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Market Risk Measurement
Preliminary Lessons from the COVID-19 Crisis

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Abstract This chapter presents a preliminary analysis on how some market risk measures dramatically increased during the COVID-19 pandemic, with measures computed over longer horizons experiencing more pronounced effects. We provide examples when regulatory market risk measurement proved to be suboptimal, overestimating risk. A further issue was the large number of Value-at-Risk 'exceptions' during the first few months of the crisis, which normally leads to overinflated bank capital requirements. The current regulatory framework should address these problems by suggesting improvements to the calculation of risk measures and/or by modifying the rules which determine capital requirements to make them appropriate and realistic in crisis situations.

Keywords Market risk. Measurement. Value-at-Risk. Expected Shortfall. Regulation. Basel.

Summary 1 Introduction. – 2 Overview of the Market Risk Regulation Before the Crisis. – 3 Market Risk Measurement Over the First Five Months of the Crisis. – 4 Challenges to the Regulatory Framework. – 5 Looking Ahead. – 6 Conclusions.

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1 Introduction

The coronavirus pandemic has been one of the most devastating global crises since the Second World War. It has had far-reaching consequences that affected all countries to varying degrees. The most tragic impact has been the loss of lives, but also job losses, the lack of healthcare access and the effects on mental health etc. have been devastating. The outcome of the pandemic in the financial sector has been a financial crisis, named the COVID-19 crisis. Ramelli and Wagner (2020; forthcoming) compare stock performances by industry as early effects of the crisis, and identify the Energy sector as being the worst hit whilst Telecom, Pharma & Biotech reaping the largest gains. Acharya and Steffen (2020) highlight how stock performance depended on liquidity as stocks with high liquidity performed better. Aldasoro et al. (2020) raise concerns about the long-terms prospects of banks, as the banking sector has been more severely hit than most sectors, and argue that the consequences are comparable with the outcomes of the 2008 global financial crisis.

Here we investigate how financial risks increased and how the crisis affected financial institutions, with a focus on market risk measurement, and we discuss the challenges faced by regulators. We examine the first five months of the crisis, analysing the effects of equity market index risk factors, and to some extent commodity risk factors, as these are the risk dimensions most affected by the COVID-19 crisis. Other risk factors indicated serious levels of market stress. Examples include government bond yields, which reached historical lows, and volatility risk factors, such as the CBOE VIX index, which had its largest shocks, both positive and negative and reached its highest value ever of 82.69 in March 2020, as illustrated in figure 1 **[fig. 1]**. At the time of writing the crisis is still affecting the economies worldwide as well as the day-to-day lives of millions.

2 Overview of the Market Risk Regulation Before the Crisis

Market risk refers to the risk of losses arising from adverse movements in market prices of assets. From a regulatory perspective, the Basel Committee on Banking Supervision (1996) first introduced market risk capital reserves against unexpected asset price movements in the trading books of banks. Since then, Value-at-Risk (VaR) has become the dominating measure of market risk, which financial institutions and regulators use to make risk-informed decisions and to calculate market risk capital requirements. VaR is defined as the potential loss one may face over a given time horizon with a pre-defined confidence level. For example, if the 99% 10-day VaR is $1 million, there is 99% chance that the losses will not exceed $1 million over the next 10 trading days.

