Margin-setting by Central Counterparties of Over-the-counter Derivatives

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Abstract

On the Margin-setting by Central Counterparties of Over-the-counter Derivatives

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Regulation of the over-the-counter (OTC) derivatives market since the financial crisis of 2008 has had the objective of reducing risks within this marketplace. OTC derivatives are now cleared through central clearing counterparties (CCPs), and one tool of the CCPs is to set adequate margin requirements for their clearing members. In this thesis, I address the obligations of CCPs and the effect of risk management using margin requirements. I develop the methodology of margin setting using a historical simulation and evaluate the resulting risk-based margin requirements for interest rate swaps. I also address an important aspect of margin-setting which is margin procyclicality, under which margin requirements are increased in stressed markets resulting in an increased risk of default on margin calls as well as feedback effects on the underlying assets of clearing members.

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1. Introduction

The objective of this thesis is to review margin setting methods in financial markets to adapt these methods to address margin setting by central counterparties (CCPs) in over-the-counter (OTC) markets, and to examine mitigation methods to solve the margin procyclicality problem. I first review the background and importance of margin setting by CCPs for OTC derivatives, and then examine the methods which have been used in the literature and how they perform for OTC derivatives, specifically with reference to the interest rate swap (IRS) contract. Lastly, I examine five anti-procyclicality tools and their mitigation effects based on a scenario analysis.

1.1 The central counterparties

In stock markets, futures markets and over-the-counter (OTC) derivatives markets, a CCP is needed to provide clearing and settlement services for the financial transactions of its clearing members. These transactions could be exchange-traded contracts or cleared derivatives, may be executed on a futures exchange or on a securities exchange, or could be transacted off-exchange in the OTC market. The CCP stands between two counterparties taking opposite sides in the same transaction, and when either counterparty does not honor its settlement obligations, the CCP meets that counterparty's obligation to its counterparty.

In Europe, CCPs like the European Multilateral Clearing Facility (EMCF) based in the Netherlands, SIX Swiss Exchange based in Zurich, and LCH.Clearnet (formerly known as The London Clearing House), provide major clearing services for a broad range of assets. LCH Clearnet covers approximately 50% of the global IRS market and is a CCP to many financial groups under the supervision of the European Market Infrastructure Regulation (EMIR). In this thesis, I will apply the procyclicality mitigation tools used by this CCP to the North American market.

In the United States, the major CCPs of the stock market are The Depository Trust & Clearing Corporation (DTCC) or Federal Reserve Wire Network (Fedwire). There are two major clearing houses for OTC derivatives in North America. One of them is the CME Clearing, a unit of CME Group Inc (CME.O), which acts as an intermediary between buyers and sellers of futures contracts as a futures clearing house and also as a CCP to OTC derivatives counterparties. The other is the Intercontinental Exchange Inc, (ICE.N) which operates 12 regulated exchanges and marketplaces. ICE Clear U.S is a clearing house under the ICE.N which was established in 1915 as the New York Cotton Exchange Clearing Association, is regulated by the Commodity Futures Trading Commission (CFTC) and acts as a derivatives-clearing organization. According to the CFTC, these two clearinghouses together with the LCH Clearnet are able to generate enough liquidity to settle payments, if two of their largest members defaulted.

1.2 Margin requirements

CCPs face the risk of loss due to their guarantee of the open positions of their clearing members, they collect collateral from their members in the form of cash or high-quality securities as initial margin. CCPs follow a system of daily settlement as futures clearinghouses do and call for variation margin from their clearing members. The CCP members are generally banks, credit institutions, investment firms, insurers and pension providers, investment funds/managers or alternative investment funds with regulated managers. Common concerns raised in the literature include the trade-off between market integrity and market liquidity, that the optimal level of initial margin should be both adequate and prudential, and that the clearing house needs to balance the opportunity cost of counterparties and adequate coverage of risk exposure (e.g., Booth et al., 1997; Longin, 1999, 2000; Cotter, 2001). Hence, the choice of the optimal margin requirement is critical. It is the CCPs' duty to hold an adequate amount of collateral from their members to maintain all transactions settled through them. The margin requirement is a critical tool of CCPs' liquidity management strategy. Every time a CCP requires a member to post variation margin, it must be fulfilled as quickly as possible, sometimes within 2 hours. A margin call is always made at the end of the day for a centrally cleared portfolio, and sometimes it is made intra-day. Failure to fulfill the margin call would be regarded as a default by the clearing member.

1.3 Regulations governing OTC derivatives

Subsequent to the recession of 2007-2009 which was a consequence of the subprime mortgage crisis, OTC derivatives supervision is of more importance to regulators. Regulations have come into effect gradually.

As for margin setting of CCPs, regulation plays an important determining role. Heckinger et al. (2016) interviewed people at six of the world's largest and most diversified CCPs to examine margin setting from the perspective of regulations, principles, rules, policies and procedures. According to their study, Principles for Financial Market Infrastructures (PFMIs) contains international principles regarding organization, management, and resources of CCPs. Principle 6 of the PFMIs states that "a CCP should cover its credit exposures to its participants for all products through an effective margin system that is risk-based and regularly reviewed", which provides a general principle for CCPs to set margin for derivatives.

OTC margins are the focus of working groups as well, such as the Working Group on Margin Requirements (WGMR), a joint initiative of the Basel Committee on Banking Supervision (BCBS) and the International Organization of Securities Commissions (IOSCO) (BIS/BCBS/IOSCO, 2015). Regulators had been developing rules to reach a final framework of the margin policy adopted by the WGMR in September 2013 (revised in March 2015) (Canadian Securities Administrators' Derivatives Committee, 2016).

In North America, the Dodd-Frank Wall Street Reform and Consumer Protection Act (2010) of the United States Congress stipulates that various trading derivatives must be cleared through regulated CCPs. The European Commission has taken similar actions, and the G20 leaders launched reforms in the aftermath of Lehman's collapse (FSB, 2013) and stipulated that all standardized OTC derivatives be cleared through CCPs by the end of 2012. With the increasing and widening use of CCPs, finding the CCPs' optimal margin requirement has become increasingly relevant.

1.4 Procyclicality

Procyclicality is a feature of margin requirements which has been discussed in recent years. Margin requirements are considered procyclical if they are positively correlated with market fluctuations. When a market becomes very volatile and extreme loss is expected to occur to a centrally cleared portfolio, the margin requirement tends to increase. A general explanation for procyclicality of margin requirements is that, the requirement to post margin in a stressed market would naturally result in an even greater margin requirement, when this is calculated using traditional risk-based margining models. Thus, it would pose a greater burden upon margin posters, who would then be less likely to fulfill their margin obligations.

The procyclicality effect could consequently make the model-based margin setting suboptimal and under-estimate the margin requirements which would generate potential default risk.

This phenomenon has a feedback effect in two ways in a stressed market. When a greater level of margin is required from counterparties to a derivatives transaction, the counterparties could default on the margin requirement or liquidate their derivatives portfolio to meet their margin requirement. If a counterparty who receives a margin call, choses to default, the associated CCP or the non-defaulting counterparty will have to liquidate its collateral or derivatives portfolio, respectively, which action would lead to a more stressed market. If a counterparty with a position in a portfolio of derivatives choses to liquidate the portfolio on receipt of a margin call, this would result in a further decrease in the price of the derivatives and a more stressed market.

Regulations on controlling the procyclicality of margin requirements have already been introduced by some authorities. In the European market, EMIR is a body of European legislation for the regulation of OTC derivatives which came into effect in 2013. It states:

"Margin calls and haircuts on collateral may have procyclical effects. CCPs, competent authorities and ESMA [the European Securities and Markets Authority] should therefore adopt measures to prevent and control possible procyclical effects in risk management practices adopted by CCPs, to the extent that a CCP's soundness and financial security is not negatively affected."

In North America, regulations have been made which address the procyclicality of bank capital requirements in the context of systemic risk. In North American OTC markets, to minimize the risk of default by clearing members and to make the derivatives markets more stable, it is essential to address the procyclicality of margin setting by CCPs, as well.

2. Literature review

In this section, I review the previous research on margin setting of centrally-cleared OTC derivatives, and procyclicality of margin requirements.

2.1 Margin setting models

I address the use of margin-setting models to set the initial margin requirement. In the area of research on futures markets, many methods have been used to set margin requirements for exchanges and clearing houses. Default risk in futures contracts is managed by futures exchanges and clearinghouses by optimally setting initial margin requirements and using a system of daily settlement of profits and losses.

The margin requirements for standardized OTC derivatives are also risk-based margin requirements. The margin requirement depends on the expected loss of a portfolio of derivatives. Regulators set the initial margin requirement equal to a pre-set percentile of the expected loss of the portfolio.

Carter and Cole (2018) classify risk-based initial margin requirement setting models which are commonly used by CCPs, under two types: 1) standard portfolio analysis of risk (SPAN); and 2) historical value at risk (HVaR) and conclude there is no significant difference in the performance of these two types.

SPAN is a sophisticated methodology created by the CME in 1988, and in use for futures contracts and options on futures contracts. SPAN is reported to be the official Performance Bond mechanism of 54 exchanges and clearing organizations world-wide. The core of SPAN is to use grid simulations, and 16 fixed scenarios which are referred to as SPAN Risk Arrays, to simulate hypothetical market shocks and calculate the potential gain and loss of individual contracts. The system calculates the largest loss of individual contracts across all scenarios, and the margin is set by taking into account the risk of each asset in the portfolio, with some modifications. (CME Group, 2010). This feature has been applauded by practitioners since it takes into consideration the covariance between different assets and thus has the potential to reduce the margin requirement below the level required if each asset were margined separately. The performance of SPAN-based margins has been analysed by previous researchers (e.g. Kupiec, 1994; Kupiec and White, 1996; Eldor et al., 2011).

