Reviewing on China Development on Stock Market Volatility Model for The Last 20 Years

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Abstract. Studying for volatility is important for risk management, since extreme shock can have terrible impact on the economy as well as on people's lives. Therefore, this article would like to review on the development of stock market volatility model in China for the last 20 years, hoping to find out how the scholars think of those models, what are the problem to these models and what is the future direction of studying the volatility model. The article does a literature review on some of the researches done for the study on the volatility of China stock market, focusing on what model they use, what data they use as well as the reason and what they find in conclusion and whether there is any latest research on some new model to estimate volatility. The review finds that finding the suitable distribution instead of normal distribution on volatility model to better describe the heavy-tailed, high-kurtosis and asymmetric characteristic of China stock market, and applying high-frequency and mixed frequency data has been a trend of research in China. Therefore, applying more latest and derived mixed frequency data when predicting the volatility of China stock market or looking for more macro variables that are related with the fluctuation, comparing how they perform in China stock market and which distribution can help those models to predict the volatility better will be the research direction and possibly the development trend of future research for China.

Keywords: Risk management, VaR; GARCH, China stock market, Mixed frequency volatility model.

1 Introduction

Describing the volatility and the fluctuation as a tools of risk management has been a hot topic for financial research for decades. In the last 20 years, China also started to try studying the advanced model in financial area, apply them to China stock market and look for the one that suits the actual situation in China market best, but haven't found the most suitable one yet. In the meantime, looking for the best model for financial asset has also been an important topic globally and models has been derived all the time. This article will look back on the development of using VaR, ARCH, GARCH model and many other models derived from them to describe the risk and the fluctuation

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of China stock market, how they are applied by Chinese scholars, what is the reason for using these models and how the performance are when these models are actually applied to China stock market and finally some latest study on it. This article will review on many literature related to VaR, ARCH and GARCH model that has been done since 2000 and compare them base on the model they used, the period of data, the stock market they choose and what conclusion do they have. This can help the future research by summarizing the research method used by previous scholars, learning about how they decided the model to be used and why they believe the model to be appropriate, what data they use and how did they do with those data and to see the latest research direction and what haven't the previous scholars done. The following article will summarize some of the literature on VaR, ARCH and different type of GARCH model mainly based on the publication time.

2 VaR model

Value at Risk (VaR) represents the financial losses at a certain level of probability at a specific moment, has been treated as one of the most important models in risk measurement since it was put forward. According to Wang, Wan and Zhang [1], VaR was put forward in a situation where some traditional risk management tools were not universally applicable for nonlinear financial derivative, therefore, a model that can not only handle with the nonlinear options but also provide a quantile indicator to the market risk is in need.

VaR is calculated with the quantile of a certain distribution of returns, where the process of determining the distribution affect the effectiveness of VaR in describing risk, inappropriate choose of distribution can usually leads to miscalculation of risk, mostly underestimated. There are mainly three ways of calculating VaR, that is the historical method, the variance-covariance method and the Monte Carlo method. The historical method is to consider the frequency of all changes of market factors in the history and use them to simulate the future distribution for the VaR, while the Monte Carlo method assume the market factors follow such as normal distribution and use the historical data to calculate the coefficient of the distribution to build a model and finally use the model to simulate the result. The variance-covariance method simply assumes the historical return to follow some specific distribution as use the characteristic of that distribution to simulate the future return.

However, VaR also has some trouble when using. In Wang, Wan and Zhang's article [1], they mentioned that the heavy-tailed characteristic can be found commonly in financial probability density function, which means in real life, the possibility of suffering from extreme shock will be higher than that from normal distributed assumption, the one which people often use for calculating VaR. This heavy-tailed characteristic together with the high-kurtosis characteristic later become the problem that almost every researcher has to face. Besides, as long as historical data is used to estimate the future one, it assumes that future fluctuation are somehow can be describe by the historical one. However, this is very likely to be false in an extremely volatile market. When studying the fluctuation and volatility of China stock market, scholars may prefer

the daily data after 2000 or 1997, when China stock market first have the Price Limits System. Xu and Huang [2], Chen and Yu [3] both expressed such reasons in their works.

3 ARCH and GARCH model

Since the model of estimating the future return and volatility in VaR is not specified, models that can describe the uncertainty in the stock market are also required. Autoregressive Conditional Heteroskedasticity (ARCH) model, proposed by Engle [4] in 1982, use conditional volatility in replace of constant volatility since heteroskedastic is commonly seen and Engle finds that the past data has influence on the future data. Therefore, he assumed the volatility to be autoregressive and build up the model base on this. Engle first use this model to solve the volatility problem in his work. ARCH model can describe the volatility clustering in a certain level, where volatility clustering means "large changes tend to be followed by large changes, of either sign, and small changes tend to be followed by small changes." [5], which is a fairly common phenomenon in the time series data of financial assets. Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model was developed by Tim Bollerslev in 1986 [6]. GARCH model incorporates a moving average term together with the autoregressive term base on the ARCH model.