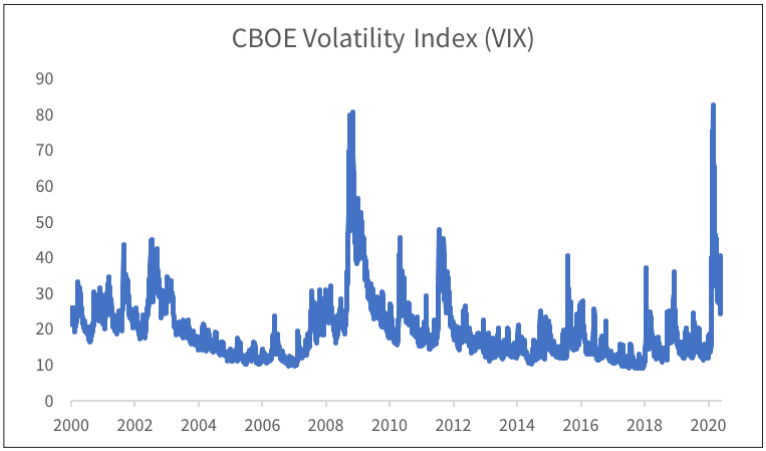

Figure 1 CBOE volatility index from 2000-01-23 to 2020-06-23

In the aftermath of the 2008 global financial crisis, the flaws of market risk regulation have become evident. For instance, the VaR-based risk assessment has been found to underestimate the risks in turbulent markets. To address these problems, the Basel Committee on Banking Supervision (2019) published revisions to its global regulatory standards that include a move from Value-at-Risk to Expected Shortfall (ES). ES measures the average loss beyond the VaR threshold in the tail of the loss distribution, producing more accurate gauges of tail risk. The typical confidence level is 99% for VaR and 97.5% for ES, corresponding to the 1% and 2.5% worst-case losses, respectively. Moreover, considering the liquidity of various assets, varying time horizons are used to evaluate financial risks, i.e. 10 days for large cap equities, 20 days for small cap, and up to 120 days for some risk categories. However, the latest regulations stipulate that these risk calculations are based on overlapping 10-day returns and we discuss this procedure in our risk assessments.

Figure 2 shows the 10-day 97.5% ES[1] calculated using the most widely accepted risk model in the industry, Historical Simulation (denoted by HS in the following), based on the S&P 500 index returns (2000-06-26/2020-06-23), and plots it along the index **[fig. 2]**. Within one week during March 2020, the index was hit by a shock of around -19% cumulative return. As the figure shows, during the global finan-

1 Throughout this chapter, ES is expressed in returns, of which the value is nonnegative; a rolling window scheme is used to estimate ES with a window length of 250 trading days.

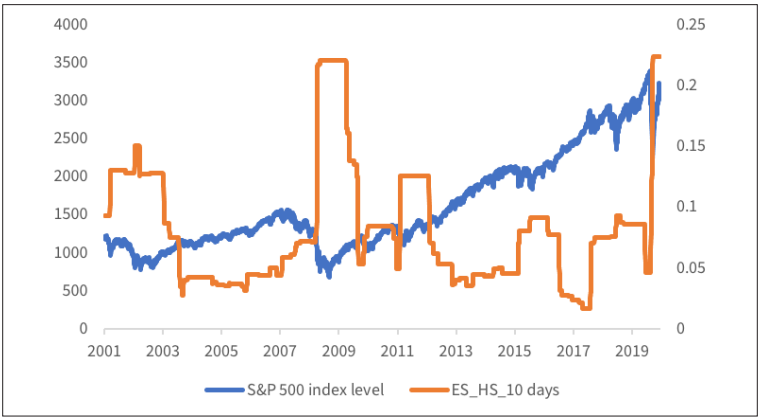

Figure 2 10-day Historical Simulation ES at 97.5%, based on S&P 500 index returns from 2000-06-26 to 2020-06-23

cial crisis between mid 2007 and early 2009, as well as during the sovereign debt crisis which peaked between 2010 and 2012, the risk measure, ES, peaked. The same can be seen during the crisis wrought by the coronavirus pandemic, with ES reaching a level comparable with the ES during the financial crisis, as also discussed in Capelle-Blancard and Desroziers (2020). It is to be noticed that the ES during the crisis increased to multiple times the level before the crisis.