However, CCPs are reported to have discontinued the use of SPAN recently. For example, the Eurex Exchange adopted the Prisma margin calculator in May 2013 and fully applied it to all products. An announcement has been made by the LME in one of their projects titled "Value-at-risk" that they will implement VaR-based margin methodology instead, to benefit from a more custom-tailored margin. Critics of SPAN note that it cannot fully address the covariance between different contracts, and scenario analysis cannot capture all the risks in the portfolio. Thus, the VaR method that has been adopted by many CCPs has been addressed by previous research.

VaR was developed by J. P. Morgan, who published the methodology used in estimating VaR and provided free access to estimates of the necessary underlying parameters to the general public (Risk Metrics, 1996). In 1997, the U.S. Securities and Exchange Commission (SEC) required that financial institutions disclose quantitative information on their derivatives activity, including VaR, in their financial statements. VaR measures and quantifies the level of financial risk and does not split the portfolio into individual assets, it only calculates the overall value of the portfolio and provides a scenario-tailored margin requirement. VaR provides the possibility for an ex-post validation of margin, while SPAN cannot, and provides a more feasible approach for decision makers of CCPs to use in margin setting.

VaR risk measurement is basically an answer to the question "How bad can things get?" and provides a numerical estimate of how much a portfolio might lose with a given probability, called the confidence level. VaR is popular since a decision maker could select different confidence levels and accordingly, the outcome is straightforward.

Based on the VaR technique, there have been works in the literature on methods of margin setting (e.g., Heller and Vause, 2012; Duffie et al., 2015), and these methods are widely used and long-developed. Heckinger et al. (2016) summarize the derivatives margin setting history into two eras: 1) the ad hoc era, during which cleared derivatives were primarily futures contracts and the daily price limit was a baseline for margin setting; and 2) the volatility-based era, under which margin setting models are based on the volatility of the values of cleared derivatives which depends on the volatility of the prices of the underlying assets.

CCPs consider volatility as a critical input to determine the margin requirement. The CME use HVaR as margin setting model as well, under which the volatilities are estimated by the EWMA process simulated with 1250 scenarios based on 5-year samples of historical data on derivative prices. The Eurex Prisma uses filtered historical simulation (FHS) to simulate VaR with 3-year data combined with a 1-year sample of stressed data. Heller and Vause (2012) concludes from interviews of fourteen major derivatives dealers known as the 'G14 dealers', that the components to set a prudent margin requirement for CCPs are hypothetical IRS and credit default swap (CDS) portfolios, a joint probability distribution of volatility of these portfolios, and a confidence level of 99.5%. Glasserman and Wu (2017) analyze the persistence and procyclicality features of margin setting using FHS with volatility estimation using a GARCH(1,1) process. Lee and Seo (2018) examine a method similar to that used by the CME, with margin setting based on the FHS with a 5-day interval time series with 1-day lag and volatility estimated by the EWMA model.

2.2 Effect of procyclicality

It is important to address procyclicality when setting the margin requirement, regardless of which type of model is used.

In Europe, regulators have introduced tools to mitigate procyclicality in margin requirements and required that they be implemented. EMIR officially provides three tools and urges all CCPs in the European Union (EU) to adopt at least one of them in calculating the initial margin. These mitigation tools are called Anti-Procyclicality (APC) tools, according to Article 28 of the EMIR Regulatory Technical Standards. Murphy, Vasios and Vause (2016) describes these APC tools as follows:

> "(a) applying a margin buffer of at least equal to 25% of the calculated margins, which is allowed to be temporarily exhausted in periods in which calculated margin requirements are rising significantly;
>
> (b) assigning at least 25% weight to stressed observations in the lookback period, calculated in accordance with Article 26;

(c) ensuring that margin requirements are not lower than those that would be calculated using volatility estimated over a 10-year historical lookback period."

They examine the performance of these procyclicality mitigation tools by using historical simulation to estimate VaR and calculate the required margin and conclude that the usage of APC tools would provide a significant mitigation of procyclicality of the initial margin. As an improvement upon the EMIR provided procyclicality tools, they offer two additional tools: 1) the adaptive stressed volatility, which applies different weights to stressed VaR and current VaR in estimating the margin required, and 2) speed limits on the margin increase in order to avoid over-reaction to the variations in market conditions

3. Background on valuation of interest rate swaps and margin procyclicality mitigation tools

In this thesis, I will determine the optimal margin for interest rate swaps (IRSs) using methods adapted from previous research. The historical simulation based on volatility is used as a framework in this analysis. As noted earlier, EMIR standards provide guidelines for possible mitigations of the procyclicality problem, I will take these into account and compare the results of margin setting using traditional methods with those of procyclicality mitigation tools.

Volatility determines margin levels, and volatility is estimated from the prices of underlying assets. Two popular methods used to estimate IRS volatility in previous research are the EWMA and GARCH models. Due to lack of data on IRS values from G14 dealers, in my thesis the estimate of IRS volatility is based on an estimate of IRS values.

In this section, I address IRS valuation based on Hull (2003), use the FHS method to calculate initial margin requirements for a CCP which clears IRSs and test the performance of the three mitigation tools provided by the EMIR in the context of North American markets, in addition to the two extra tools suggested by Murphy, Vasios and Vause (2016).

3.1 LIBOR rate

The LIBOR rate is defined as 'the rate at which an individual Contributor Panel bank could borrow funds, were it to do so by asking for and then accepting inter-bank offers in reasonable market size, just prior to 11:00 London time' (ICE LIBOR) and reported at 11:30 am. LIBOR is calculated using the same method as that previously used by the British Bankers' Association (BBA), which is to throw out 'the highest 4 and lowest 4 responses,' from surveyed banks and average 'the remaining middle 10, yielding a 22% trimmed mean.' (BBA LIBOR, The Basics)

The LIBOR rate is calculated for five currencies: the US Dollar, the Euro, the British pound, the Japanese yen, and the Swiss franc. Since 2013, LIBOR rates are calculated for 7 maturities: 1 day, 1 week, 1 month, 2 months, 3 months, 6 months, and 12 months. For the North American market, the U.S. Dollar LIBOR is primarily used as the reference rate for IRSs.

Some problems should be considered to find an optimal size of the sample of LIBOR rates. The PFMI principles summarizes these problems as: at least 99% confidence level, sufficient historical samples, period of extreme market conditions to test CCPs' liquidation ability, procyclicality, etc.

3.2 Valuation of interest rate swap (IRS)

A swap is an example of an OTC derivative between two parties under which the two parties agree to exchange cash flows in the future. The first IRS contract was negotiated in the early 1980s. The most common type of IRS is a "plain vanilla" IRS, which is provided by financial institutions to companies to transform the nature of their liabilities and assets. These institutions act as market makers and are counterparties of CCPs. Hull (2003) describes the plain vanilla interest rate swap as an agreement under which an institution 'agrees to pay cash flows equal to interest at a predetermined fixed rate on a notional principal for a predetermined number of years and receives interest at a floating rate on the same notional principal for the same period of time'.

IRS contracts have two legs: the fixed rate leg and the floating rate leg, the difference between the value of these two legs is the value of the IRS from the viewpoint of either the fixed or floating rate payer. Hull (2003) provides two approaches to valuation of IRSs, of which the first values the swap as a long position in a fixed rate bond and a short position in a floating rate bond, while the second values the swap as a series of forward rate agreements. I will use the first method to value IRSs. Note that the swap contract length, the notional principal, and the payment interval are predetermined in the IRS contract. The only exogenous variable that needs to be obtained from the market is the floating rate. The London Interbank Offered Rate (LIBOR) is commonly used as the prime reference rate or the floating rate. This is used to determine the discount factor used to calculate the present value of the fixed-rate bond. The value of the floating-rate bond equals the notional principal immediately after an interest payment. I use an IRS margin setting methodology based on this valuation method.

3.3 Setting margin for IRSs

Assume that a CCP is clearing a 2-year IRS with a fixed rate of 2% which is annually compounded on a notional principal of $100 million, while the floating rate is the US dollar LIBOR interest rate. Following Hull (2003) the value of the swap is given by

$$S_t = B_{fix,t} - B_{fl,t} \tag{1}$$

where S_t is the value of the swap at time t, and $B_{fix,t}$, $B_{fl,t}$ are the value of the fixed rate bond and the floating rate bond at time t, respectively. Then the daily return on the IRS from time t-1 to t is:

$$X_t = \frac{S_t - S_{t-1}}{S_{t-1}} \tag{2}$$

One possible method used to calculate the volatility of an asset is the GARCH model which is described by:

$$X_t = \sigma_t Z_t \tag{3}$$

$$\begin{aligned} \sigma_t^2 &= \gamma V_L + \alpha X_{t-1}^2 + \beta \sigma_{t-1}^2 \\ &= \gamma V_L + (\alpha Z_{t-1}^2 + \beta)\sigma_{t-1}^2 \end{aligned} \tag{4}$$

where Z_t is independent and identically distributed (i.i.d.) with $\mathrm{E}Z_t = 0$ and $\mathrm{E}{Z_t}^2 = 1$, $\omega = \gamma V_L > 0$ is the weighted long-term variance, $\beta > 0$ is the decay rate, $\alpha > 0$ is constant, with $\omega + \alpha + \beta = 1$. These parameters control the price change of the IRS, specifically, with a larger α, the price change is larger. According to Bollerslev (1986) the following simple and widely applicable conditions must hold:

(A1) The parameters satisfy $\alpha + \beta < 1$

(A2) Z_t has a symmetric distribution, thus the probability density function F_Z is continuous with $0 < F_Z(x) < 1$ for all $x \in \mathbb{R}$

(A3) For some $0 < \gamma < \infty$, we have $1 < E[(\alpha Z_{t-1}^2 + \beta)^\gamma] < \infty$

The EWMA model is a particular case of GARCH(1,1) where $\gamma = 0$, $\alpha = 1 - \lambda$ and $\beta = \lambda$, where λ is a decay factor.The EWMA model estimates volatility as:

$$\sigma_t^2 = \lambda X_{t-1} + (1 - \lambda)\sigma_{t-1}^2 \tag{5}$$

When $\lambda = 1$, the volatility only depends on the most recent observed return, while when $\lambda = 0$, the volatility depends solely on the previous estimate of volatility. σ_0 equals long-term volatility, which can be calculated by the variance of historical returns. According to Risk Metrics, when $\lambda = 0.94$, the estimated volatility is close to realized volatility. This model is used by the CME to calculate historical simulation of volatilities for HVaR and has been used in previous research (e.g., Murphy et al., 2016; Lee and Seo, 2018).

