Designing a Margin Lending Policy for a Prime Broker

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Abstract

The key services provided by prime brokers defines prime brokerage as a collateralised business. This research reviews contemporary literature and industry standard policies for calculating margin requirements, and from an equity centric database, a new rules-based margin lending policy is defined with inherent sensitivity to market conditions via the inclusion of volatility and equity beta in the base margin calculation. Final margins are reviewed against portfolio performance, value at risk and contemporary wider market data.

Keywords: Margin Policy, Equities, Rules Based, Prime Brokerage

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1 Introduction

Prime brokers provide services for professional clients, primarily hedge funds. The services provided varies between clients but will normally include trade clearance; capital introduction; custodianship of assets and stock lending, which enables the client to establish short positions. The most important service, however, is common to all clients: financing to allow clients to buy assets on margin.

The process of financing and stock lending defines prime brokerage as a collateralised business. Collateral is provided by clients to mitigate the risk of a credit loss and can be made up from an accumulation of cash and tradeable assets, with clients usually opting to trade a mixture of physical assets and derivatives such as exchange-traded futures, options, swaps and Contracts For Difference (CFD).

What makes for good collateral can be summarised by three key factors: firstly, the asset must be freely tradeable to allow for accurate and frequent price discovery, secondly liquidity is of upmost importance; the value of an asset is of diminishing importance if it is severely illiquid, and finally the asset must be wholly unrelated to the client in order to remove the risk of share price manipulation or alternative foul play.

The process of collateralised lending implies the risk-averse nature of prime brokers. There is an equitable balance to be reached between stringent lending rules and driving margins too high to prevent profitable business. Prime brokers make money by achieving and maintaining a balance between these factors consistently over time.

The first prime brokerage business was offered by Alfred Winslow Jones in 1949, however it failed to come to prominence within the financial services industry until the latter half of the 1970s, via the services offered by US broker-dealer, Furman Selz. The services came as a solution to difficulties experienced by portfolio managers as investment popularity grew and mangers were overwhelmed with responsibilities to track and record all trades, consolidate positions and analyse performance across all brokerages. Taking on the responsibility for these services, prime brokerage developed as an equities centric industry, and this remains largely true today (See Data Selection).

Witnessing the early success of the prime brokerage business model, larger banks also began to offer prime brokerage services. Today the majority of tier one banks have a prime brokerage division, with Morgan Stanley, JP Morgan and Goldman Sachs leading the industry.

As the rise of prime brokerage grew in the United States, so did the regulation which surrounded the operations. Regulation T, a Federal Reserve Board regulation, has controlled the extension of credit by US broker dealers since 1974. The regulation stipulates all US brokers must apply an initial margin requirement of 50%, meaning an investor can borrow no more than 50% of the price of the asset. Many argue therefore that the rise in prime brokerage popularity outside of the US can, at least in part, be attributed to the introduction of Regulation T. Outside of the US, brokers were able to set margins at an increasingly competitive rate, and attract business from American hedge funds looking for risk-sensitive margins. They wanted a linear relationship between the risk of their portfolios and the margin they were offered. Outside of US jurisdiction, prime brokers have the capabilities to do this.

For prime brokers operating in locations without margin regulations, the primary concern is to decide exactly how large a margin should be. Models need to account for both long and short positions and the risk inherent to each individual position. This project aims to produce a contemporary model for margin requirements, allowing for sensitivity to daily changes in asset price along with factors contributing to credit risk, including country of registry and sector concentration. Further discussion of the importance of each of these parameters is discussed in the Methodology section.

The approach to model building aims to produce a highly risk-sensitive system, while simultaneously maintaining simplicity of specification. Simplicity is attractive to prime brokers owing to the fact that clients can understand and interpret the rules with relative ease, therefore allowing the client to pre-empt or at least predict a margin call. The ease of interpretation is in effect a parameter directly correlated to reducing credit risk.

This research is informed by academic and corporate literature; Chapter 2. The data selection process is outlined in Chapter 3 which is followed by a detailed explanation of research methodology in Chapter 4, including the derivation of a new set of margin policy rules in subsection 4.2. Analysis of the performance of the margin policy is evaluated thoroughly in Chapter 5. Final conclusions are drawn in Chapter 6.

2 Literature Review

2.1 Academic Literature

The literature surrounding setting margin requirements spans the best part of the last four decades. The review is considered largely with respect to European markets, since American institutions have been subject to minimum margin requirements set by the Federal Reserve Board since the introduction of the Securities Exchange Act of 1934 (SEC, 1934).

The literature for modelling margin requirements divides naturally into two schools of thought: those which apply statistical approaches and analysis, against those which utilise economic models. Figlewski (1984) is one of the first authors to contribute to the *prudential approach* on setting margin requirements. Figlewski (1984), and others who contribute to this view, consider the main purpose of margins as guaranteeing the performance of contracts which require transactions in the future, whereby covering losses if and when default occurs. Distinction is made between credit margins (used to limit spending against collateral in the stock markets) and performance margins (commonly attributed to futures contracts) with margins on options being referred to as a hybrid between the two. Figlewski (1984) forwards a simplistic model for setting optimal performance margins; the natural logarithm of futures prices is modelled as a Weiner process and guaranteeing performance is assumed to be the only objective. The maintenance margin is stated as a function of the security's price volatility and the length of the 'grace period', with two further key parameters defined as the probability of a margin call and the probability of a second price change that removes the remaining margin coverage during the grace period. The probabilities are then computed as solutions to a first passage problem.

Gay et al. (1986) further the prudential approach with continued focus on futures contracts. While the authors highlight that it is difficult to observe and directly model the relationship between expected probability and the risk of loss from default, their model successfully forwards Figlewski (1984) in enabling the testing of whether a selection of contemporary margins at the time of publication are set in concurrence with Figlewski's model. The authors make one key adaptation: using dollar price change in place of percentage price change. Four hypothesis were developed and tested leading the authors to conclude that not only are margins set in a manner as though a formal Figlewski style specification were applied, despite the converse being true, but furthermore, in line with Figlewski (1984) an appropriate margin level for commodity contracts would be to set the margin such that the probability of the futures price moving by greater than or equal to the margin, is constant across contracts within the commodity class. Daskalaki and Skiadopoulos (2016) find that commodity markets in particular are sensitive to the effects of margin changes on speculation and hence recommend policy makers recognise that the effect of margin changes varies across commodity groups, with only margin increases affecting the commodity futures market.

Along with Figlewski (1984) and Gay et al. (1986), Edwards and Neftci (1988) develop a parametric model (a development of Figlewski (1984) for time series analysis of correlated commodity price movements) with the assumption that normality holds for futures prices. Contrastingly, Warshawsky et al. (1989) develops a non-parametric model and concludes normality of futures returns is not always a necessary or sufficient condition and may cause underestimated margins. This is an observation which has been found to hold true by a number of other authors, particularly those who have applied *Extreme Value Theory* (EVT) to setting margin levels. Broussard and Booth (1998), Longin (1999), Cotter

(2001), Bhattacharyya and Ritolia (2008) and Kao and Lin (2010) find that the probability of a margin call is underestimated when normality is assumed as the distribution of large price movements is significantly leptokurtic when EVT is used to measure optimal margins.