Though the first cases of COVID-19 date back to December 2019, the lockdown in China occurred on January 23, 2020. Following this, the virus spread quickly over other parts of the globe and a global pandemic was declared by the WHO on March 11, 2020.[2] On seeing the widespread effects of the coronavirus outbreak on the economy and the banks, prudential authorities as well as local jurisdictions decided to delay the implementation of the latest version of market risk regulatory framework (Basel Committee on Banking Supervision 2019), called the Fundamental Review of the Trading Book (FRTB), until January 2023. This gives regulators time to consider suitable changes to market risk measurement and management in the new Basel framework, if required. It also gives financial institutions breathing space to reevaluate their market risk estimation methodologies as well as the steps needed to be taken to reduce risk exposures to an acceptable level. Also, risk estimates such as VaR and ES depend

2 More information about how this global event unfolded and a detailed timeline can be found in `https://www.who.int/news-room/detail/27-04-2020-who-timeline--covid-19`.

on the modelling framework, and in the following we examine this dependence in more detail.

3 Market Risk Measurement Over the First Five Months of the Crisis

For regulatory purposes and for internal risk assessment of institutions, the estimation of VaR and ES measures over a given time period is of interest, since market risk capital calculations are based on risk assessments. Here we focus on the estimation of ES as it is a central element of the recent regulations. To illustrate the dramatic increase in risk witnessed in the first half of 2020,[3] figure 3 presents the level of 97.5% ES risk over 10 days, for two assets: FTSE 100 index returns as well as Europe Brent Crude Oil Spot returns, based on two methods: Historical Simulation, computed using overlapping 10-day returns, as well as the well-known GARCH(1,1) model that assumes normally distributed returns. For the GARCH model, the h-day ES is calculated based on the daily ES estimates, written as $h\text{-day ES} = 1\text{-day ES} \times \sqrt{h}$, which is called the 'square root of time' rule **[fig. 3]**.

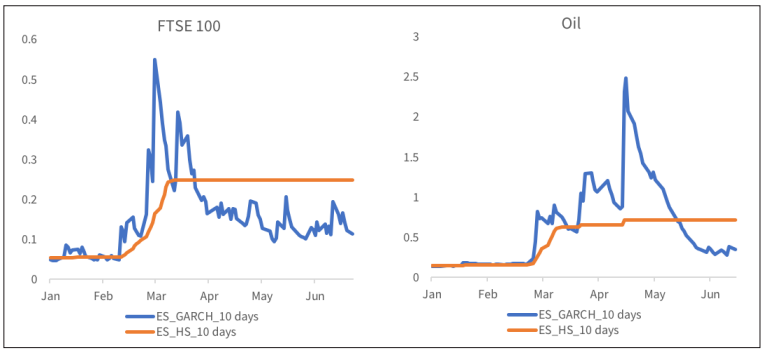

Figure 3 10-day HS ES and GARCH ES at 97.5% for FTSE 100 and oil returns

The first thing to notice from figure 3 is that the general level of ES risk computed using HS increases dramatically during March 2020, by a multiplier of more than 4 for the FTSE index, and by a multiplier of more than 5 for the risk computed from oil returns. Also, the ES stays at this level until the end of the sample period, unaffected by the

3 Similarly, Ibikunle and Rzayev (2020) show a substantial increase of a cross-sectional average volatility for 110 European stocks from 24 Jan. to 24 March in their figure 1.

events during this period. If these values are used for capital calculation, the required capital would also increase multiple times, with many financial institutions not being able to meet these increased capital requirements.[4] To address this, banks across the world are allowed to temporarily suspend the new capital calculation method against the radically increased risk, as discussed by Borio and Restoy (2020). Moreover, the GARCH model does a good job in terms of the speed of reaction to large negative returns, but it leads to risk estimates increasing dramatically, by a multiplier of more than 10, as can be seen in figure 3 for the FTSE returns, which would give capital requirements that are impossible to meet, reaching levels of more than 10 times the pre-crisis levels. Followed by this initial sharp rise in risk, the risk level estimated by GARCH decreases back within a month, and in the second part of the sample period it is below the risk level estimated by the HS method.

For oil returns, the risk estimate obtained by GARCH displays a large variation. After the initial sharp rise in risk at the beginning of March, on April 20 the market experienced its deepest fall in the price of a barrel of West Texas Intermediate (WTI), the benchmark for US oil, even leading to negative prices for this commodity – caused by an abrupt drop in demand. This aroused investors' fears and created a turbulent oil market, as evidenced by the predictions of GARCH ES of oil returns, with the ES risk reaching levels more than 15 times higher than the level in January 2020. This shows the high dependence of GARCH risk estimates on returns; although the model is quick to react to events, due to the high level of risk estimates it is less suitable to be used for capital calculations. These risk estimates highlight the severity of the COVID-19 financial crisis, especially after the coronavirus pandemic was declared in March 2020.