The FHS of volatility method is used along with VaR to calculate initial margins. Given market variables estimated at time t, the initial margin requirement is estimated from the requirement that the probability of a price change (loss) no greater than the initial margin is p. I denote the margin determined thus as Mod_t, given by

$$Mod_t = \inf\{x \in \mathbb{R}: \mathrm{P}_t(X_t \geq x) \leq p\} \tag{6}$$

where P_t denotes the cumulative probability function. Mod_t may be represented as:

$$Mod_t = \sigma_t F_Z^{-1}(p) \tag{7}$$

Consequently, the initial margin requirement is the estimated volatility multiplied by the $(1-p)$th quantile of F_Z. This equation links the margin chosen to volatility and is used by many futures exchanges. Assuming that F_Z is a standard normal cumulative distribution function, using the 99% confidence level of the PFMI, the margin requirement can be denoted as $Mod_t \approx 2.3263\sigma_t$.

3.4 Measures of procyclicality

As noted earlier, procyclicality is a feature under which when market conditions become stressed, the margin requirement tends to be high. Equation (7) links the margin chosen to volatility, it confirms that when market conditions become stressed, and the volatility of the underlying asset increases, the margin requirement would be higher than under normal market conditions.

Two measures are used by Murphy, Vasios and Vause (2014) to capture procyclicality, the 'Peak-to-trough' procyclicality measure applicable to a long-term economic cycle and an 'n-day' procyclicality measure applicable to short-term margin changes when markets become stressed. The peak-to-trough procyclicality measure is the ratio of the maximum initial margin to the minimum initial margin over a fixed observation period. The n-day procyclicality measure is the largest margin call over an n-day period. Murphy, Vasios and Vause (2014) choose 30 days to measure procyclicality, since Basel III requires banks to hold a sufficient level of assets to meet liquidity needs for 30 calendar days under stressed liquidity scenarios.

Murphy, Vasios and Vause (2016) define a 'stressed period' as a period in which the market volatility exceeds the threshold volatility set by CCPs, and may be represented by:

$$The\ market\ condition\ is\ stressed\ if\ \sigma_t^2 > S_{threshold} \tag{8}$$

The threshold $S_{threshold}$ can be pre-set and calculated using a certain percentile of the volatility distribution. For example, using the 90th percentile of volatility, $F_{\sigma_t}^{-1}(0.9)$, the market condition is stressed if $\sigma_t^2 > F_{\sigma_t}^{-1}(0.9)$.

3.5 Margin procyclicality mitigation tools

There are five tools to mitigate the procyclicality of margin requirements in a stressed market: three from the EMIR, which are the choice of a margin buffer, use of stressed data and use of a floor; and the two other mitigation tools proposed by Murphy, Vasios and Vause (2016). The buffer and floor choices modify the margin requirement, while the stressed data technique modifies the sample data used to determine the margin requirement.

3.5.1 Margin buffer

The use of the margin buffer adds an extra margin requirement above the margin requirement given by the model in normal periods. The EMIR requires CCPs to hold at least a 25% buffer. The buffer is built up in normal periods and released in stressed periods, thus increasing the margin requirement in normal periods and reducing it in stressed periods, above and below what would be specified by the margining model, respectively. Hence, the buffer is a 'market smoother' which should smooth out the shocks in a stressed market. If the buffer is exhausted before the shocks subside, the margin call would increase, and the buffer would not be able to mitigate margin procyclicality. Consequently, it is important to set the buildup and release criteria carefully.

The buffer is the difference between actual margin requirement and the margin estimated by the model. Let Buf_t be the buffer at time t, and Mar_t be the non-procyclical margin, then:

$$Buf_t = Mar_t - Mod_t \tag{9}$$

The stressed margin is a constant multiple of the model determined margin at the initial date. Thus, at time t = 0, under normal market conditions, the optimal margin using a buffer is $Mar_0 = 1.25 \cdot Mod_0$. At time $t > 0$, we determine if the market is stressed or not, using the criterion that:

$$the\ market\ condition\ is\ stressed\ if\ 1.25 \cdot Mod_t > StressedMargin \tag{10}$$

If the market is not stressed, then the margin requirement is set to be $1.25 \cdot Mod_t$; if the market is stressed, the buffer is used to reduce the margin requirement below what would be called for based on the model, and would equal

$$Mar_t = max(StressedMargin, Mod_t).$$

3.5.2 Stressed data

The second procyclicality mitigation tool specifies that in volatility estimation, at least 25% of the observations on the asset return should be from a stressed period. When using a GARCH(1,1) or EWMA model to estimate volatility, then a normal estimation process would use the most recent n-day observations in the estimation. When implementing the stressed data tool, the sample period would be constructed with the most recent 0.75n-day observations of return, and a 0.25n-day observations of return from a stressed period.

3.5.3 Floors on margin

The third mitigation tool is to set a floor on margin requirements. The EMIR requires 'that margin requirements should not be lower than those that would be calculated using volatility estimated over a 10-year historical lookback period'. I calculate the model margin Mod_tusing equations (5)-(7) and an 500-day lookback period. The floor margin $Floor_t$ is estimated using a 10-year sample of observations preceding the n-day sample period. The margin requirement is then given by $Mar_t = Max(Floor_t, Mod_t)$.

3.5.4 Adaptive stressed volatility

Murphy, Vasios and Vause (2016) note that 'there are some periods where volatility is materially lower than average', thus he basic idea behind the adaptive stressed volatility tool is to use an adaptive weight rather than a constant 25% of observations of stressed data to calculate the margin requirement.

To calculate the stressed margin requirement, we can either give different weights to normal data and stressed data as described in section 3.5.2, or we can calculate the margin requirement separately with stressed and non-stressed samples of observations, and then calculate the margin requirement as a weighted average of the stressed and non-stressed margin requirements. If the adaptive weights α and 1- α are applied, then the margin requirement is given by:

$$\begin{gathered} Mar_t = \alpha \cdot stressed\,Mod_t + (1-\alpha) \cdot Mod_t \\ Mar_t = [\alpha \cdot stressed\,\sigma_t + (1-\alpha) \cdot \sigma_t] F_Z^{-1}(p) \end{gathered} \tag{11}$$

The criteria for setting α is to use an α>25%, if market conditions are not stressed, and to use α<25% if market conditions are stressed.

3.5.5 Speed limit

The fifth procyclicality mitigation tool is to use a speed limit on margin increases, to avoid over-reaction to extreme market conditions. The speed limit is a numerical threshold for everyday margin increases and works like price limits in futures markets.

A sample of historical day-to-day margin changes $y_t = Mar_t - Mar_{t-1}$ is identified. A certain percentile of the sample of margin changes, for example, the 90th percentile, is used to set the benchmark margin increase speed limit $L = F_Y^{-1}(0.9)$. The margin requirement is then set to equal the higher of the model determined margin plus the speed limit and the model determined margin, as $Mar_t = Max(Mod_{t-1} + L, Mod_t)$.

This method is an ex post adjustment for margin procyclicality and is commonly used in futures markets. However, for those exchange-traded derivatives, risk management is much easier than for OTC derivatives. In stressed periods, when the speed limit is triggered, OTC counterparties could rationally tend to default rather than fulfill the margin obligation.

4. Methodology and results of margin setting for a representative IRS contract

As reported by the CME Group, the most traded IRS is the U.S. Dollar denominated contract with a 2-year tenor. The IRS contract that I address is a 2-year contract with a fixed annually compounded rate of 2% on a notional principal of $100 million, a floating rate equal to the U.S. dollar LIBOR rate, and with interest payments made every 3 months. I use U.S. dollar LIBOR rates acquired from open resources of the Federal Reserve Bank of St. Louis. The sample data I use is 15 years (from 2004-06-01 to 2019-05-31) of observations which includes a period of extreme market conditions, and an out-of-sample period (from 1986-01-02 to 2004-05-31) to fulfill the 500-day lookback window for all the simulation processes and a 10-year lookback window for the floor mitigation tool, in accordance with previous work. I use a confidence level of 99% to calculate the model margin requirement. The data consist of daily observations on the 3-month, 6-month and 12-month U. S. dollar LIBOR rates.

In subsections 4.1 and 4.2, I explain the valuation of the IRS and the margin setting process, respectively. Subsection 4.2 describes how the margin changes over the sample period. In subsections 4.3 and 4.4, I explain the estimation of margin procyclicality and APC tools to mitigate procyclicality, respectively. In subsection 4.5 I provide a comparison of the performance of the APC tools on the basis of the peak-to-trough ratio.

4.1 IRS Valuation

I calculate the value of the IRS for each day during the 15-year sample period, 10-year and 500-day lookback window in out-of-sample period, starting from 1986-01-02 to 2019-05-31. There are 8 exchanges of interest payments over 2 years, at 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75 and 2 years. Daily LIBOR rates with times to maturity coinciding with the times of each interest payment are needed to discount each of these payments. Data on 3-month, 6-month and 12-month U. S. dollar LIBOR rates are available. The 0.75, 1.25, 1.75 and 2 year U.S. dollar LIBOR rates are estimated by interpolation using the observations on the 6 month and 1 year rate and by assuming that the slope of the yield curve is constant.