Following Figlewski (1984), margin policy research is developed through an alternative view with Brennan (1986) introducing *efficient contract design*. His work considers how margins can be defined for self-enforcing contracts when price limits are used as a proxy for margin requirements. With the fundamental view of minimizing costs to brokers, Brennan's approach considers how various economic factors may influence determination of the optimal margin level (Kao and Lin, 2010). Shanker and Balakrishnan (2005) furthers Brennan (1986) to set optimal margins and price limits which minimize costs to clearing houses. The authors conclude that for a self-enforcing contract the summation of margin and capital should not only be equal to the expected loss of the short clearing firm on an upper price limit hit, but should also exceed the price limit.

Forwarding the paradigm of efficient contract design, Fenn and Kupiec (1993) and Telser (1981) introduce the concept of procyclicality of margin changes. Central Counterparty Clearing Houses (CCPs) have recently recognised the need for, and benefit of, margin setting to limit procyclicality while retaining sufficient risk-sensitivity (Alexander et al., 2019). In this light, Glasserman and Wu (2018) consider the extent to which margin levels must rise in order to avoid procyclical effects while maintaining reduced levels of counterparty credit risk. Their initial GARCH model formulates the procyclicality through conditional and unconditional margins, leading to two key conclusions: firstly that 'the buffer required to offset procyclicality depends on the tail exponent', and secondly, 'the lookback period required to estimate the quantile accurately depends on the extremal index'. Their research further concludes that the two aforementioned parameters should hold using alternative models to GARCH, and thus should inform current practice in mitigating procyclicality.

Ongoing findings of Berlinger et al. (2018) contribute to research on anti-cyclical margin policies. This research is in line with European Parliament (2012) legislation which states that since margin calls may have procyclical effects, CCPs, and other authorities should try to prevent and control possible procyclical effects via risk-management practices. Berlinger et al. (2018) construct a model of margin requirements derived from the prevailing work on credit risk by Merton (1974). Their discrete-time model takes into account major factors and trade-offs in deriving the optimal margin level for minimizing counterparty risk.

Standardized Portfolio Analysis of Risk (SPAN) is a type of market simulation based Value At Risk (VaR) system and risk-centric margin setting methodology developed in 1988 by the Chicago Mercantile Exchange (CME) to effectively assess risk on an overall portfolio basis (CME, 2019). SPAN is the global standard for portfolio margining, used to assess risk for financial instruments such as: futures, options, physicals and equities. There have been a number of contributions to the empirical literature on SPAN margins. Firstly, in researching calendar spreads on S&P 500 Futures with daily SPAN values for four years from December 1988, Kupiec (1994) finds a coverage level of less than 95% and concludes that the SPAN margining system is significantly more effective than strategy-based margining systems. In a later work, Kupiec and White (1996) test SPAN against Regulation T. The research finds that for S&P vanilla option portfolios, SPAN generates lower margins than Regulation T but does provide 99–100% coverage of daily return movements.

Following the introduction of the 'Dodd–Frank Wall Street Reform and Consumer Protection Act' in 2010, it is legislated that standard OTC derivative contracts must be cleared through a CCP. Furthermore, the act grants supervisory organizations authority to examine and approve the margin requirements of CCPs. In a further contribution to SPAN, Park and Abruzzo (2016) review how these margin policies are currently constructed and further discuss situations in which SPAN margins have been altered by exchanges such as the CME and the Intercontinental Exchange (ICE). They find that the CME has been slow in reducing margin levels and suggest intervention from government may still be required (discussed by Chowdhry and Nanda (1998) and Chen (2018)). Significantly, Park and Abruzzo (2016) report the CME will increase margins when a volatility threshold is breached, although the converse does not apply. This prompts research which will is developed within this project.

Continued in the methodology section, the model presented in this dissertation seeks to utilise volatility as a parameter within margin setting rules which applies in both directions: increasing the margin in times of greater volatility and decreasing margins in more stable periods. As highlighted by Park and Abruzzo (2016), while a sensitivity to volatility better protects the prime broker, it will exacerbate the financial positions of the borrowers with increasing severity during economic downturns and provide further supporting evidence to the procyclicality of margins. (Additionally, Daskalaki and Skiadopoulos (2016) have evaluated the effect of large changes in SPAN margins. They find that large margin increases were positively correlated to prices). The procyclicality means brokers are trapped into a 'race to the bottom', where lenders are incentivised to reduce their margins below that of their competitors. The authors highlight in particular how competition induces competitive margining between the CME and ICE.

2.2 Industry Literature

Three margin policies from major brokers are reviewed to inform this research. In compliance with company confidentially these shall be referred to as company A, B, C. Given that these policies are either recently or currently in operation, and are representative of industry best practice standards, there are few major criticisms to be made. Therefore, critique is given with respect to how well-suited the policies are to informing the model specified within this dissertation.

The three policies divide into two categories: statistical and rules-based. Each of the policies can be categorised into either group, and subsequently are reviewed against general influencing factors for the class and for nuances specific to the policy.

Policy A is of the rules-based variety. The model is built upon a base margin specific to each asset class, meaning equities have a different margin to corporate and government bonds which is reflective of the risk appetite of the brokerage. Bond margins increase with time to maturity for example, with bond spread and rating also influencing factors. This brokerage chooses not to specify margin policies for listed options and futures, dealing with such on a case-by-case basis.

Since delta-neutral portfolios are inherently less risky than portfolios with unbalanced positions, Company A details provision for this via attributing a lower base margin for the proportion of the portfolio for which the long and short positions are matched. Company A then builds upon the base margin mechanism by introducing a number of multiplicative factors. These include single-issuer concentration; sector concentration; emerging market concentration; country of risk; and market capitalisation. Each multiplier categorises the possible scenarios in which an asset, or portfolio can fall, and assigns multiplicative values for each scenario. For example, portfolios which are less diversified and have high sector concentration are at risk of high losses in the event of industry wide crisis. Each asset within the highly represented sector would therefore be subject to a larger base margin multiplier than assets from a range of sectors. Similar logic is applied with respect to the other concentration multipliers.

If Company A applied all three concentration multipliers (single issuer concentration; sector concentration; emerging market concentration) they would risk 'double counting'. Double counting refers to the situation in which an asset is penalised more than once for the same shortcoming. For example, a portfolio of positions from a single-issuer would be penalised twice by means of higher margin requirements if the issuer was also from an emerging economy. Company A combat this issue by ranking the concentration multipliers, and only applying the highest of the three to the position as the concentration multiplier.

In addition to the concentration multipliers, Company A transform the base margin rate into the final margin via the addition of a 'liquidity margin add-on'. This parameter is determined by the percentage of average daily trading volume for each equity position. Specifically, where an equity position exceeds 50% of average daily volume, the portion above 50% is subject to a liquidity margin add-on. The size of the add-on is categorised into tranches, with larger positions with respect to average daily volume calling for a larger liquidity margin add-on. While the liquidity margin add-on is a necessary parameter, we believe use of average daily volume does not account for extreme values within the time frame, and therefore median trading volume is a more representative measure of liquidity risk.

In the event that excessively large margins occur for reasons other than double counting or large liquidity margin add-ons, Company A ensures margins remain competitive by declaring that all positions will be subject to a cap on their final margin, with a higher margin cap allocated to short positions than their long counterparts.

Policy B is also of the rules-based category of policies with specification only provided for equity assets. While the policy is similar to that of Company A, in that a base margin is specified before application of other parameters, these are not as multiplicative factors, but rather a series of add-on factors for sector, country, long/short pairs, liquidity and concentration.

