinese markets.

1. Introduction

China's economic growth has been remarkable over the past 2 decades. According to the World Bank, its GDP growth has been consistently greater than 7.5% per annum since 1991. Rapid equity market development has accompanied this economic growth. The first stock exchange of mainland China was found in Shanghai in November 1990. In 2011, its market capitalization was RMB 14,838 billion, more than 5000 times its amount 20 years ago. The number of listed companies increased from 8 in 1990 to 931 in 2011. In December 1990, China's second stock exchange was established in Shenzhen. This stock exchange, which is located in the country's richest province, is also a success story. As of this writing, it has 1537 listed companies and a market capitalization of RMB 8,010 billion.

These two Chinese stock markets attract a wide range of investors, both domestic and foreign. In particular, the exchanges issue two types of stocks: "A" shares and "B" shares. Trading in A shares was initially restricted to domestic investors only, and B shares were available only to foreign investors. In 2003, the Chinese government launched the Qualified Foreign Institutional Investor (QFII) program, under which some foreign institutional investors are permitted to buy and sell A shares. At present, 98 foreign institutional investors have been approved to trade A shares. Many local and overseas institutional investors in the two stock markets are asset management firms or pension funds, some of which may offer guaranteed returns to their clients. To these investors, modeling and managing the risk associated with their equity investments are highly important.

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A fair amount of research work has attempted to model investment risk in the Chinese stock markets. For instance, Fabozzi, Tunaru, and Wu (2004) model volatility for the Chinese equity markets using a series of univariate GARCH models. Darrat and Zhong (2000) investigate whether the random-walk hypothesis holds in the Chinese stock markets by conducting various statistical tests. Guo, Brooks, and Shami (2010) use a Markov regime-switching model to detect hot and cold cycles in the Chinese A-share IPO market. Wang, Chen, and Huang (2011) use a time-varying copula approach to evaluate the dependence between the Chinese stock markets and other major world markets. Other contributions on this topic include the work of Bhar and Nikolova (2009), Chiang, Nelling, and Tan (2008), Kang, Jiang, Lee, and Yoon (2010), Lima and Tabak (2004), Lin, Menkveld, and Yang (2009), Los and Yu (2008) Moon and Yu (2010), Ureche-Rangau and de Rorthays (2009), Yu, Fung, and Tam (2010), Zhang and Li (2008), Zhu (2009) and the references therein. Nevertheless, in the aforementioned papers, the two markets are often considered in isolation, leaving the dynamic relationship between the two markets being relatively unexplored.

More sophisticated investors are exposed to both the Shanghai and Shenzhen stock markets, and models that incorporate the dynamic relationship between the two markets may help these investors better plan or carry out their risk management strategies. Furthermore, both markets have the same trading currency (RMB, the official currency of PR China) and hours. Each day starts with a pre-open phase (from 09:15–09:25), a morning session (09:30–11:30) and an afternoon session (13:00–15:00). The non-linear TAR model allows investors and risk managers to further explore possible cross market arbitrage opportunity under different market conditions (Perlin, Dufour, & Brooks, 2013). The first objective of this paper is to introduce an alternative approach to modeling the non-linear dynamic relationship between the equity markets in Shanghai and Shenzhen. We add to the developing literature on the subject, known for using advanced modeling techniques such as multivariate GARCH models (Johansson, 2009; Li, 2007), time-varying copula models (Guegan & Zang, 2009) and vector autoregressive (VAR) models (Groenewold, Tang, & Wu, 2004; Liu, Song, & Romilly, 1997; Zhu, Lu, Soofi, & Wang, 2004).

We implement the threshold autoregressive (TAR) model, which was first introduced by Tong (1983) and subsequently generalized to a multivariate version by Tsay (1998). This modeling approach has been used to capture the non-linear dynamics of various time-varying random variables, ranging from foreign exchange rates to unemployment rates (e.g., Chan & Cheung, 2005; Chung, Chan, & Batten, 2011; De Gooijer & Vidiella-i-Anguera, 2003; Montgomery, Zarnowitz, Tsay, & Tiao, 1998; Potter, 1995; Yadav, Pope, & Paudyal, 1994). The idea behind the TAR model is to model the conditional mean of a time-varying variable in a piecewise linear manner. However, unlike traditional piecewise linear models that permit structural changes in the "time" space, the TAR model uses the "threshold" space to improve approximation. The model contains $k \geq 2$ regimes, each of which is characterized by a different parameter set and possibly a different autoregressive order. The switch between the k regimes is governed by a threshold variable, which in our setup is defined as the average difference between the returns in the two Chinese stock markets over a certain lookback period.

There are several advantages to modeling the dynamic relationship between the equity markets in Shanghai and Shenzhen using a multivariate TAR model. First, through the threshold variable, the TAR model is able to incorporate information about the difference between the performances of the two stock markets in mainland China. Second, the TAR model is able to capture the two-way asymmetric relationship between the two stock markets, and even permits the relationship to depend upon the current market landscape. Consequently, relative to a Granger causality test, which gives only a uni-directional relationship (e.g., Liu et al., 1997; Zhu et al., 2004), the TAR model may be more informative. Third, the TAR model reveals the lead–lag relationships between the two stock markets. Understanding which market leads the other may allow fund managers to execute their risk management decisions more effectively.

Among the different ways to manage equity risk, derivatives are often considered as a low-cost, effective risk management tool. For instance, one may limit the loss on an equity fund by purchasing put options on the stock index(es) to which the equity fund is related. An appropriate use of options may also improve the equity fund's risk profile, in terms of risk metrics such as Value-at-Risk. In comparison with buying and selling shares of stocks directly, trading derivatives enables a fund manager to adjust the fund's exposure to the stock market(s) more quickly and at a smaller cost. To fund managers who are tapping into both stock markets in mainland China, exotic options written on both equity indexes are particularly useful. Such options permit fund managers to hedge the risks arising from multiple markets with a single instrument, thereby decreasing the effort required for risk management (see Ng, Li, & Chan, 2013).

Despite the usefulness of multivariate TAR models in modeling the return dynamics of multiple stock markets, option pricing under a multivariate TAR model has not yet been explored. The second objective of this paper is to fill this gap by studying how the risk-neutral pricing of options written on multiple underlying assets may be accomplished under a multivariate TAR model. This research problem is difficult because the use of a TAR model implies market incompleteness. When a market is incomplete, there exists more than one risk-neutral probability measure, which in turn means that the price of an option is not unique. A crucial step in solving this problem is to identify an appropriate risk-neutral probability measure. Although this can be achieved in a few ways, we make use of the economically justifiable Esscher transform.

The original Esscher transform was proposed by Gerber and Shiu (1994, 1996). It was then extended by Bühlmann et al. (1996) to the "conditional" Esscher transform, which may be used to identify risk-neutral probability measures for several classes of univariate time-series models, including the GARCH (Li, Hardy, & Tan, 2010; Siu, Tong, & Yang, 2004), regime-switching (Siu, 2005; Siu, Lau, & Yang, 2008) and TAR (Siu, Tong, & Yang, 2006) models. This paper offers a multivariate extension of the work of Siu et al. (2006), on the basis of the multivariate version of the conditional Esscher transform, documented by Kijima (2006), Rombouts and Stentoft (2011) and Ng and Li (2011, 2013). Our contribution permits one to price exotic options written on both the Shanghai and Shenzhen stock indexes, and consequently helps fund managers calculate the cost of an option-based risk management strategy for funds involving the two markets. We also add a numerical illustration based on a multivariate TAR model fitted to real stock index data.