For example, the implied 9-month U.S. dollar LIBOR rate R_9 is obtained as follows:

$$\frac{R_9 - R_6}{\frac{9}{12} - \frac{6}{12}} = \frac{R_{12} - R_6}{\frac{12}{12} - \frac{6}{12}} \tag{12}$$

Where R_9 is the implied 9-month U. S. dollar LIBOR rate and R_6 and R_{12} are the observed 6-month and 12-month LIBOR rates, respectively. For maturities beyond 1 year, rate R_n for an n-month maturity may be calculated as:

$$\frac{R_n - R_{12}}{\frac{n}{12} - \frac{12}{12}} = \frac{R_{12} - R_6}{\frac{12}{12} - \frac{6}{12}} \tag{13}$$

where n = 15, 18, 21 and 24 months.

The value of the IRS is calculated using Equation (1), as the value of a fixed rate bond minus the value of the floating rate bond. The value of the fixed rate bond,

$$\begin{aligned} B_{fix,t} = \{&0.5e^{-R_3\times 0.25} + 0.5e^{-R_6\times 0.5} + 0.5e^{-R_9\times 0.75} + 0.5e^{-R_{12}\times 1.00} \\ &+ 0.5e^{-R_{15}\times 1.25} + 0.5e^{-R_{18}\times 1.5} + 0.5e^{-R_{21}\times 1.75} \\ &+ 100.5e^{-R_{24}\times 2.0}\} * 100\ million/100 \end{aligned} \tag{14}$$

The value of the floating rate bond,

$$B_{fl,t} = Notional\ principal\ =\ 100\ million \tag{15}$$

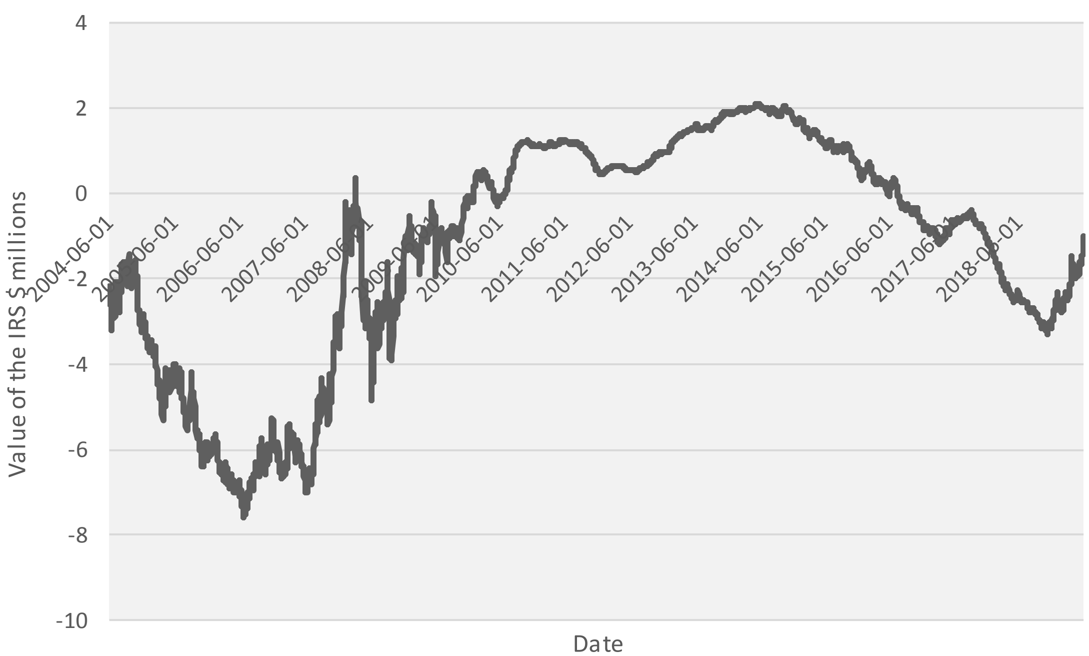

Figure 1: Estimated value of the IRS 2004-06-01 to 2019-05-31

Figure 1 plots the estimated IRS value over the 15-year sample period and demonstrates that it changes significantly over the period.

4.2 IRS margin setting

4.2.1 Estimation of volatility

I follow Murphy et al. (2016), Lee and Seo (2018) and CME, use the EWMA model to calculate the daily volatility of the IRS.

In theory, the estimate of the volatility of the IRS using the EWMA model is based on the return of the IRS. If this return is calculated as the ratio of the change in value of the IRS between t and t-1 to the absolute value of the IRS at t-1, the return becomes extremely high for those days t on which the value of the IRS at t-1 is close to zero. Note that the value of the floating rate bond equals the notional principal at any time t. Hence, the change in value of the IRS is captured by the change in the value of the fixed rate bond underlying the IRS, as LIBOR rates change. Accordingly, the volatility of the IRS is estimated by using the return on the fixed rate bond portion at time t, which is defined as:

$$\frac{B_{fix,t} - B_{fix,t-1}}{B_{fix,t-1}} \tag{16}$$

I use a 500-day rolling lookback window using data from t-500 to t-1 to estimate volatility for each day in the 15-year period and a decay factor of $\lambda = 0.94$, which, according to Risk Metrics, allows estimated volatility to most closely correspond with realized volatility. Figure 2 shows the frequency distribution of the estimated EWMA volatilities.

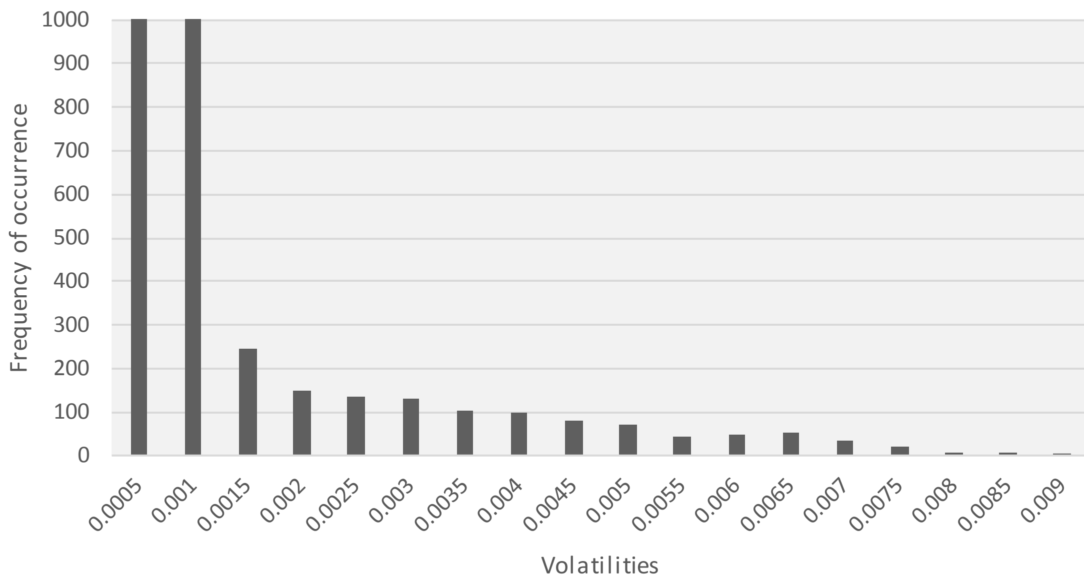

Figure 2: Frequency distribution of the daily EWMA volatilities of the IRS, 2004-2019

4.2.2 Estimation of the model margin

Using Equation (7), the model level of margin is given by $Mod_t \approx 2.3263\sigma_t$.