The issue of double counting is addressed in Policy B with a similar approach to Policy A. The total margin requirement is a maximum function with three different scenarios. The first of these is the initial base margin combined with an add on amount for country, sector, liquidity and portfolio concentration. The second scenario is a calculation of 10% of gross exposure, and the final scenario calculates a stressed proportion of the largest short single-issuer exposure. Of these three scenarios, the largest is taken as the total margin requirement.

Company C provide a margin framework which is more closely aligned to statistical methodology, although there are aspects which mirror a rules-based approach. Policy C is based around stress testing to determine the minimum risk-based requirement to which clients are held, with risk exposures measured at both the individual security and at the portfolio level.

The policy stress tests for each of equity, credit, convertible bond, foreign exchange, interest rate and commodities risks. The largest two losses from each of these stress tests are then added to the square root of the sum of the squares of the remaining stress losses, with default charges forming the final margin add on amount.

While the stress testing methodology is particularly effective in informing how margins are calculated during periods of volatile markets and uncertainty, the complex nature of the tests is not entirely user-friendly, and require substantially more data than the rules-based models. The stress testing approach definitely covers a wider breadth of portfolio scenarios; however, I believe the rules-based models offer immediate clarity of parameter interactions, without having to run the simulations, which enhances their predictive-power more so than policies similar to C.

3 Data Selection

This study will utilise a database of 1044 equities from Cowen Inc Ltd.'s assets under management. The equities have all been pre-approved for use as collateral and their number represent in excess of 12 key sectors; 43 countries and varying market capitalisation sizes. The decision to focus on margin requirements for equities stems from the fact that approximately 75% of Cowen Inc's Prime Brokerage business is equities alone. This is a trend displayed across the hedge fund industry with Goldman Sachs (2019), for example, reporting that since 2009, the majority of new funds set up on their prime brokerage platform have been equity-based funds, and in 2018 this number was recorded as 61%.

Margins are calculated and evaluated over a one-year period, 7th August 2018 - 6th August 2019, with all equity prices downloaded and models specified in USD. From the large data set three portfolios will be constructed to use within simulations of the final margin policy. The portfolios each represent a different investment style and therefore illustrate the extent to which the model is representative of margin sensitivities to portfolios with different levels of risk.

Each portfolio is constructed of size $10,000,000 and is held without rebalancing for the entire evaluation period. While this is perhaps not wholly representative of common portfolio management practice, the parity through the year allows for evaluation of margins against a variety of portfolio return periods. At a fundamental level, it is the hope of margin lenders that margin policy is sensitive to periods of portfolio distress. Holding portfolios constant over the year will allow affective evaluation of this.

The first portfolio constructed is a concentrated portfolio of ten equities. The portfolio is net short with absolute unitary portfolio weights held in each equity. This portfolio is designed to capture how margins behave against portfolios with little diversification across sectors. Equities are selected from the data set which have been performing well, at the time of selection, with higher than average return on equity for the dataset. In construction, via the Bloomberg terminal portfolio manager, active total risk is set as a constraint to be minimised. Table 6 (see Appendix) outlines the portfolio composition.

The second portfolio constructed is an income fund. The portfolio selects equities from the data set which have high dividend yields, particularly in comparison to other equities in the same asset class. In order to reflect a further investment style, this portfolio is designed to be long only, and equally weighted. Table 7 (see Appendix) outlines portfolio composition.

The third portfolio is a growth fund, designed to include a range of equities with more volatile prices; price earnings growth in the top 10% of the dataset, and with lower dividends per-share than in the income portfolio. It is the largest portfolio by number of equities. After minimising active total risk via the Bloomberg terminal portfolio manager, manual adjustments are made to ensure a number of positions are considered to be illiquid (in order to test the responsiveness of the margin policy to such scenario). Table 8 (see Appendix) outlines the portfolio composition.

4 Methodology

4.1 Model Development

After evaluation of the three example margin policies and in light of the positive review of rules-based policies outlined in subsection 2.2 we choose to centre our model around a rules-based framework.

The process of developing this margin policy has been one of trial and error. A descriptive overview of this process, with reference to the selection of different parameters and methodologies, is outlined with key findings of the process summarised before a full mathematical specification of the final margin rules are given in subsection 4.2.

The challenge has been to design a framework which captures portfolio idiosyncrasies and which is sensitive to portfolio performance, while remaining representative of the risk appetite of the broker. This has ultimately been achieved by producing margins with various parameters and evaluating which had success in capturing an equitable balance of both ideals.

The first margin model drafted, defined parameters for market capitalisation; country of risk and sector concentration. After consultation with experts at Cowen Inc., the base margin rate (on which the multiplicative parameters were to be applied to capture a basis level of risk of holding each equity position) was initially specified as 30%. This was an arbitrary value selected to develop awareness of a suitable region for the base margin in future more informed models. Market capitalisation and sector concentration were categorised into bands, the market capitalisation data being drawn directly from Bloomberg and sector concentration calculated as the sum of each equity's market capitalisation within each representative sector (following GICS sector names). This method has been evaluated to constitute double counting; equities with large market capitalisations were contributing to high sector concentration at the portfolio level, and therefore receivieved an inflated margin. But in situations where the equities were from emerging markets (and therefore categorised as higher risk countries), this resulted in the equity also receiving an increased margin for the country specific risk. This failure was corrected in later models by introducing beta into the base margin in place of a country of risk multiplier (outlined fully in subsection 4.2).

Furthermore, provision for portfolio directionality has to be included within the model. Equity positions should be eligible for a reduced margin for equity delta-neutral risk offset; fundamentally a delta neutral portfolio should have a lower portfolio margin than a long only portfolio. After discussing with Cowen the intuition behind offsetting rules, I designed the following scheme which considered portfolio directionality in terms of long/short tails: Firstly, the portion of the portfolio which is unhedged is defined as the 'tail', for example, if the portfolio was net long then all short positions and the equivalent proportion of long positions are defined as 'hedged', with the remining proportion of long positions constituting the tail. The hedged proportion is then subject to a reduced margin, while the tail is attributed to the originally specified base margin. Calculation of a parameter defined as 'hedged allowance' was the first step in the reduction process. Calculated as the one minus the ratio of hedged market value and gross market value, the hedged allowance was then applied to each position via a lengthy calculation of the proportion of each position which could be attributed to the tail, the proportion which was hedged then received the lower margin, proportional to the position size.

This process was reviewed to be cumbersome and ineffective. As margins are paid on the portfolio level, rather than on each individual equity, the proportion of each equity which contributed to the hedged proportion did not need to be simulated. Applied in the final margin model, the simpler method of multiplying each equity position by one minus the hedged allowance has been found to be a more robust approach to increasing margins on unbalanced portfolios.

Significant progress with respect to improving the initial model has been made via consideration of how the parameter for country of risk could best be incorporated with market capitalisation in order to mitigate double counting. After review, it has been decided that utilising each equities beta score, from a regression of daily equity returns against a relevant index, would be an innovative way to combine the two multipliers. First categorising the beta scores into tranches to become base margin multiplicative factors, the model has improved as more parameters are derived rather than arbitrarily specified. Further evaluation of the process led to a trial of using beta itself as the base margin multiplier so that each equity's margin increased in parallel to the risk level within the relative index. This development was reviewed to be especially neat, and a novel approach to base margin determination.