Zou, Zhang and Qin applied of GARCH model on China stock market in 2003 [7]. In their work, they use the data of the closing price of Shanghai Composite Index (SSEC) from 1997.10.27 to 2001.2.8 to calculate the rate of return. Due to the heteroscedastic shown by the non-normal data, they believe that the GARCH model can describe the data well to some extent, and they use GARCH(1,1) model to fit the data base on the normality assumption. They eventually find that GARCH(1,1) can estimate the fluctuation at both 95% and 97.5% confidence level, while RiskMetrics can only done it at 95% confidence level, which is another method of calculating VaR launched by J.P. Morgan early in 1994. However, they do find that at 99% confidence level, GARCH(1,1) model will underestimate the level of risk, which they believe comes from the high-kurtosis and heavy-tailed characteristic of the data.

In 2002, Chen and Yu also studied on applying the GARCH model and the VaR model on China stock market [2]. They use some other models derived based on GARCH called GARCH-in Mean (GARCH-M) model, EGARCH-M and LGARCH-M model proposed by Engle, Lilien and Robbins in 1987 through adding a heteroskedasticity term into the mean equation [8]. Chen and Yu tried to apply each of normal distribution, t-distribution and Generalized error distribution (GED) on those three models to see how well they can describe the volatility. They find out that at 99% confidence level, both t-distribution and GED can make each model fitting the data better than normal distributed one. This is mainly because both t-distribution and GED can better describe the situation of heavy-tailed and high-kurtosis distribution, which is more practical in financial context. Besides, since they apply their models to not only the SSEC from 1996.12.16 to 2001.5.23 but also on Shenzhen Composite index (SZSC) in the same period, they find the VaR in average is higher for SZSC than for SSEC,

which shows that Shenzhen stock market has higher risk than Shanghai stock market from 1997 to 2001.

Later, Xu and Huang also studied on using different distribution on GARCH model as well as many derived forms for China stock market [3]. They use a Skewed-t distribution proposed by Fernández and Steel in 1998 by adding a skewness term to study the asymmetric [9]. They use only the SSEC from 1998.1.5 to 2006.11.6 because they think the data of SSEC are highly related with SZSC. In the meantime, Shanghai Stock Exchange opened earlier, had higher market value than Shenzhen Stock Exchange and are more sensitive to the external shock. They find that when assuming normal distribution, all model cannot perform well in fitting the data and will underestimate VaR. As for Skewed-t distribution, model can then fit the data much better and the phenomenon of underestimated VaR will be mitigated significantly. This proved the Skewed-t distribution to probably be a better distribution to be used when applying model. Xu and Huang also find that Fractionally Integrated GARCH (FIGARCH) model, fractionally integrated exponential GARCH (FIEGARCH) and Integrated GARCH (IGARCH) can also improve the performance in estimating the risk and can help mitigated the underestimation of VaR.

Exponential GARCH (EGARCH), proposed by Nelson in 1991 [10] and Threshold ARCH (TARCH), proposed by Zakoian [11], Glosten, Jagannathan, Runkle [12] are two model developed from ARCH and GARCH model, which can characterize information asymmetry and include the leverage effect. Xu [13, in her studies in 2010, use both Shenzhen Component Index (SZI) and SSEC from 2000.1.3 to 2007.1.1 to calculate the rate of return, and find out that the data not only displayed high-kurtosis and heavy-tailed, but also has a nonzero skewness, which is further evidence of the non-normality of China stock market. Xu then applied GARCH, EGARCH and TARCH model on the data and find EGARCH and TARCH both able to describe the data better than GARCH model. This prove that there is leverage effect in China stock market.

In 2010, Wei did research on comparing some of the volatility model to try finding the one that best suit China stock market [14]. He mentioned that there are mainly three types of volatility model for financial asset: historical volatility (HV) model, built base on the historical return such as ARCH, GARCH and stochastic volatility (SV) model, implied volatility (IV) model which is used for determining option price and realized volatility (RV) model which use high-frequency data as a component of estimating daily volatility. Wei used daily data from CSI 300 index from 2005.4.8 to 2008.4.8 as the low-frequency data and the high-frequency data for every 5 minutes from CSI 300 during the same period. He finally finds that RV model with high frequency data perform much better than HV model. Even by adding RV as a component into the GARCH model cannot help the GARCH model to have a better prediction on the fluctuation to CSI 300 index.