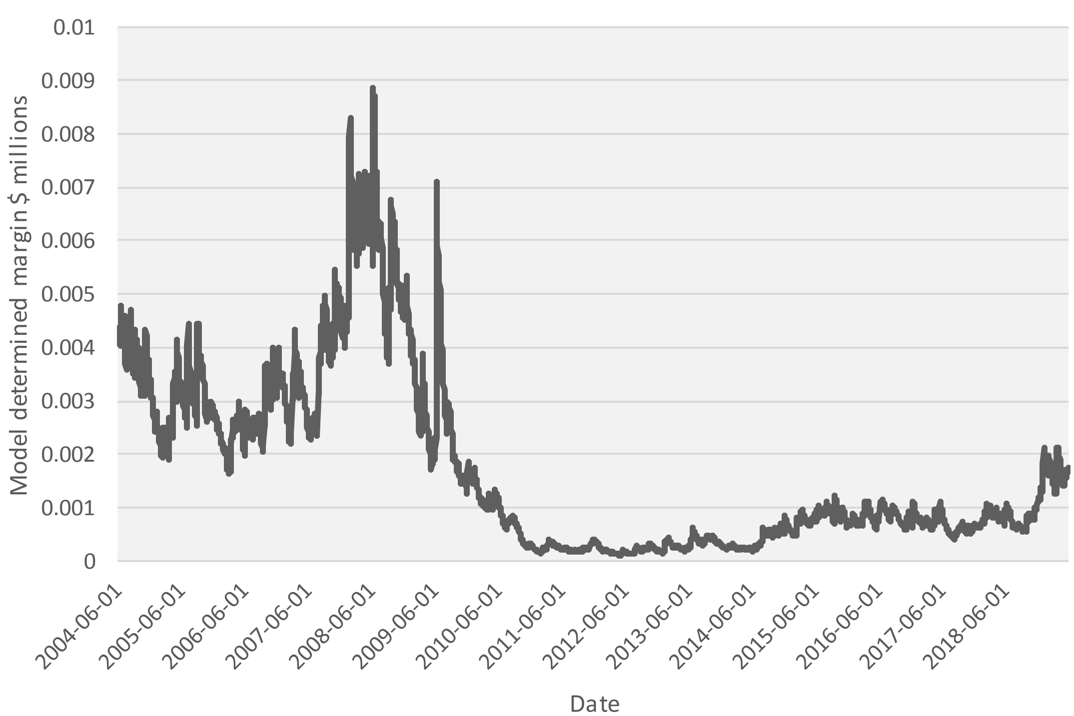

Figure 3: Model determined margin for the IRS, 2004-2019

Figure 3 graphs the model determined daily margin against the date for the 15-year period 2004-2019. I divide the overall period into 3 parts: pre-crisis (889 days, extending from 2004-06-01 to 2007-11-30), crisis (397 days, extending from 2007-12-03 to 2009-6-30), and post-crisis (1790 days, extending from 2012-05-01 to 2019-05-31). The crisis time interval is that of the subprime mortgage crisis, which was reported and archived by the National Bureau of Economic Research (NBER) in 2009. This period has a relatively higher margin level than the other two periods, with a maximum margin of $0.008861 million and a minimum margin of $0.001728 million. The post-crisis period is chosen when the volatility has decreased to a relatively low level on 2012-05-03 and we could regard the market as 'non-stressed'. The pre-crisis and post-crisis periods have margin requirements which are much lower than in the crisis period, with a maximum of $0.005451 and $0.002142 million, respectively, and a minimum of $0.001628 and 0.000108 million, respectively.

We see the sharp changes in margin level during the crisis, under which the margin requirement has increased to a significantly higher level, which is associated with highly volatile market conditions. In the pre-crisis and post-crisis periods, the margin requirements are relatively lower than during the crisis period, indicative of a more stable market. However, even in these relatively stable periods, the margin level varies over time.

4.3 Measure of procyclicality

Procyclicality of margin requirements is the property under which the margin requirement is higher in a stressed market and lower in less volatile markets.

Figure 4 indicates the daily return on the IRS and the margin requirement calculated using the model over the period 2004 through 2019. I measure procyclicality by calculating the peak-to-trough ratio for the three periods, pre-crisis, crisis and post-crisis. This ratio is 3.35, 5.13 and 19.80 in the pre-crisis, crisis and post-crisis periods, respectively. Procyclicality of the model determined margin is higher in the crisis period than in the pre-crisis period. However, procyclicality of the model determined margin is higher in the post-crisis period than in the two preceding periods. This implies that procyclicality of the model determined margin occurs in stressed periods when the market volatility is high, but it also exists in relatively tranquil periods. Consequently, it is critical to detect procyclicality and mitigate accordingly with modified margin.

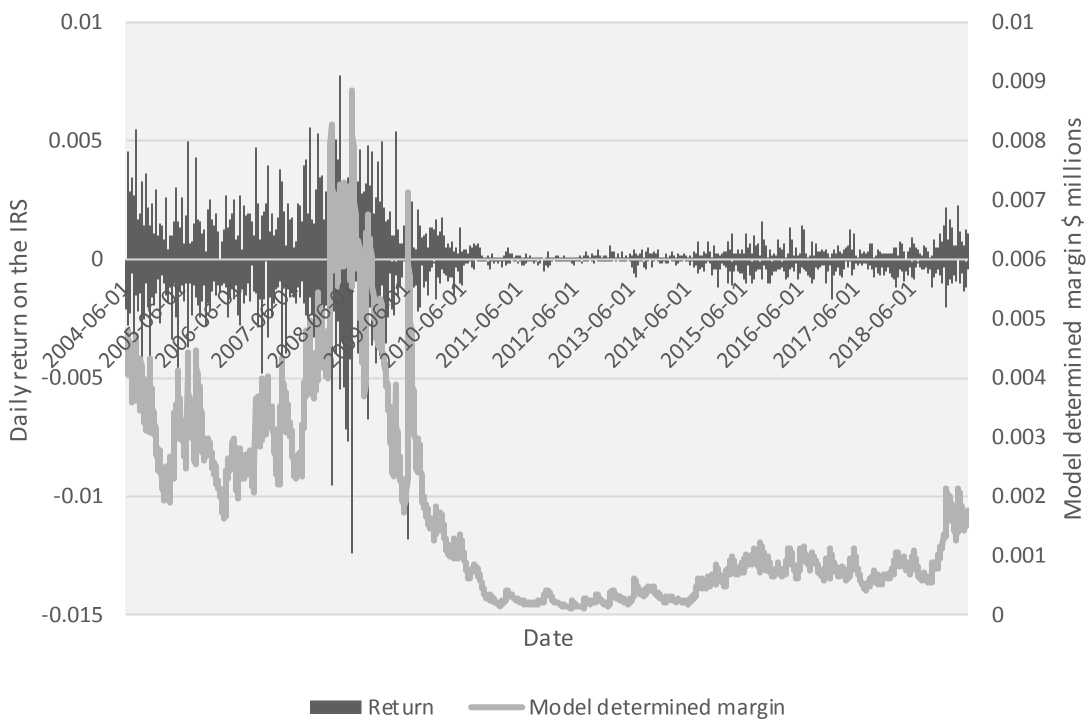

Figure 4: Daily return on the IRS and the model determined margin, 2004-2019

As noted earlier, the peak-to-trough measures long-term procyclicality if the period is long enough to cover economic booms and recessions, while if short-term liquidity is a concern of the CCP, the n-day procyclicality measure is appropriate. This measure is defined as the largest increase for a n-day period over a fixed observation window. Following previous research, the 30-day measure over a 15-year observation window, is adopted to measure short-term procyclicality in my thesis.

Figure 5 graphs the 30-day procyclicality measure again date for the 15-year period. The highest 30-day procyclicality measure is 0.004799 on 2009-06-10, caused by a margin increase to $0.007115 million on 2009-06-09. This is a consequence of the change in the value of the IRS which is caused by an abnormal increase in the 12-month LIBOR rate on 2009-06-08.

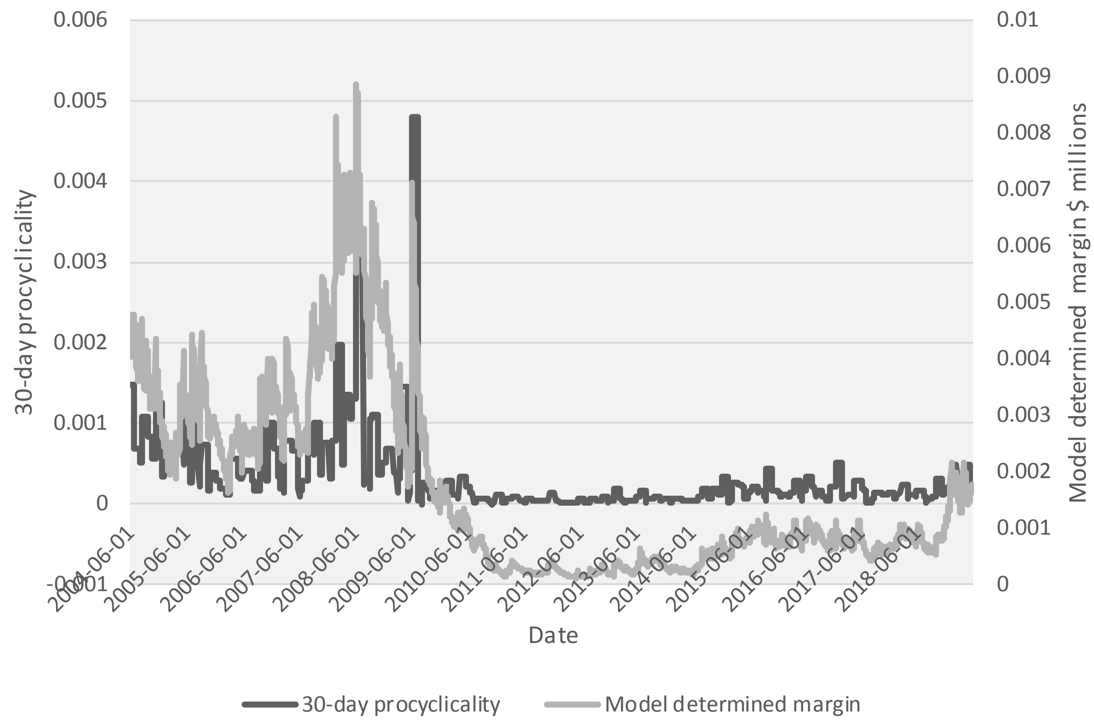

Figure 5: 30-day procyclicality and model determined margin requirement, 2004-2019

These measures are created to detect if the margin requirement is higher in a stressed market and lower in less volatile markets. The objective behind the application of the mitigation tools is to require a higher level of margin in less volatile markets and a lower level in more volatile markets, than called for by the model. The mitigation tools are described in the following sections.

4.4 Evaluation of margin procyclicality mitigation tools

In this section, I explain the methodology and results of evaluation of the margin procyclicality mitigation tools, three of which are suggested by EMIR guidelines, while the remaining two are proposed by Murphy, Vasio and Vause (2016).

4.4.1 Margin buffer mitigation effect

The EMIR requires CCPs to hold at least a 25% buffer. Basically, the margin buffer is an extra amount that a CCP should collect from its clearing members in stressed market conditions. I classify the market condition as 'stressed' if the estimated margin level with the buffer ($1.25 \cdot Mod_t$) is higher than the stressed margin threshold, where the threshold is the 90th percentile of historical margin estimated using a 500-day lookback window.

The buffer mitigation criteria, which is known as 'Release and Re-fund Rules for the Margin Buffer' Murphy et al. (2014), is to set the margin requirement $Mar_t = Max(StressedMargin, Mod_t)$ under stressed market conditions; if not, the margin requirement is set equal to 1.25 times the margin estimated by the model.