For the final adaptation to the base margin calculation, I removed the specified base parameter, and replaced with a measure for equity volatility. Hence, the base margin became the product of beta and volatility, which not only constitutes a fully derived parameter, but is also sensitive to both equity specific and wider market conditions. This derivation was the final step in the model development process, from which the final margin model has been defined and evaluated.

In summary, the model development process concluded the following:

- Sector concentration multipliers are necessary to capture well or poorly diversified portfolios.
- Portfolio margins should be sensitive to position hedging on a portfolio level, rather than on an individual equity basis.
- The base margin should be a calculated parameter, rather than an arbitrary value, in order to further improve risk sensitivity.
- Inclusion of equity beta within the parameterisation would remove the risk of double counting with respect to country of risk and market capitalisation.
- Combining measures for equity volatility and the beta parameter produces margins which are sensitive to both equity specific and wider market conditions.

4.2 Final Margin Policy Rules

As is traditional with rules-based margin policy documentation, the system can be defined as one fundamental equation with components to be subsequently defended. The framework calculates a margin for each equity, $i = 1... N$. The notation used within the fundamental equation is defined as follows:

- Equity Margin = M_i
- Base Margin = B_i
- Sector Concentration Multiplier = S_i
- Hedging Multiplier = H
- Liquidity Margin Add-On = $L_{i,t}$
- Total Margin Cap = C_i
- \$ Portfolio Position = $P_{\$}$
- Total Portfolio Margin = TM

The fundamental equation can thus be defined as follows:

$$M_i = \min[(\ B_i^{[1]}\ *\ S_i^{[2]}\ *\ (1 - H)^{[3]}\ +\ L_i^{[4]})\ ,\ C_i^{[5]}\ ] \tag{1}$$

Therefore, the margin for an entire portfolio is hence defined as:

$$TM = \sum_{i=1}^{N} M_i\ *\ P_{\$} \tag{2}$$

The numerical citations for each parameter in the fundamental equation are reference to the derivation of each parameter included below:

[1] Base Margin, B_i :

$$Base_i = \sigma_i \ * \ \beta_i, \qquad \beta_i > 1 \tag{3}$$

In the base margin calculation, σ_i is representative of average 30-day equity volatility, rounded to the nearest 5. By rounding volatility to the nearest 5 σ_i is categorised into bands, introducing stability to the system and a monomict relationship between the margin and to the underlying equity volatility.

Furthermore, β_i is calculated from a linear regression of equity returns against returns of the underlying relative index (see Appendix) over a 21-day window. We make the assumption that the relative stock index is less volatile and therefore less risky than the equity position, hence the $\beta_i > 1$ condition ensures that the margin for an equity is not less than that of the relative stock index.

[2] Sector Concentration Multiplier, S_i :

For each GICS sector represented in the portfolio (See Appendix), the ratio of net sector exposure and net portfolio exposure is used as a representation of sector concentration; notated s_j for every sector; $j = 1... N$. Net sector exposure is calculated as the summation of the \$ Positions for every equity, $z = 1... k$, categorised into the relevant sector. Net portfolio exposure is simply the aggregation of every equity \$ Position in the portfolio.

$$s_j = \frac{\sum_{z=1}^{k} P_{\$,z}}{\sum_{i=1}^{N} P_{\$}} = \frac{Net\ Sector\ Exposure}{Net\ Portfolio\ Exposure} \tag{4}$$

For each calculated sector concentration ratio, s_j, there is a corresponding sector concentration multiplier, S_i given in Table 1.

Table 1: Sector Concentration Multiplier

s_j	S_i
0%	1
25%	1.25
50%	1.5
75%	1.75

[3] Hedging Multiplier, H:

The hedging multiplier is the value of the proportion of the portfolio which is hedged. This is equivalent to the ratio of hedged market value (the smaller of total long positions and absolute total short positions) and gross market value.

$$H = \frac{\min\left[\sum_{i=1}^{N} Long\ Position_i, \left|\sum_{i=1}^{N} Short\ Position_i\right|\right]}{\sum_{i=1}^{N} Long\ Position_i + \left|\sum_{i=1}^{N} Short\ Position_i\right|} \tag{5}$$

As per the fundamental equation, all equities are subject to the same hedged allowance multiplier of $(1-H)$ %. This is to account for the fact that a portfolio which is completely hedged (i.e. delta neutral, where net market value is 0) should have a proportionally smaller margin than a long or short only portfolio.

[4] Liquidity Margin Add On, $L_{i,t}$:

The liquidity margin add-on is included in the model to ensure that illiquid positions receive a higher margin than very liquid positions. $l_{i,t}$ is the calculation of the ratio of the absolute value of each equity position, $i = 1 \ldots N$, and the median trading volume

($MTV_{i,t}$) over a rolling 21-day window, for $t = 1...T$ This figure gives the proportion of each equity's median trading volume which is held in the portfolio, and can thus be looked up in Table 2 to give the liquidity margin add on amount, $L_{i,t}$.

$$L_{i,t} = \frac{\mid P_{\$i} \mid}{MTV_{i,t}} \tag{6}$$

$$MTV_{i,t} = Median[V_{i,t-21} \; ... \; V_{i,t}] \tag{7}$$

where $V_{i,t}$ is the volume of trades for equity i on day t.

Table 2: Liquidity Add-On

$l_{i,t}$	$L_{i,t}$
0	0.00%
0.25	2.50%
0.5	5.00%
0.75	7.50%
1	10.00%
1.5	15.00%
2	20.00%
2.5	25.00%
3	30.00%
3.5	35.00%
4	40.00%
5 +	100.00%

The use of median trading volume rather than average trading volume removes the risk of volume data being influenced by extreme spikes in the markets.

[5] Margin Cap

Each equity position is subject to an overall cap:

- Long positions: 100%
- Short positions: 200%

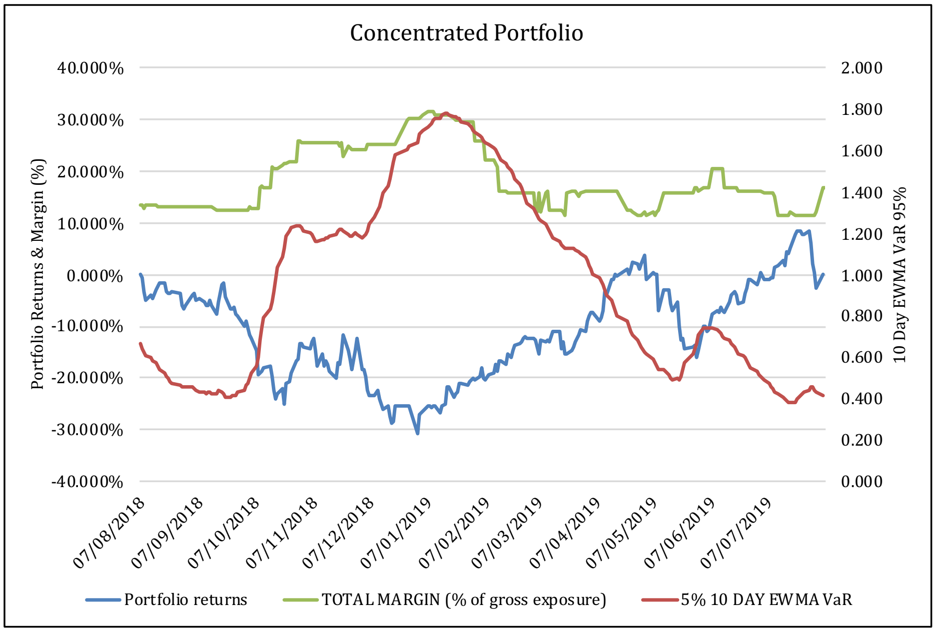
5 Results

Having specified the margin policy in Chapter 4, each portfolio outline in section 3 has been simulated with the system. Margins are presented as a percentage of gross portfolio exposure, before a comparison is made against daily total portfolio returns, and against a 10-day 95% Value At Risk (VaR) calculation. This was initially calculated by historical simulation over a 1 year period, adaption was made to simulate using Exponentially Weighted Moving Average (EWMA) methodology with the lambda parameter set as $\lambda = 0.94$ in line with research by JP Morgan & Reuters (1996). The EWMA calculation is significantly more risk-sensitive than the previous methodology, and thus provides a more robust basis for comparison.