To illustrate the effects of the COVID-19 crisis on the global financial markets, we consider the market indices S&P 500 (spx), FTSE 100 (ftse), DAX (dax), Nikkei 225 (nky), and Shanghai Composite (sse), as well as several commodities including Europe Brent Crude Oil Spot prices (oil), Henry Hub Natural Gas Spot Prices (gas), London PM fix gold prices (gold), Copper Jul 20 futures contract (copper), as well as the Sugar #11 Oct 20 futures contract (sugar), from January 2019 to June 2020. Figure 4 shows the multipliers for Historical Simulation ES, calculated as the ratio of the average ES over the last five trading days of the sample period, ending with June 23, 2020, and the average ES over the first five trading days starting with January 23, 2020 **[fig. 4]**. We use three different time horizons (1

4 More measures are taken by governments and banks to alleviate the adverse financial and economic effects of the COVID-19 crisis, as suggested by Basel Committee on Banking Supervision (2020).

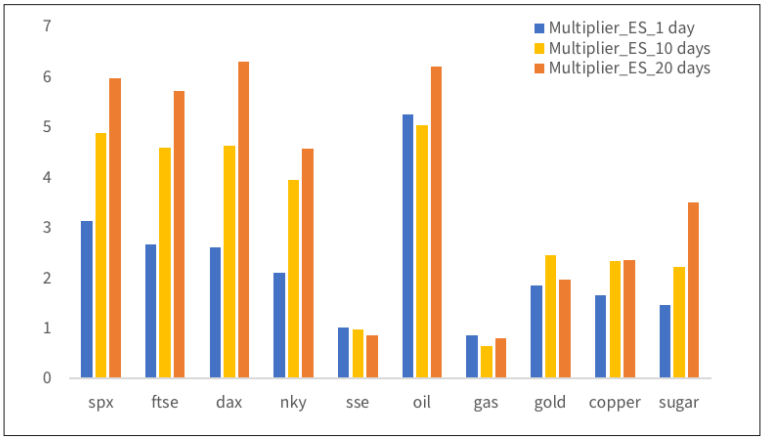

Figure 4 Multipliers for HS ES at 97.5% over 1, 10 and 20 days across various assets, calculated as the ratio of the average ES over the last five trading days of the sample period divided by the average ES over the first five trading days of our sample

day, 10 days and 20 days) to compute the risk estimates and the multipliers. For some assets the multipliers take large values: index returns and oil returns, most noticeably. For the S&P 500, FTSE, DAX and Nikkei 225 index returns, the increase in the risk level shows a similar pattern: the risk increased by 3 to 6 times, depending on the risk horizon. For the Shanghai Composite index, the value of the multiplier is less than one, showing that this index didn't display an increase in the level of ES risk estimates. The gas market seems unaffected as well in terms of risk estimates. The other commodities considered – gold, copper and sugar – show an increase in the risk level by about twofold, whilst the risk estimates obtained from oil returns increased dramatically during the crisis.

It is interesting to note the dependency of the multiplier on the risk horizon: for most assets considered, the multiplier for the 1-day risk horizon is smaller than the multiplier for the 10-day horizon, and the multiplier for the 20-day horizon is the largest. If the 'square root of time' rule was valid, then these multipliers should have been at the same level, regardless of the time horizon. However, this is not the case, which highlights that longer horizon risks were affected by the COVID-19 crisis more than short horizon risks, with some of the risk estimates going up sixfold over the sample period. This pattern is not followed by all asset classes, but it seems to be a typical behaviour of risk estimates for the majority of assets considered here.