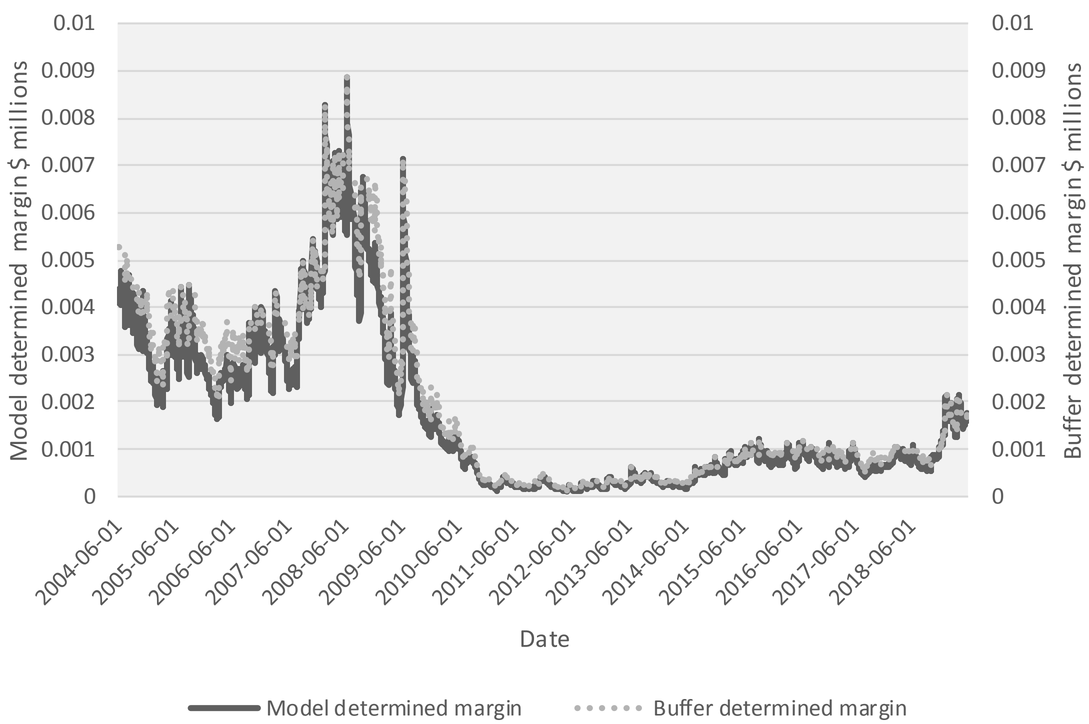

Figure 6: Model determined margin and buffer determined margin, 2004-2019

Figure 6 compares the model determined margin and the buffered margin for the overall period. The continuous curve denotes the model determined margin while the dotted curve indicates the buffered margin, when the buffer is triggered in a non-stressed market or the margin is modified in a stressed market. We can see from the figure, that the effect of the buffer is to increase margin requirements in normal market conditions and to reduce them in stressed markets. The peak-to-trough ratio using the model determined margin is 3.34, 5.13, and 19.80, in the pre-crisis, crisis and post-crisis periods, respectively. These indicate that the model determined margin is the most procyclical in the post-crisis period. After buffer mitigation is used, the peak-to-trough ratio is 2.68, 4.10 and 15.84, in the pre-crisis,

crisis and post-crisis periods, respectively, which indicates that this APC tool provides mitigation of procyclicality of margin requirements.

4.4.2 Stressed data mitigation effect

The EMIR requires CCPs to include 25% of observations from a stressed period in estimating volatility and setting margins. Eurex Prisma build stressed margin with 1-year stressed volatility.

There are two ways to calculate the procyclicality mitigated margin. The first is to estimate volatility using 25% of the observations of returns (125 days) from a stressed period and 75% of the observations of returns (375 days) from a regular period. The second is to estimate a stressed margin based on a period of stress, and a regular margin based on a normal period, and estimate the margin requirement as the weighted average of the two, where the weight applied to stressed margin is 25% and the weight applied to the regular margin is 75%.

I calculate the model determined margin using a 500-day lookback window which includes the out-of-sample period. The first observation of stressed market is 1990-08-29, thus I collect stressed volatilities extending from 1990-08-29 to 2019-05-31 and determine the stressed margin with most recent 125 stressed data. 375 days of observations of returns preceding each date is used to obtain the regular estimate of margin. The modified margin requirement is calculated by the weighted average of stressed margin (25% weight) and regularly estimated margin (75% weight). Figure 7 shows the results.

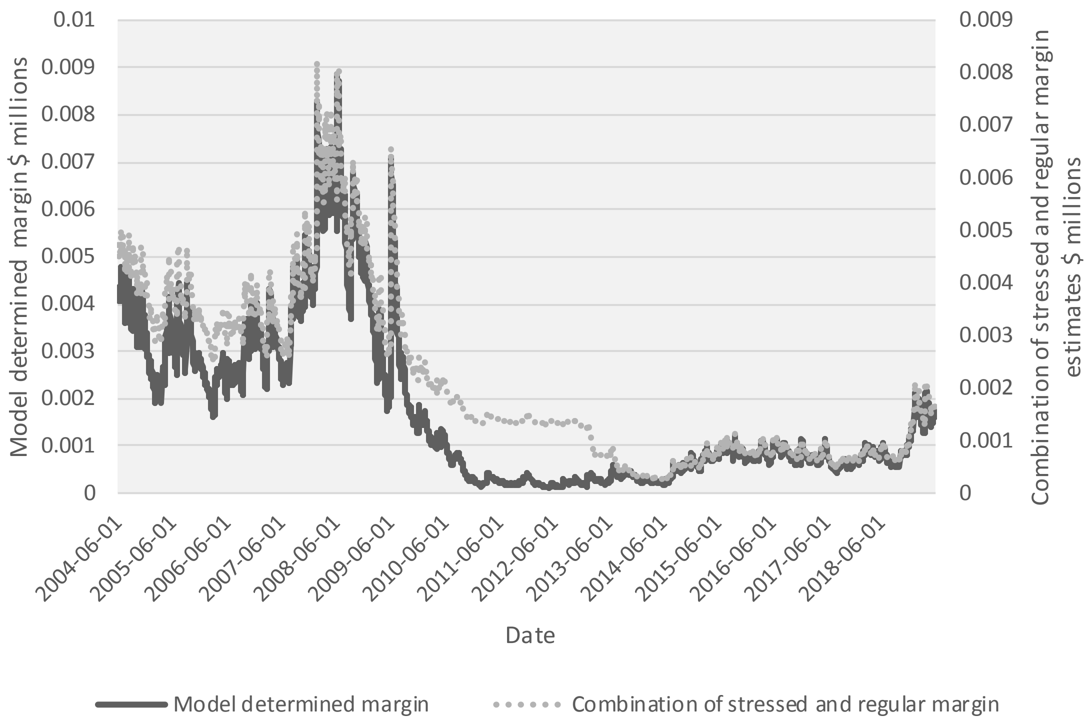

Figure 7: Model determined margin and margin based on 25% stressed margin and 75% regularly estimated margin, 2004-2019

The continuous curve shows the model determined margin while the dotted curve shows the margin based on a combination of stressed margin (25%) and the regular margin (75%). The peak-to-trough ratio using the model determined margin is 3.34, 5.13, and 19.80, in the pre-crisis, crisis and post-crisis periods, respectively. After stressed data is used, the peak-to-trough ratio is 2.15, 3.19 and 9.18, in the pre-crisis, crisis and post-crisis periods, respectively. Consequently, the stressed data APC tool efficiently decreases the procyclicality of margin requirement in all three period.

4.4.3 Floor on margin mitigation effect

The EMIR requires 'that margin requirements are not lower than those that would be calculated using volatility estimated over a 10-year historical lookback period', so that this regulation sets a floor level for the margin requirement, below which it is not allowed to fall.

I use a continuous window of the previous 10 years of observations on daily returns including the out-of-sample period, preceding each 500-day period used to estimate the model determined margin. The n% floor level is a threshold such that the CCPs will always maintain a minimum margin level equal to the n-th percentile of the historical model determined margin requirement. The minimum margin level is a pre-set variable: a higher floor would better mitigate procyclicality but will also impose higher margin requirements on counterparties and thus cause a higher burden. Thus, the modified margin is calculated by comparison between the n% floor level and the regularly estimated margin on a daily basis.