After each of the three portfolios are reviewed, tables (3, 4, 5) will provide further insight into how the margins change month on month, and a review of the success and shortcomings of the margin system, in light of the results, is discussed in subsection 5.4.

5.1 Concentrated Portfolio Results

Figure 1: Concentrated Portfolio: Total Margin and Returns



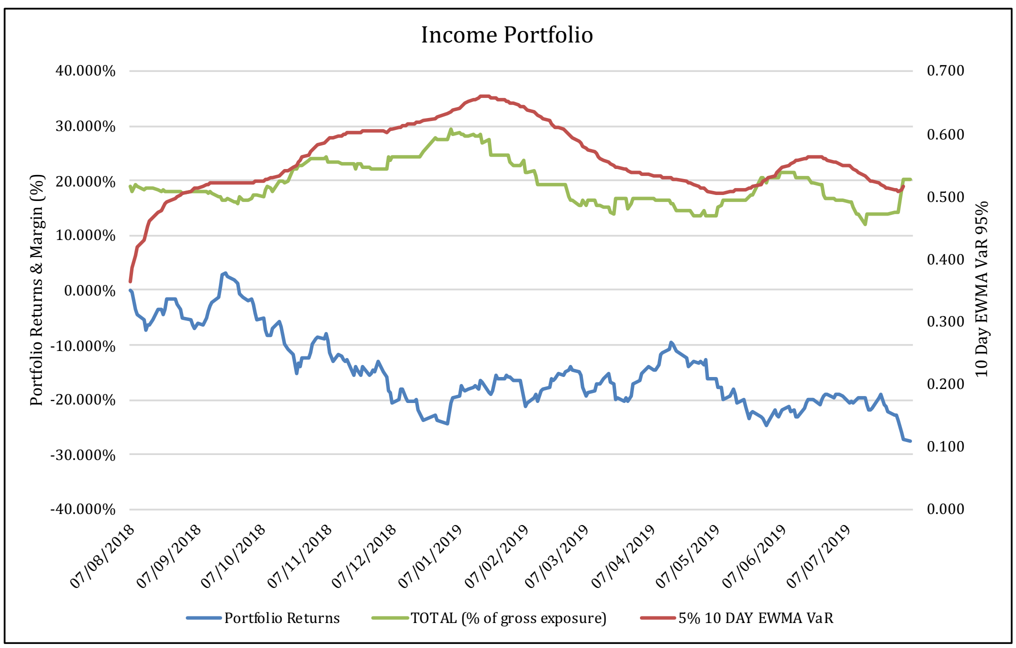
First, considering the concentrated portfolio, it is evident from figure 1 that there appears to be a negative correlation between portfolio returns and the computed total margin. This initial observation is confirmed by statistical calculation of correlation: -0.8042 (4dp), which supports the model specification: margins should increase as portfolio returns decrease. Regressing the simulated daily margin against portfolio returns (figure 5 included in Appendix) reports an R squared value of 0.6467 (4dp), representative that portfolio returns explain 64.67% of the variability in the total portfolio margin each day.

The performance of the final margin compared to the concentrated portfolio's 10 day VaR provides pleasing results with the correlation between VaR and the total margin calculated as 0.7831 (4dp). This comparison implies that the margin specification is risk-sensitive when applied to the concentrated portfolio.

The construction of the concentrated portfolio was successful in testing the effectiveness of the sector concentration multiplier as the ratio of net sector exposure and net portfolio exposure was particularly high for the financial sector, there was a call for the highest sector concentration multiplier (see Table 1). While only two of the ten equities in the portfolio were from the financial sector, they constituted the largest proportion of exposure, thus illustrating the need and importance of sensitivity to such concentration.

5.2 Income Portfolio Results

Figure 2: Income Portfolio: Total Margin and Returns



From a diagrammatic perspective (see Figure 2) there is again a clear negative correlation between income portfolio returns and the total margin. However, while the negative relationship is confirmed via the calculation of the correlation statistic, -0.1597 (4dp), the value is representative of significantly lower correlation than within the concentrated portfolio.

Considering the regression analysis for the income portfolio (see figure 7 included in Appendix), the R squared result of 0.0255 (4dp) is significantly lower than would be hoped; only 2.55% of the variation in the margin is explain by portfolio returns. Of course, since portfolio returns are not a parameter within the model, a completely linear relationship would not be expected, however a stronger trend would better support the reliability of the model for use against any portfolio.

The relationship between total margin and the 10 day VaR is stronger than the returns based comparison. The correlation statistic is recorded as 0.6513 (4dp) and the R squared value from the regression output (see figure8) is 0.4504 (4dp). While these figures could be stronger, there is cause to state that the relationship between total margin and risk is captured to some extent by this relationship.

5.3 Growth Portfolio Results

The growth portfolio was designed to induce the occurrence of the liquidity margin add on, and therefore included a number of illiquid positions. Equities 'RCDO LN Equity' and 'OXIG LN Equity' both generate a number of positions over the evaluation year, in excess of 100% of median trading day volume. On days such as this, each of these equities therefore carry a higher individual margin to reflect the risk of holding illiquid positions.