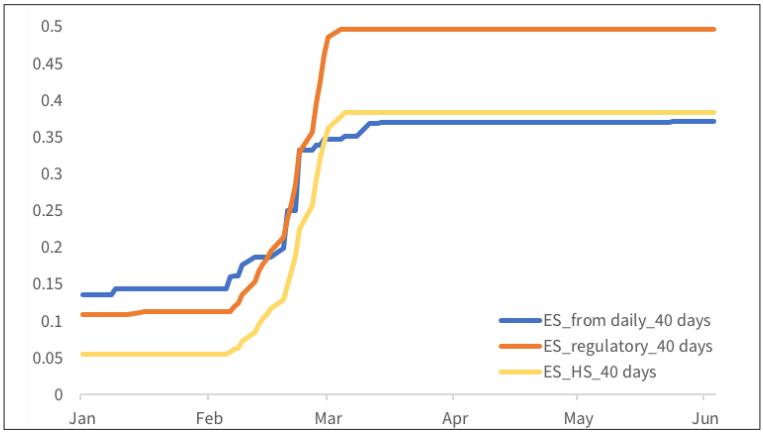

Figure 5 Comparison of three approaches to compute 97.5% HS ES over 40 trading days, based on FTSE 100

4 Challenges to the Regulatory Framework

In the following we consider the current Basel framework for market risk calculations, with a focus on the risk horizons considered in these assessments. As specified by the regulation, different risk horizons are applied to different categories of risk factors, ranging from 10 days for the most liquid asset classes and up to 120 days for some risk factor categories. Under the current framework, these calculations are based on 10-day ES assessments, and then the 'square root of time' rule is used to compute risk over longer horizons, written as $h\text{-day ES} = 10\text{-day ES} \times \sqrt{h/10}$. The question we are asking here is whether this approximation was proved to be correct or not during the recent crisis.

Figure 5 investigates three different approaches to estimate ES of an individual asset,[5] the FTSE 100 index, over h days: 1) in the first approach, the h-day ES is calculated based on the daily ES using the 'square root of time' rule, so $h\text{-day ES} = 1\text{-day ES} \times \sqrt{h}$; 2) in the second approach, we follow the FRTB recommendations and calculate the h-day ES from the 10-day ES estimates (computed from overlapping observations) as $h\text{-day ES} = 10\text{-day ES} \times \sqrt{h/10}$, hereafter referred to as the regulatory ES; 3) in the third approach we directly use the h-day overlapping observations to get h-day ES **[fig. 5]**. We focus on the calculation of 40-day ES ($h = 40$) at 97.5% level, considering the above