4 Mixed frequency volatility model

In 2018, Wei also did research with Lei, Yu and Lai on the uncertainty of economic policy uncertainty [15]. The reason for their study is that they find Baker use the data

from the US to prove that the uncertainty of economic policy uncertainty played an important role during 2007 and 2011 that leads to the uncertainty of the outlook of US economic in 2012 [16] and later proposed an index called economic policy uncertainty (EPU) index in 2016 [17]. Also, there was a model proposed by Ghysels, Santa-Clara and Valkanov in 2004 called the mixed sampling frequency data analysis (MIDAS) [18] and later combined with GARCH model and proposed the GARCH-MIDAS model by Engle, Ghysels and Sohn in 2013 [19]. This GARCH-MIDAS use both long-term and short-term components to describe the high-frequency volatility and use low-frequency volatility or macro variables as factors to describe the long-term fluctuation. Since no one has used EPU as a low-frequency variable to study on the volatility of China stock market at that time, Lei, Yu, Wei and Lai decided to apply GARCH-MIDAS on it. They use the daily data of SSEC from 1996.12.16 to 2016.6.30 together with Baker's monthly data of EPU index of China and find out that GARCH-MIDAS can fit the data well and EPU index does can reflect the long-term fluctuation of the China stock market. By using EPU index in GARCH-MIDAS model, the model can have a good performance in estimating volatility of China stock market. By using the mixed sampling frequency data, the model can perform much better than the original GARCH model using same frequency data.

Yu and Wang also studied on the mix frequency data in 2018 [20]. Learning from some previous studies, they believe that high-frequency data can help improve the accuracy of estimation on volatility. Also, they think that the high-frequency data can be used to describe or predict low-frequency data. They built a Mix frequency Realized GARCH (M-Realized GARCH) model base on the Realized GARCH model proposed by Hansen in 2010 [21]. They use high-frequency days of yields to build the realized volatility function, and combine it with the GARCH model for this M-Realized GARCH model. Yu and Wang use both Realized GARCH, M-Realized GARCH as well as the traditional GARCH model separately under the assumption of normal distribution, t-distribution and GED on both the low-frequency and high-frequency data collected from the CSI 300 index from 2013.11.14 to 2016.11.11. They also collect the closing price for the first hour every day during this period. In the process of research, they find that the first hour data contribute 58.6% of both the daily return and the daily volatility, this shows that the trading behavior is very active and the market fluctuate wildly for the first hour in a trading day. Eventually, under the SPA test, they find their M-Realized GARCH model to be able to estimate the volatility best comparing to other model, and the M-Realized GARCH model under the assumption of t-distribution fit the data better than any other model with other distribution they tried.

5 Conclusion

There have been many studies focusing on the estimating volatility for the stock market in the last 20 years in China. The use of models, data, statistical testing methods and risk management tools have developed a lot rapidly. As we can see from the article above, China have just started to learn from some basic concept and model early in the

beginning of 21st century, such as the basic VaR, ARCH and GARCH model. Researchers now has begun to apply some latest model into China stock market and develop their own model that suit China stock market better lately these years. Besides, most of the research before use only the data from Shanghai Stock Exchange before 2010. As the Shenzhen stock market development.

The appearance of CSI 300 index also provides the researchers with a new data to be used for further learning about China stock market after the index came out in 2005. This also reflects the evolution and development of China stock market. As the time goes by, CSI 300 index can provide us with data with larger sample in the future. Also, we can see that many researchers have the trend of starting to focus on the studies of high-frequency data and the mixed frequency data model because we can see that high-frequency data and the mixed frequency data model can have better performance than some traditional data using low-frequency data and the data in same frequency. In the meantime, some scholars mentioned that normal distribution has a poor performance on the volatility estimating model and try some other one such as t-distribution, GED and the Skewed-t distribution on volatility mode since they can describe the heavy-tailed, high-kurtosis and asymmetric characteristic, which shows commonly in China stock market. Therefore, applying more latest and derived mixed frequency data when predicting the volatility of China stock market or looking for more macro variables that are related with the fluctuation such as EPU into different mixed frequency model such as GARCH-MIDAS model, comparing how they perform in different stock market or CSI 300 index, and which distribution can help those models to predict the volatility better will be the research direction and possibly the development trend of future research. As market conditions can change under extreme shocks, it is also possible to look at retesting the validity of some previously established findings, such as different distributions and volatility models after Covid-19.

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