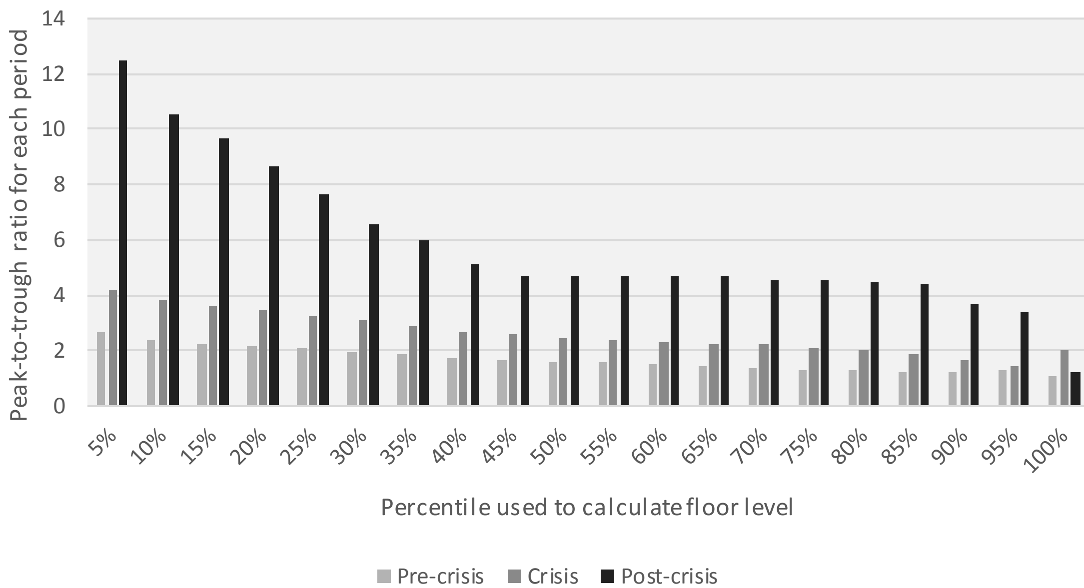

Figure 8: Peak-to-trough ratio calculated with different floor levels, 2004-2019

Figure 8 graphs the peak-to-trough ratio against the percentile used to set the floor, for the pre-crisis, crisis, and post-crisis periods. The graph indicates that the higher the percentile, the lower is the peak-to-trough ratio, the better is mitigation of procyclicality. This is because a high percentile is associated with a higher floor level. However, the higher the floor level, the higher is the margin requirement. When market conditions change, CCPs could chose an optimal floor level by choosing an appropriate percentile. This would be a trade-off between the advantage and disadvantage associated with a high percentile. I use the 20th percentile of the previous 10-year model determined margin following Murphy et al. (2016).

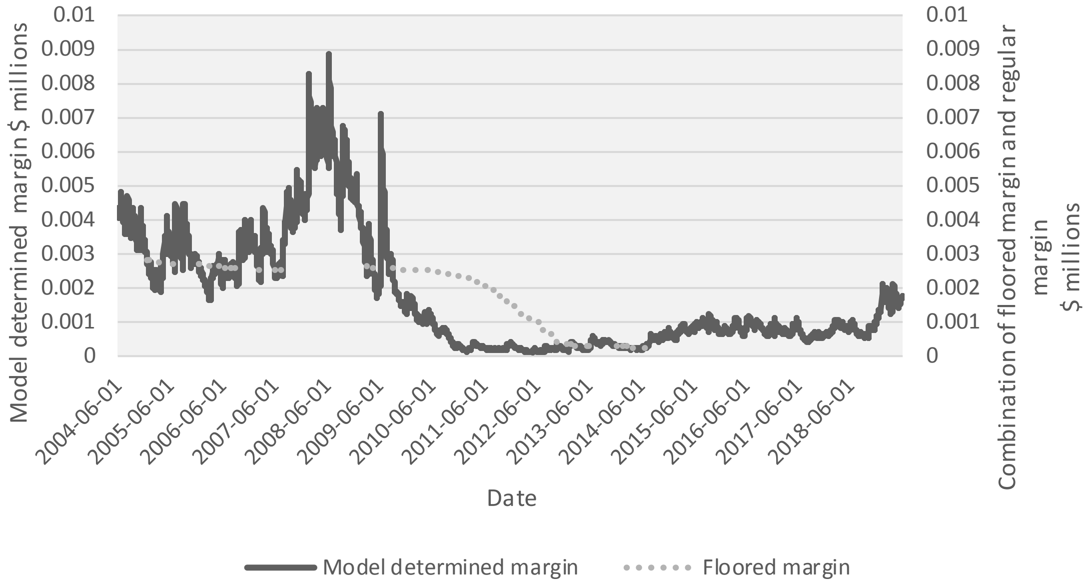

Figure 9: Model determined margin and a 20% floored margin, 2004-2019

Figure 9 compares the model determined margin and the floored margin over 2004-2019. The continuous curve denotes the model determined margin while the dotted curve indicates the combination of regular margin and floored margin. The figure indicates that during periods of low values for the model determined margin, the floor increases the margin to a higher level so that when extreme market conditions occur, the margin called upon from clearing members would not increase too much. The peak-to-trough ratio using the model determined margin is 3.34, 5.13, and 19.80, in the pre-crisis, crisis and post-crisis periods, respectively. After a 20% floor is used, the peak-to-trough ratio is 2.17, 3.44 and 8.64, in the pre-crisis, crisis and post-crisis periods, respectively. The results indicate that the floor on the margin requirement does limit procyclicality.

4.4.4 Adaptive stressed volatility mitigation effect

Murphy, Vasio and Vause (2016) develop two new methods for procyclicality mitigation. The first one is adaptive stressed volatility. This method is an improvement over the 'stressed data' method, in the sense that an adaptive weight is used to calculate stressed margin instead of a constant 25% weight.

Two methods could be used to estimate the margin requirement, using a proportion of data from stressed periods and from normal periods to estimate volatility and then to estimate the margin based on this volatility, or to separately calculate the margin based on stressed periods and from normal periods and use a weighted average of these estimates to calculate the margin requirement.

It is rational for CCPs to choose an appropriate weight to optimise the effectiveness of this mitigation tool. The adaptive weight can be expressed as a function of EWMA estimated volatility. When EWMA estimated volatility indicates that market conditions are not stressed, the weight attached to stressed observations or stressed margin is increased to more than 25%; while, if the market conditions are stressed, the weight attached to stressed observations or stressed margin is reduced to less than 25%. I follow Murphy et al. (2016) to determine the weight. This is described in what follows.

Denoting α as the appropriate weight or blending factor for stressed margin, then the modified margin can be written as

$$Mar_t = \alpha \cdot stressed\ margin + (1 - \alpha) \cdot Mod_t$$

The blending factor is negatively corelated to volatility estimated by the EWMA model σ_t, as follows:

$$\alpha = \beta exp^{-\kappa \sigma_t}$$

The independent variable volatility is estimated by the EWMA model, thus to get the dependent variable α we need values for β and κ.

a) I define the stress threshold volatility as $\sigma_{stressed}$, and the criteria for applying adaptive weights can be interpreted as: use $\alpha < 25\%$ when $\sigma_t > \sigma_{stressed}$, and use $\alpha > 25\%$ when $\sigma_t < \sigma_{stressed}$. Thus, we have, $\alpha = 25\%$ when $\sigma_t = \sigma_{stressed}$.
b) When the market is totally risk-free, $\sigma_t = 0$, $\alpha = \beta$. The CCP can set a value for β to determine the weights under a risk-free market. Following Murphy et al (2016), I set $\beta = 50\%$ which means an equal weight is assigned to the stressed and regular margin. Thus, we have $\alpha = \beta = 0.5$ when $\sigma_t = 0$.

We can estimate α from conditions above:

$$\alpha = 0.5exp^{-\kappa\sigma_t}, \quad \text{where } \kappa = \frac{ln2}{\sigma_{stressed}}$$

I use this adaptive weight to calculate the modified margin. Note that, as in section 4.4.2, a 500-day lookback window which includes the out-of-sample period is used to calculate σ_t and the model determined margin. The stressed data are collected from 1990-08-29 to 2019-5-31, and the most recent 125 stressed data is used to determine each day of the stressed margin, 375 days of observations of returns preceding each date is used to obtain the regular estimate of margin.

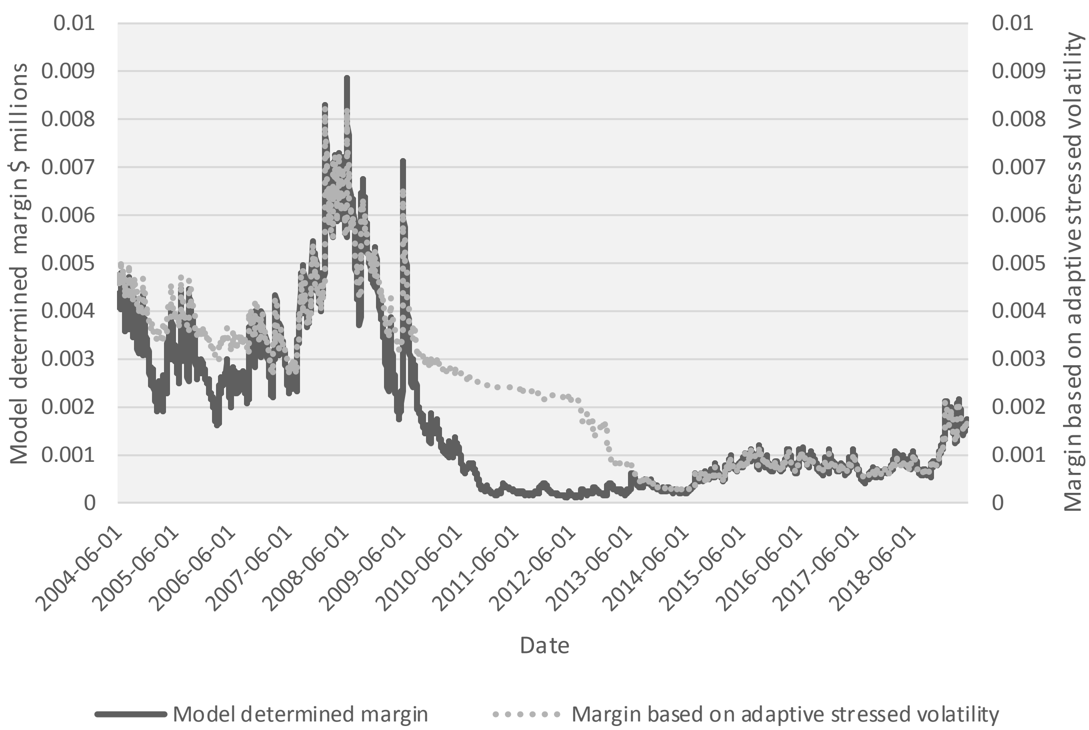

Figure 10: Model determined margin and margin based on adaptive stressed volatility, 2004-2019

Figure 10 shows the model determined margin and the margin based on adaptive stressed volatility over the period 2004-06-01 to 2019-05-31. The continuous curve denotes the model determined margin while the dotted curve indicates the modified margin based on adaptive stressed volatility. The peak-to-trough ratio using the model determined margin is 3.34, 5.13, and 19.80, in the pre-crisis, crisis and post-crisis periods, respectively. After adaptive stressed volatility is used, the peak-to-trough ratio is 2.02, 2.62 and 8.64, in the pre-crisis, crisis and post-crisis periods, respectively. The results indicate that the adaptive stressed volatility tool does limit procyclicality.