Figure 3: Growth Portfolio: Total Margin and Returns

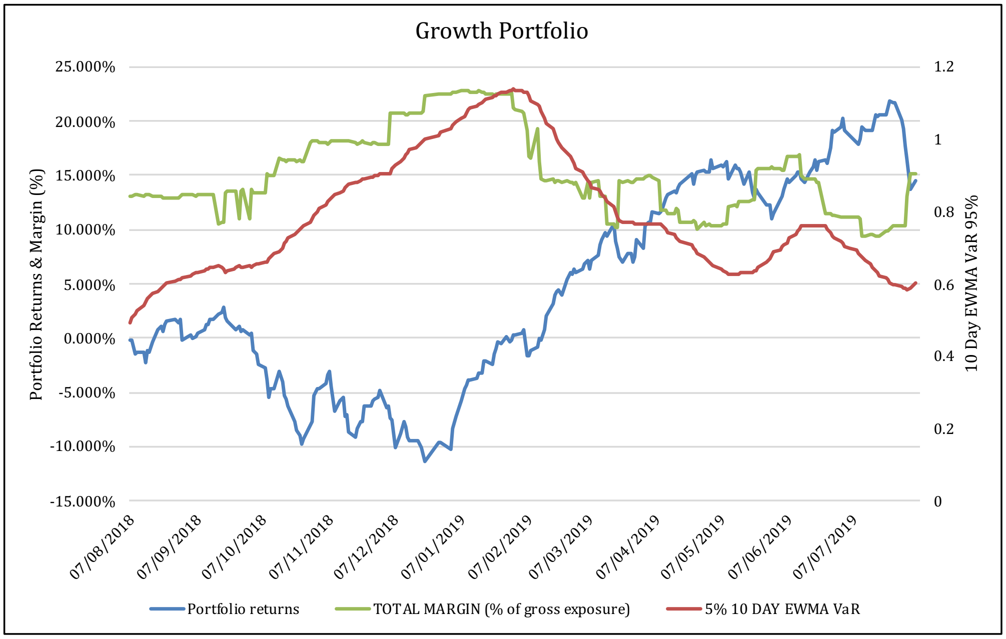


Figure 3 again illustrates a clear negative correlation between the margin and portfolio returns and, unlike with the income portfolio, the growth portfolio correlation statistic of -0.7122 (4dp) supports the diagrammatic representation. Regression analysis (see figure 9 included in Appendix) is significantly more successful than the income portfolio as well; the R squared value of 0.5073 (4dp) is acceptable. Additionally, the margin performs well in comparison to the 10 day VaR. The statistical correlation calculation is recorded as 0.7771 (4dp) and the R squared is 0.6062 (4dp) (See regression output in figure 10 - included in Appendix).

5.4 Results Review

The results presented above illustrate a clear relationship between portfolio returns and the total portfolio margin for each of the three simulations, on a visual basis for all three, and with statistical underpinnings for the concentrated and growth portfolios. The comparison against a 10 Day 95% VaR calculation have also illustrated inherent risk-sensitivity within the margin specification.

The following tables (3, 4, 5) will provide further intuition of the success of the margin specification by comparing on an average month-by-month basis, portfolio returns, the margin, SP500 as a relative index, and the VIX for a volatility environment reference. This allows analysis of how sensitive the final margin is to the wider markets for each portfolio. The average portfolio returns have been calculated as the average of all recorded values for daily portfolio returns and the average margin is the average of the daily portfolio total margins. The SP500 daily closing price has been downloaded, and the average found for each month with comparable dates to the returns series, and similarly for VIX, the average of each daily VIX quote is calculated across the month.

Table 3: Concentrated Portfolio: Month-On-Month Comparison

	Average Portfolio Return	Average Margin	Average SP500	Average VIX
Aug-18	-3.11%	13.21%	$ 2,861.21	12.68%
Sep-18	-5.24%	12.81%	$ 2,901.50	12.80%
Oct-18	-17.32%	18.31%	$ 2,785.46	12.97%
Nov-18	-15.60%	25.12%	$ 2,719.90	13.16%
Dec-18	-23.29%	25.51%	$ 2,597.25	13.25%
Jan-19	-24.18%	30.45%	$ 2,610.27	13.22%
Feb-19	-17.10%	19.32%	$ 2,755.90	13.21%
Mar-19	-13.12%	14.18%	$ 2,803.98	13.13%
Apr-19	-4.03%	15.03%	$ 2,903.59	13.07%
May-19	-5.72%	14.59%	$ 2,851.00	13.04%
Jun-19	-6.66%	17.54%	$ 2,890.17	13.11%
Jul-19	3.14%	13.08%	$ 2,996.11	13.10%

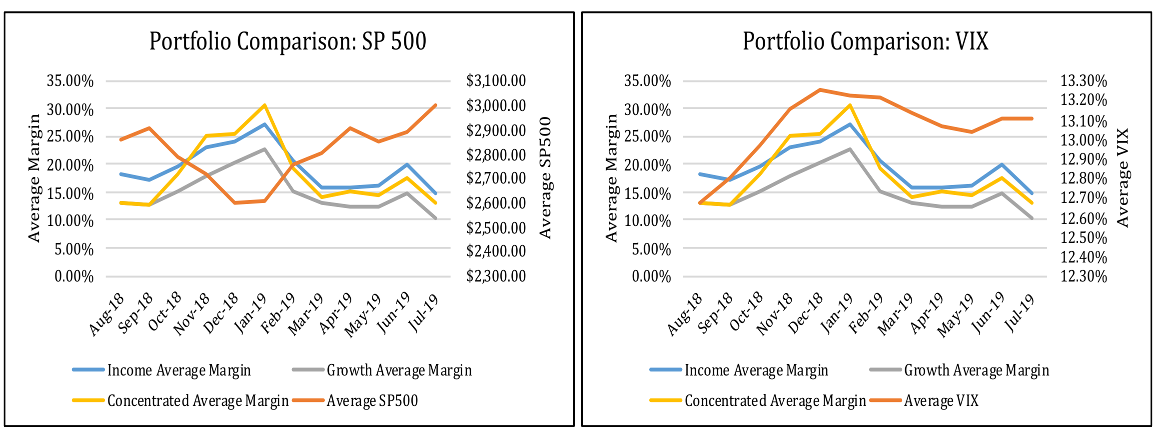
Table 4: Income Portfolio: Month-On-Month Comparison

	Average Portfolio Return	Average Margin	Average SP500	Average VIX
Aug-18	-3.58%	18.40%	$ 2,861.21	12.68%
Sep-18	-2.07%	17.24%	$ 2,901.50	12.80%
Oct-18	-8.06%	19.62%	$ 2,785.46	12.97%
Nov-18	-12.46%	23.09%	$ 2,719.90	13.16%
Dec-18	-19.36%	24.15%	$ 2,597.25	13.25%
Jan-19	-18.29%	27.01%	$ 2,610.27	13.22%
Feb-19	-17.46%	20.57%	$ 2,755.90	13.21%
Mar-19	-17.58%	15.72%	$ 2,803.98	13.13%
Apr-19	-13.32%	15.79%	$ 2,903.59	13.07%
May-19	-19.25%	16.32%	$ 2,851.00	13.04%
Jun-19	-21.49%	20.13%	$ 2,890.17	13.11%
Jul-19	-20.58%	14.76%	$ 2,996.11	13.10%

Table 5: Growth Portfolio: Month-On-Month Comparison

	Average Portfolio Return	Average Margin	Average SP500	Average VIX
Aug-18	0.01%	13.03%	$ 2,861.21	12.68%
Sep-18	1.13%	12.70%	$ 2,901.50	12.80%
Oct-18	-4.75%	15.28%	$ 2,785.46	12.97%
Nov-18	-6.03%	18.05%	$ 2,719.90	13.16%
Dec-18	-8.64%	20.39%	$ 2,597.25	13.25%
Jan-19	-3.56%	22.62%	$ 2,610.27	13.22%
Feb-19	2.68%	15.11%	$ 2,755.90	13.21%
Mar-19	7.75%	13.21%	$ 2,803.98	13.13%
Apr-19	12.57%	12.43%	$ 2,903.59	13.07%
May-19	14.56%	12.50%	$ 2,851.00	13.04%
Jun-19	15.13%	14.68%	$ 2,890.17	13.11%
Jul-19	19.77%	10.29%	$ 2,996.11	13.10%

Figure 4: Average Monthly Margin Comparisons



(a) Average Monthly SP500 (b) Average Monthly VIX

The comparison of each portfolio against the SP500 & VIX indexes provides two fundamental conclusions which point to the robustness of our margin specifications. Firstly, all three portfolios have an inverse relationship between total average monthly margin and the monthly average SP500 closing price. This is a desired relationship; margins should fall when performance of the wider markets improves. Secondly, the comparison of total average monthly margin against the average VIX percentage for each month illustrates a positive relationship. The portfolio margins each increase when volatility in the wider markets (as measured by VIX) increases. This trend further supports the view that the margin specification is suitably risk-sensitive.