5 For simplicity, we illustrate the calculation of ES where only one risk factor is considered.

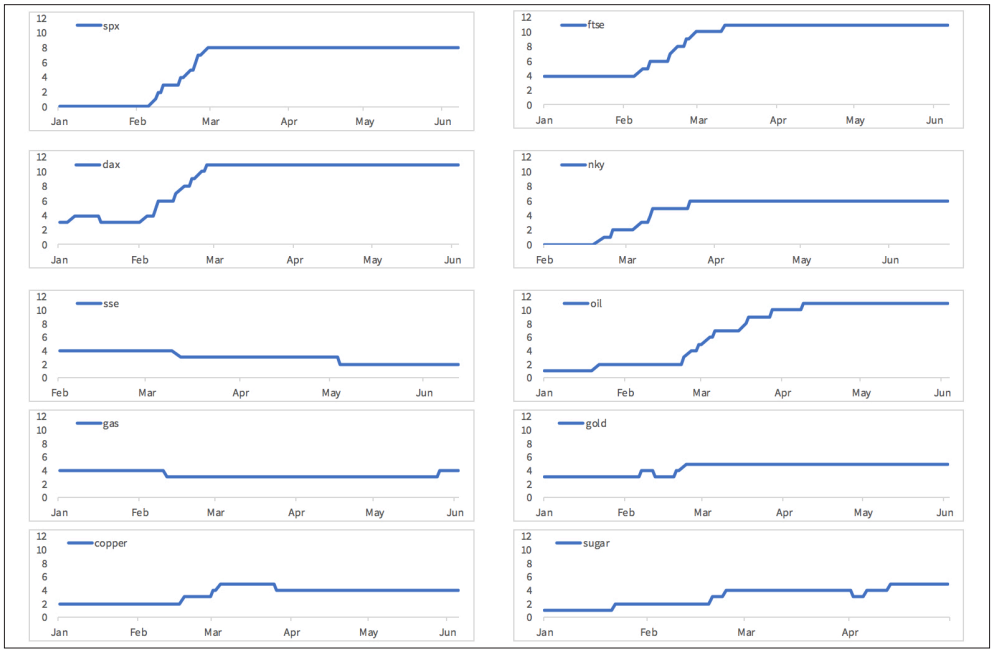

Figure 6 Time-varying number of VaR exceptions (the daily returns being below the negative of the daily HS VaR at 99%) over a 250 trading day backtesting period

three approaches with the estimates displayed in figure 5. It is to be noted that the regulatory ES (as shown using a red line) overestimates the actual risk (as shown by the yellow line), whilst the approach based on the simple 'square root of time' rule computed from daily ES estimates (as shown by the blue line) gives a better fit. This pattern, which we noticed for other asset classes and for other risk horizons as well, suggests that regulatory capital might overestimate risk in such cases.

Whilst market risk measurement has moved from VaR to ES, backtesting ES is a debating area and the current regulation stipulates VaR backtesting only. As such, the focus is on counting the number of daily VaR exceptions (cases when the daily return is below the negative of daily VaR estimate) over a period of 250 days. Coloured zones are considered, with the green zone applying if the number of exceptions is less than or equal with 5, amber zone when the number of exceptions is more than 10, and yellow zone in between. Different zones carry different levels of multipliers applied for capital calculations.

In figure 6, over a five-month period in early 2020, we show the total number of exceptions of HS VaR, with a backtesting period of 250 trading days specified in the regulatory framework **[fig. 6]**. Nev-

ertheless, the major indices (except for the Shanghai Composite index, sse) and oil experienced a steep increase in the number of exceptions between March and April 2020 (with the FTSE, DAX and oil risk estimates in the amber zone), indicating that the Historical Simulation method is unable to accommodate for the extreme market events of early 2020. This shows a weakness of the HS method, and raises a point that needs to be addressed by regulators and financial institutions, namely to improve on the current market risk models.

5 Looking Ahead

As the previous sections highlight, some of the challenges in terms of market risk measurement, as a result of the COVID-19 crisis, faced by the regulatory bodies, local jurisdictions, and financial institutions can be summarised as:

1. as a result of the increased values of risk measures, obtained using regulatory calculations, the level of capital requirements rose dramatically, which is a challenge because such high capital needs are very hard to meet; as such, improvements should be made to the risk and capital calculations that would lead to more realistic capital requirements;
2. risk assessments depend on the models used; and the estimated risks can display large variations as a result of this; this model dependence needs to be addressed;
3. risk estimates obtained over longer horizons seem to be affected more by the crisis, as compared to risk estimates obtained over shorter horizons, which is a pattern shown by the majority of assets considered in this study. This highlights that the suitability of the 'square root of time' rule, which is currently stipulated by the regulation, needs more investigation;
4. a typical pattern we found is that market risk calculation based on the current regulatory framework overestimates the actual risk, which leads to the question of how the currently stipulated risk calculations can be improved;
5. the large number of VaR breaches over the first 5 months of the COVID-19 crisis is worrisome; these can be addressed via improved risk calculations, or via improvements in the regulatory framework (e.g. the number of exceptions allowed).

6 Conclusions

As seen above, the events of early 2020 have had devastating consequences globally including serious financial outcomes. In terms of market risks, we found that in general the effects of the COVID-19 crisis were more pronounced for longer horizons. It is vital for financial institutions to do their best to prepare for such events, and for regulators to encourage banks to set aside enough capital for future crises. So, it is important to have an appropriate modelling framework that is able to quickly and appropriately respond to crisis events, whilst leading to realistic and suitable bank capital requirements.

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