



**EFFECTS OF SYSTEMIC RISK, EXCHANGE RATE RISK
AND COLLATERAL DEMAND:
THE ENFORCEMENT OF INITIAL MARGIN ON SOUTH
AFRICAN OVER-THE-COUNTER DERIVATIVES**

BY

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Abstract

In their commitment to implementing G20 regulatory reforms to the over-the-counter derivatives market, a critical decision faced by South African Authorities is whether to authorise the use of risk-sensitive models or the standardised schedule to estimate initial margin requirements on non-centrally cleared derivatives and which central clearing counterparty/ies, if any, to licence. Overburdensome collateral demand has systemic risk implications; therefore, collateral demand for local dealers under three potential market structures is estimated in this study. Initial margin requirements calculated using risk-sensitive models vary with market risk to cover counterparty credit risk; thus, the volatility dynamics of the underlying asset are analysed to determine the degree of fluctuation in collateral demand under various market stress scenarios. Lastly, the potential foreign exchange rate exposure to local dealers from licencing an international central clearing party is quantified and examined.

Collateral demand calculated with the risk-sensitive models used by central clearing counterparties and for non-centrally cleared derivatives is sensitive to the market volatility scenarios, spiking during periods of market stress, highlighting the pro-cyclical nature of these requirements. The standardised schedule is not pro-cyclical; however, collateral requirements were found to be higher during tranquil and normal market conditions. Authorities should weigh this trade-off between microprudential and macroprudential goals. There is an incentive for dealers using the standardised schedule to centrally clear contracts to lower collateral requirements.

The sensitivity of collateral demands to other risk-sensitive model inputs was investigated. It was found that dealers can limit their collateral exposure on non-centrally cleared derivatives when using the risk-sensitive approach by using a higher decay factor and VaR risk measure if Authorities do not prescribe these. The most significant reduction of initial margin on both centrally and non-centrally cleared derivatives can be achieved by dealers balancing their books instead of relying on more complicated delta hedging techniques. Should an international clearing counterparty be licenced, Authorities should be prepared for a substantial increase in the demand for foreign currency. The transaction foreign exchange rate exposure was measured in USD and GBP, and it was found that the exposure demanded in USD was lower and relatively more stable than that in GBP. Authorities could significantly reduce foreign exchange rate exposure by licencing domestic central clearing counterparty/ies instead of international clearers.

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Plagiarism declaration

I hereby declare that this thesis is my own work, both in concept and execution, and that apart from the normal guidance from my supervisor, I have received no assistance. Further, I declare that neither the substance nor any part of the above thesis has been submitted in the past, or is being, or is to be submitted for a degree at this University or at any other university.

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Abbreviations

AIC	Akaike information criterion
ARCH	Autoregressive Conditional Heteroskedasticity
AR	Autoregressive model
BCBS	Basel Committee on Banking Supervision
BEER	Behavioural equilibrium exchange rate
BIC	Bayesian information criterion
BIS	Bank for International Settlements
CCPs	Central clearing counterparties
CCR	Counterparty credit risk
CDS	Credit default swap
CGFS	Committee on the Global Financial System
CPMI	Committee on Payments and Market Infrastructures
CVA	Credit valuation adjustment
DAT	Derivatives Assessment Team
DF	Default fund
DTCC	Depository trust and clearing corporation
E-GARCH	Exponential GARCH
EMH	Efficient market hypothesis
ES	Expected Shortfall
ERSB	The European Systemic Risk Board
EUR	Euro
Fed	Federal Reserve System
FMA	South African Financial Markets Act of 2012
FRA	Forward rate agreement
FSCA	Financial Sector Conduct Authority
FSB	Financial Stability Board
G14	The Group of 14 largest global derivatives dealers
G20	The Group of 20
GARCH	Generalised Autoregressive Conditional Heteroskedasticity
GBP	Great British Pound

GDP	Gross domestic product
GED	Generalised error distribution
GJR-GARCH	Glosten, Jagannathan & Runkle GARCH
G-SIB	Globally systemically important bank
HQLA	High-quality liquid assets
I-GARCH	Integrated GARCH
IM	Initial margin
IMF	International Monetary Fund
IOSCO	International Organisation of Securities Commissions
IRD	Interest rate derivatives
IRS	Interest rate swap
ISDA	International Swaps and Derivatives Association
Jibar	Johannesburg interbank average rate
LCR	Liquidity coverage ratio
LM	Lagrange multiplier test
MS	Markov-switching
MV	Maturity value
NCD	Negotiable Certificates of Deposit
NGR	Net current replacement cost to gross current replacement cost
OCC	Office of the Comptroller of the Currency
ODPs	OTC derivatives providers
OPEC	Organisation of petroleum exporting countries
OTC	Over-the-counter
PA	Prudential Authority
PDF	Probability density function
PFE	Potential future exposures
PFMI	Principles for Financial Market Infrastructures
PPP	Purchasing power parity
PV	Present value
QE	Quantitative Easing
QPMM	Quantitative portfolio margin model
SABOR	South African benchmark overnight rate

SARB	South African Reserve Bank
SMS	Standardised margin schedule
T-GARCH	Threshold GARCH
TtM	Time to maturity
UIP	Uncovered interest rate parity
UPI	Unique Product Identifier
USA	United States of America
USD	United States Dollar
UTI	Unique Transaction Identifier
VaR	Value at Risk
VIX	Chicago Board Options Exchange Volatility Index
VM	Variation margin
ZAR	South African rand