It is important to note that in all comparative graphs, (against portfolio returns, VaR, SP500 and VIX) there is arguably a slight lag between margins and the comparative series. This is perhaps not unexpected. For example, portfolios may start to decline as a result of just one factor initially, and it is not until a number of factors are subject to the shock that the margin is triggered to fall. To a certain extent this is unavoidable, although there are a number of improvements to the model which should be trialled in future research. Firstly, adjusting the bands for volatility would allow for increased sensitivity to small, but consistent changes in volatility. For example, if a portfolios volatility increased by 1% each day for five days, it would not be until, on average, the third day that the volatility factor updated. Removing the rounding to the nearest five would help to reduce this, although arguably it would be at the cost of removing the monotonic relationship.

A final stage of comparison is applied in comparing the generated margins against those simulated by Cowen Inc's existing margin model. Cowen provided their margins (as a percentage of gross exposure) for each portfolio on three different dates. I have calculated the percentage difference between my margin results and theirs on each day, then calculating an average of the three day results in order to compare how close my margins are to that currently used by Cowen.

The results show that the concentrated portfolio had a 57% lower margin with my scheme, the income portfolio was 54% lower, and the growth portfolio 53% lower. While these figures may seem initially disappointing, it is important to consider that although the difference in the margin quotes is high, they are similar across all three portfolios. This can be interpreted to mean that while the margins are not to the same level of risk-aversion as Cowen would express, the portfolios are still margined in a risk-sensitive manner, and therefore adjustment of the scale of the parameters could produce results which would reflect a more vigorous risk aversion and close the gap between the generated margins and Cowen's margins. It is also important to note that, due to confidentiality of Cowen's data, the margins have only been compared on three days out of the one year evaluation window and therefore the average percentage differences may not be representative of the whole year performance.

6 Conclusion

This research has developed a new rules-based margin system for equities. The process of defining the policy has been of trial and error, with successful sensitivity to market volatility, illiquidity, sector risk and equity prices achieved in the final model. The inclusion of equity beta in the base margin calculation provides a self-enforcing risk awareness of country risk and market capitalisation. These contributions are a novel approach to setting parameters which are self-defining and deriving.

Reviewing the margin policy results as a percentage of gross exposure, and comparing against a number of market performance measures, has allowed conclusions to be drawn that: the scheme produces a desirable inverse relationship between margin rate and portfolio returns, and furthermore, the margin scheme is sufficiently sensitive to wider market volatility.

Median trading volume calculation is used to introduce some stability into the liquidity calculations since the median will not be significantly affected by outliers in the volume data set, where an average daily trading volume may well be. This is an improvement upon parameters specified in the industry literature reviewed.

The final margin system is considered to be user-friendly while remaining sufficiently vigorous to factors which influence the quality of collateral. As with most risk-based models, the success of the policy is interpreted by the user in light of their risk appetite. For this reason, the policy has been designed to include parameters which Cowen staff believe are important in deciphering inherent portfolio risk.

Review of margins against Cowen's existing margin specification shows that the model produced in this report is not as risk-averse as that of Cowen's and hence adjusting margins to be increasingly risk-averse is a key area for future research. Since there is a clear trend between our margin results and VaR, wider market volatility (VIX) and daily portfolio returns, we are confident that the model could be adjusted to sufficiently represent the risk appetite of the broker. Also, as aforementioned, future research should consider the impact of removing the volatility bands, and measure the effect of this against whether there is improvement in the results when compared to Cowen's.

7 Reference List

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8 Appendix

8.1 Appendix 1: Portfolio Constituents

Table 6: Concentrated Portfolio Constituents

EQUITY	WEIGHT	$POSITION	SECTOR
7203 JP Equity	1.00	1,000,000.00	Consumer Discretionary
AMBA US Equity	-1.00	-1,000,000.00	Information Technology
APO US Equity	-1.00	-1,000,000.00	Financials
BLK US Equity	-1.00	-1,000,000.00	Financials
BNP FP Equity	-1.00	-1,000,000.00	Financials
EQNR NO Equity	1.00	1,000,000.00	Energy
GM US Equity	-1.00	-1,000,000.00	Consumer Discretionary
MAR US Equity	-1.00	-1,000,000.00	Consumer Discretionary
NFLX US Equity	1.00	1,000,000.00	Communication Services
TIF US Equity	-1.00	-1,000,000.00	Consumer Discretionary

Table 7: Income Portfolio Constituents

EQUITY	WEIGHT	$POSITION	SECTOR
1COV GR EQUITY	5.00	500,000.00	Materials
AAL US EQUITY	5.00	500,000.00	Industrials
ACA FP EQUITY	5.00	500,000.00	Financials
BBVA SM EQUITY	5.00	500,000.00	Financials
BMW GR EQUITY	5.00	500,000.00	Consumer Discretionary
BMW3 GR EQUITY	5.00	500,000.00	Consumer Discretionary
EQNR NO EQUITY	5.00	500,000.00	Energy
FCA IM EQUITY	5.00	500,000.00	Consumer Discretionary
GLE FP EQUITY	5.00	500,000.00	Financials
MT NA EQUITY	5.00	500,000.00	Materials
RIO LN EQUITY	5.00	500,000.00	Materials
RRC US EQUITY	5.00	500,000.00	Energy
SHA GR EQUITY	5.00	500,000.00	Consumer Discretionary
SNE US EQUITY	5.00	500,000.00	Consumer Discretionary
SZG GR EQUITY	5.00	500,000.00	Materials
UCG IM EQUITY	5.00	500,000.00	Financials
UG FP EQUITY	5.00	500,000.00	Consumer Discretionary
VLKAF US EQUITY	5.00	500,000.00	Consumer Discretionary
VOW GR EQUITY	5.00	500,000.00	Consumer Discretionary
VOW3 GR EQUITY	5.00	500,000.00	Consumer Discretionary

Table 8: Growth Portfolio Constituents

EQUITY	**WEIGHT**	**$POSITION**	**SECTOR**
AMBA US Equity	-3.56	-311,243.22	Information Technology
ASC LN Equity	-3.03	-264,906.45	Consumer Discretionary
BDEV LN Equity	3.60	314,740.34	Consumer Discretionary
BRBY LN Equity	3.54	309,494.67	Consumer Discretionary
CBG LN Equity	3.56	311,243.22	Financials
CBSH US Equity	3.61	315,614.62	Financials
CEO US Equity	3.56	311,243.22	Energy
CHE US Equity	3.56	311,243.22	Health Care
CWK LN Equity	3.60	314,740.34	Consumer Staples
SPB US Equity	3.56	311,243.22	Consumer Staples
EDF FP Equity	3.61	315,614.62	Utilities
FII US Equity	3.56	311,243.22	Financials
GBG LN Equity	3.53	308,620.39	Information Technology
GPOR LN Equity	3.63	317,363.18	Real Estate
GRG LN Equity	3.56	311,243.22	Consumer Discretionary
HFC US Equity	3.56	311,243.22	Energy
KIM US Equity	3.56	311,243.22	Real Estate
MERL LN Equity	3.56	311,243.22	Consumer Discretionary
MRVL US Equity	3.56	311,243.22	Information Technology
NG/ LN Equity	3.54	309,494.67	Utilities
NVDA US Equity	-0.60	-52,456.72	Information Technology
OXIG LN Equity	3.56	311,243.22	Information Technology
PAY LN Equity	3.64	318,237.45	Industrials
PEGI US Equity	3.56	311,243.22	Utilities
RCDO LN Equity	3.56	311,243.22	Industrials
RWS LN Equity	3.56	311,243.22	Industrials
SPB US Equity	3.56	311,243.22	Consumer Staples
SRCG SW Equity	3.55	310,368.95	Communication Services
SXS LN Equity	3.58	312,991.78	Information Technology
TPK LN Equity	3.61	315,614.62	Industrials
ULE LN Equity	3.59	313,866.06	Industrials
VCT LN Equity	3.59	313,866.06	Materials
WPP LN Equity	3.57	312,117.50	Communication Services