4.4.5 Speed limit mitigation effect

The speed limit is a method used to limit the over-reaction of margin requirements to market condition changes, which works in a way similar to those of price limits in futures markets. An everyday threshold on margin requirement changes is applied when the model determined margin changes more than this numerical value.

I calculate Y_t, which represents the daily changes in the model determined margin requirement and then calculate the speed limit by $L_t = F_Y^{-1}(0.9)$. I compare the model determined margin changes with the speed limit to get the modified margin requirement,

$$Mar_t = max(Mod_{t-1} + L_t, Mod_t)$$

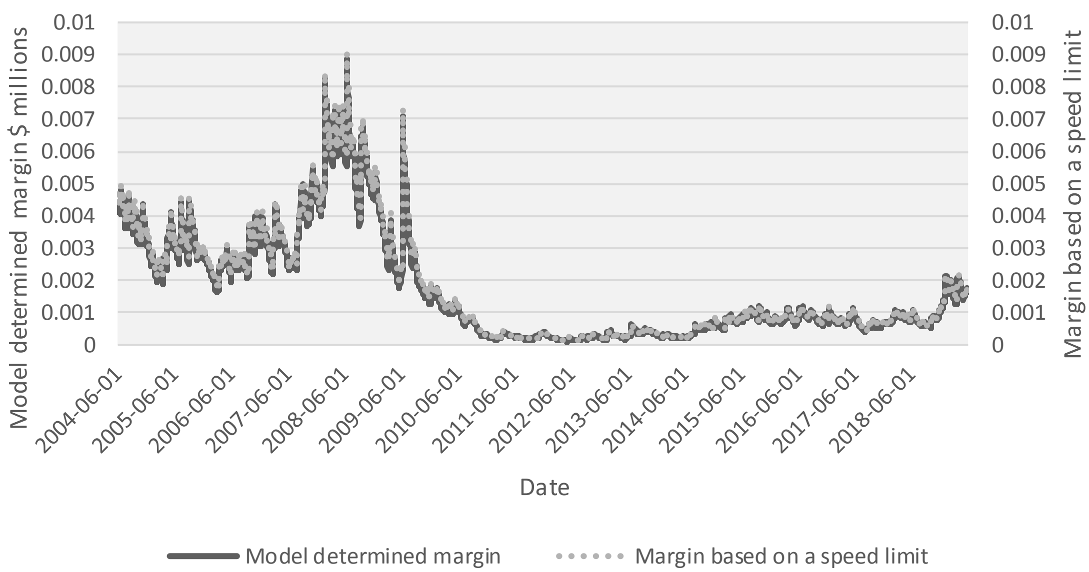

Figure 11: Model determined margin and speed limit based margin, 2004-2019

Figure 11 compares the model determined margin with the margin based on application of the speed limit. The continuous curve denotes the model determined margin while the dotted curve indicates the margin based on a speed limit. The peak-to-trough ratio using the model determined margin is 3.34, 5.13, and 19.80, in the pre-crisis, crisis and post-crisis periods, respectively. After speed limit is used, the peak-to-trough ratio is 3.21, 4.66

and 17.82, in the pre-crisis, crisis and post-crisis periods, respectively. The results indicate that the speed limit tool limits procyclicality.

Unlike the methods previously addressed, the speed limit does not mitigate procyclicality by imposing higher margin requirements in normal market conditions to smooth the margin requirement increase. It limits the rate of increase of the margin requirement.

4.5 Summary of the mitigation effect of the 5 tools

Table 1 compares the peak-to-trough ratio for the model determined margin and the margin requirement based on application of the 5 margin procyclicality mitigation tools for the pre-crisis period, the crisis period, the post-crisis period and the overall period.

Table 1. Peak-to-trough ratio for the model determined margin requirement and the margin requirement based on the 5 margin procyclicality mitigation tools

	Peak-to-trough ratio in different periods			
Margin based on	Pre-crisis	Crisis	Post-crisis	Overall period
Model determined margin	3.34	5.17	19.80	81.93
Margin procyclicality mitigation tool				
Buffer	2.68	4.10	15.84	65.54
Stressed volatility	2.15	3.19	9.18	35.40
20% floor	2.16	3.44	8.64	35.75
Adaptive stressed volatility	2.02	2.62	8.64	31.67
Speed limit	3.21	4.66	17.82	73.59

We can see from Table 1, that the peak-to-trough ratios of all five of the margin procyclicality mitigation tools are lower than those for the model determined margin in all periods. The peak-to-trough ratio is the lowest for the adaptive stressed volatility method for all periods. The stressed volatility technique has the lowest peak-to-trough ratio when the 3 tools proposed by the EMIR are compared.

Generally, three methods provide more than a 50% reduction in the peak-to-trough ratio, compared to the model determined margin requirement: stressed volatility, 20% floor and adaptive stressed volatility; while the buffer and speed limit techniques provide lower reductions in the peak-to-trough ratio.

5. Summary and conclusion

In this thesis, I discuss margin setting by CCPs, and how to mitigate the problem of procyclicality in margin requirements. I estimate the optimal margin to be set by CCPs that clear interest rate swaps, using historical simulation of volatility based on the EWMA model to estimate value at risk.

Regulations of over-the-counter derivatives require major central counterparties in these markets to set margins for derivatives that they clear. The margin requirement is the performance bond that a CCP collects from its clearing members, which is a first defence against losses that would be suffered by the CCP if the clearing member defaults. The CCPs specify an initial margin which is to be paid by the clearing member when a position in the contract is initiated. Clearing members are expected to maintain the balance in their accounts at the level of the initial margin.

There are two methods of margin setting identified in the literature: 1) standard portfolio analysis of risk (SPAN) and 2) historical value at risk (HVaR). SPAN was originated by the CME Group and was widely used in the industry but possesses some disadvantages which have resulted in its not being as widely used currently. HVaR has been used in previous research such as that of Heller and Vause (2012), and Duffie et al. (2015). Margins based on HVaR are estimated by historical simulation using estimates of asset volatility based on a model of volatility such as the GARCH model (Glasserman and Wu (2017)) or the EWMA model (Murphy et al (2014, 2016)).

The IRS is the most widely used OTC derivative. When an IRS contract comes into effect, the terms of the contract such as the expiration date, payment frequency, notional principal, and fixed rate are specified. As time passes, the value of the contract depends on the term structure of the floating rate, which is usually the LIBOR rate. Using a time series of LIBOR rates, I estimate the value of a particular IRS over time, using the method of Hull (2003), under which the contract is valued as a long position in a fixed rate bond and a short position in a floating rate bond. Using the time series of IRS values, the historical simulation method and VaR margin setting model, I estimate the margin requirement for a CCP which clears a specific IRS contract. The fluctuation of margin requirements over time reflect the change in volatility of the LIBOR rate over the sample period, with greater margin called for in more volatile periods

A problem recently raised in the finance literature is that the margin requirement set by this method is procyclical, in the sense that when the market is more volatile, the margin requirement is higher, and when the market is less volatile, the margin requirement is lower. This adversely affects the margin poster. In stressed markets, counterparties may default on sharp increases in margin requirements, or liquidate their derivatives positions to fulfill the margin requirements, which could further decrease the prices of the derivative portfolios' underlying assets and exacerbate the price move. Regulators consider that procyclicality is an important aspect for CCPs to handle. In Article 28 of the European Market Infrastructure Regulation (EMIR) Regulatory Technical Standards, three anti-procyclicality (APC) tools have been implemented. Murphy et al. (2014, 2016) test these three tools and develop two other APC tools. In this thesis, I have tested the tools of the EMIR and Murphy et al. (2016) for margin setting by CCPs clearing IRSs and find that these tools are effective in countering procyclicality.

The first four methods impose a greater margin requirement during normal periods. The buffer builds up in relatively low volatility periods and is released in high volatility periods. The margin floor sets a minimum threshold for the margin requirement level. The stressed data and adaptive stressed data methods estimate volatility by combining data from normal periods with those from stressed periods. EMIR requires a constant 25% weight to data from stressed periods, while Murphy et al. (2016) recommend a more adaptive weight allocation to stressed data. The speed limit is similar to price limits in future markets, and procyclicality is controlled by limiting the speed at which margin requirements change.

I assess the five tools for addressing procyclicality in margin requirements for CCPs clearing U. S. dollar denominated IRS. A comparison of the peak-to-trough ratio for the model determined margin with those under the 5 tools used to limit procyclicality for periods of pre-crisis, crisis, post-crisis and overall period indicates that adaptive stressed volatility performs the best.

6. Suggestions for future research

In this thesis, I have focused on using value at risk to set margin requirements for a CCP clearing an IRS. Future research could analyse the use of conditional value at risk to consider greater potential loss in extreme events than the percentile value calculated by the VaR.

The SPAN method of the CME is an alternative method which could be applied to bigger databases and uses scenarios analysis to capture the risk of a portfolio. Future research could use a combination of scenario analysis and value at risk to address margin setting for a CCP which clears many derivatives, such as interest rate swaps, foreign currency swaps, credit default swaps, etc.

Future research could use other models, such as EGARCH and IGARCH, to estimate the volatility of the derivative of interest.

Finally, new and innovative anti-procyclical margin setting tools could be invented and analyzed using the techniques employed in this thesis.

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