Table 9: Equity Relative Indexes

Equity	Relative Index
1COV GR EQUITY	DAX INDEX
7203 JP Equity	TPX INDEX
AAL US EQUITY	SPX INDEX
ACA FP EQUITY	CAC INDEX
AMBA US Equity	SPX INDEX
APO US Equity	SPX INDEX
ASC LN Equity	UKX INDEX
BBVA SM EQUITY	IBEX INDEX
BDEV LN Equity	UKX INDEX
BLK US Equity	SPX INDEX
BMW GR EQUITY	DAX INDEX
BMW3 GR EQUITY	DAX INDEX
BNP FP Equity	CAC INDEX
BRBY LN Equity	UKX INDEX
CBG LN Equity	UKX INDEX
CBSH US Equity	SPX INDEX
CEO US Equity	SPX INDEX
CHE US Equity	SPX INDEX
CWK LN Equity	UKX INDEX
EDF FP Equity	CAC INDEX
EQNR NO EQUITY	OBX INDEX
FCA IM EQUITY	FTSEMIB INDEX
FII US Equity	SPX INDEX
GBG LN Equity	UKX INDEX
GLE FP EQUITY	CAC INDEX
GM US Equity	SPX INDEX
GPOR LN Equity	UKX INDEX
GRG LN Equity	UKX INDEX
HFC US Equity	SPX INDEX
KIM US Equity	SPX INDEX
MAR US Equity	SPX INDEX
MERL LN Equity	UKX INDEX
MRVL US Equity	SPX INDEX
MT NA EQUITY	AEX INDEX
NFLX US Equity	SPX INDEX
NG/ LN Equity	UKX INDEX
NVDA US Equity	SPX INDEX
OXIG LN Equity	UKX INDEX
PAY LN Equity	UKX INDEX
PEGI US Equity	SPX INDEX
RCDO LN Equity	UKX INDEX
RIO LN EQUITY	UKX INDEX
RRC US EQUITY	SPX INDEX
RWS LN Equity	UKX INDEX
SHA GR EQUITY	DAX INDEX
SNE US EQUITY	SPX INDEX
SPB US Equity	SPX INDEX
SRCG SW Equity	SMI INDEX
SXS LN Equity	UKX INDEX
SZG GR EQUITY	DAX INDEX
TIF US Equity	SPX INDEX
TPK LN Equity	UKX INDEX
UCG IM EQUITY	FTSEMIB INDEX
UG FP EQUITY	CAC INDEX
ULE LN Equity	UKX INDEX
VCT LN Equity	UKX INDEX
VLKAF US EQUITY	SPX INDEX
VOW GR EQUITY	DAX INDEX
VOW3 GR EQUITY	DAX INDEX
WPP LN Equity	UKX INDEX

8.2 Appendix 2: Regression Outputs

Figure 5: Regression Output: Concentrated Portfolio

Regression Statistics	
Multiple R	0.804173989
R Square	0.646695805
Adjusted R Square	0.645265424
Standard Error	0.035827773
Observations	249

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.580347116	0.580347116	452.1142576	9.89077E-58
Residual	247	0.317056442	0.001283629		
Total	248	0.897403558			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.124291135	0.0035581	34.93188665	1.51401E-97	0.117283049	0.13129922	0.117283049	0.13129922
Portfolio returns	-0.005357452	0.000251962	-21.26297857	9.89077E-58	-0.005853719	-0.004861185	-0.005853719	-0.004861185

Figure 6: Regression Output: Concentrated Portfolio vs VaR

Regression Statistics	
Multiple R	0.782723583
R Square	0.612656207
Adjusted R Square	0.611075212
Standard Error	0.037566132
Observations	247

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.546863936	0.546863936	387.5130406	2.25961E-52
Residual	245	0.345747498	0.001411214		
Total	246	0.892611434			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.082573561	0.005630849	14.66449609	2.23661E-35	0.071482512	0.093664609	0.071482512	0.093664609
VaR	0.105458695	0.005357217	19.68535091	2.25961E-52	0.094906617	0.116010772	0.094906617	0.116010772

Figure 7: Regression Output: Income Portfolio

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.159674326
R Square	0.02549589
Adjusted R Square	0.02155053
Standard Error	0.038989373
Observations	249

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.00982372	0.00982372	6.462245638	0.011630892
Residual	247	0.375482288	0.001520171		
Total	248	0.385306008			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.180174524	0.005861593	30.73814889	2.1906E-86	0.168629443	0.191719604	0.168629443	0.191719604
Portfolio Returns	-0.000916491	0.000360526	-2.542094734	0.011630892	-0.001626588	-0.000206394	-0.001626588	-0.000206394

Figure 8: Regression Output: Income Portfolio vs VaR

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.671112259
R Square	0.450391664
Adjusted R Square	0.448148364
Standard Error	0.029398327
Observations	247

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.17351952	0.17351952	200.7719867	1.08275E-33
Residual	245	0.211744094	0.000864262		
Total	246	0.385263614			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.079349569	0.019362611	-4.098081958	5.66714E-05	-0.117487987	-0.041211151	-0.117487987	-0.041211151
VaR	0.489839279	0.034570212	14.16940319	1.08275E-33	0.421746542	0.557932016	0.421746542	0.557932016

Figure 9: Regression Output: Growth Portfolio

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.712242901
R Square	0.50728995
Adjusted R Square	0.505295173
Standard Error	0.026686633
Observations	249

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.181112882	0.181112882	254.3090357	7.68929E-40
Residual	247	0.17590756	0.000712176		
Total	248	0.357020442			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.163888955	0.001872128	87.54152044	6.0499E-188	0.160201584	0.167576327	0.160201584	0.167576327
Portfolio Returns	-0.28705758	0.018000647	-15.94706982	7.68929E-40	-0.32251192	-0.251603239	-0.32251192	-0.251603239

Figure 10: Regression Output: Growth Portfolio vs VaR

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.77865229
R Square	0.606299389
Adjusted R Square	0.604692448
Standard Error	0.023924156
Observations	247

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.215953565	0.215953565	377.3002786	1.66833E-51
Residual	245	0.140229484	0.000572365		
Total	246	0.356183049			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.011892549	0.007334102	1.621541303	0.106187786	-0.002553387	0.026338485	-0.002553387	0.026338485
VaR	0.176761764	0.009100071	19.42421887	1.66833E-51	0.158837411	0.194686118	0.158837411	0.194686118