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CHAPTER 1

INTRODUCTION

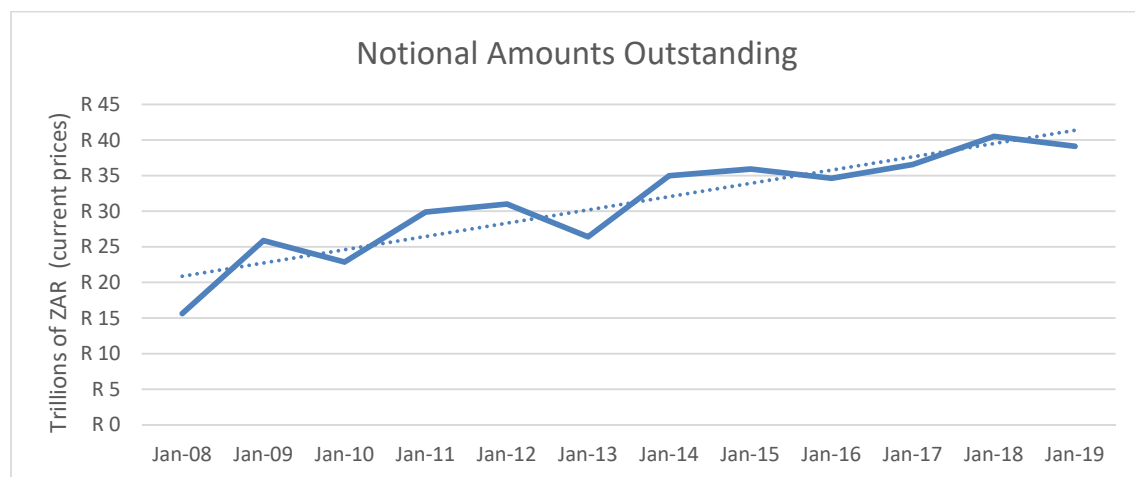
1.1 Background and context

Derivatives intensified losses during the 2008/09 Great Financial Crisis as market opacity created uncertainty about the exposure of some systemically important financial institutions from their credit derivative positions (Stulz, 2009). A derivative is a financial instrument that derives its value from changes in the value or the volatility of an underlying asset. Activity in the derivatives market exposes the participant to market, credit, liquidity, legal and operational risks. Market risk arises from the movement or volatility in the price of the underlying asset. Credit risk stems from the risk that a counterparty fails to fulfil their contractual obligations; it is commonly referred to as counterparty credit risk (CCR) in the derivatives market. Liquidity risk is the risk that obligations cannot be met when due and with the correct financial instrument. The legal risk refers to the risk that a transaction is unenforceable by law, in developed markets, legal risk is negligible but may be a consideration when entering new markets. Operational risk is the risk of a human or technology failure within a specific firm. Market risk, liquidity risk and CCR were observed to be pro-cyclical during the Great Financial Crisis, feeding into one another exacerbating losses and increasing systemic risk.

Prior to the crisis, all credit derivatives were traded over-the-counter (OTC) with almost no direct supervision despite the large size of this market (National Treasury, 2012a). This neoliberal regulatory approach to the market was called into question in the wake of the Great Financial Crisis (Lee & Martin, 2016). In an effort to improve transparency and risk transfer in the OTC market, the Group of 20 (G20) issued a directive in 2009 for the establishment of trade repositories, the central clearing and/or central trading of appropriate derivatives, and higher capital requirements for non-centrally cleared derivatives (G20, 2009). In November 2011, the G20 further agreed to add margin requirements for non-centrally cleared derivatives (National Treasury, 2015). The post-crisis reforms to the OTC derivatives market are intended to improve transparency, mitigate

systemic risk and protect against market abuse. These reforms are targeted at all derivative asset classes traded OTC, not just credit derivatives, which represent a small proportion of the total OTC derivatives market in South Africa and globally. In January 2015, notional amounts outstanding for credit derivatives represented a mere 0.52% of the notional amounts outstanding for all other derivative asset classes traded OTC in South Africa (Kennedy-Palmer, 2015). As of January 2015, the total notional amounts outstanding for all OTC derivatives reported to the South African Reserve Bank (SARB) was just under 36 trillion South African rand (from here on referred to as ZAR), see figure 1.1 below which illustrates the size of the South African OTC derivatives market in terms of notional amounts outstanding between 2008 and 2019. To put that number into perspective, South African nominal GDP for the fourth quarter of 2015 was estimated at 1 trillion ZAR (Statistics SA, 2017). The OTC derivatives market in South Africa is large in relation to the country's economy (International Monetary Fund [IMF], 2015b); however, it is one of the smallest markets amongst the member jurisdictions of the Financial Stability Board (FSB, 2015:32). Thus, specific implementation decisions taken by regulators for the OTC derivatives market could have systemic risk implications for the South African financial system.

Figure 1.1: South African OTC derivatives market size 2008 – 2019



Source: Author's calculation using data from the SARB.

According to the South African *Financial Markets Act (FMA)*, Act No. 19 of 2012, the implementation of OTC derivatives market reform is phased in to avoid unnecessary shocks to the market. The 2012 FMA identified three phases of implementation. The first phase relates to a code of conduct and registration for market participants and mandatory trade

reporting. Phase two involves the enforcement of capital and margin requirements for non-centrally cleared derivatives in order to incentivise market participants to voluntarily centrally clear. The final phase involves the central clearing of standardised products and potentially central trading, should it be deemed appropriate (National Treasury, 2012b). To date South African authorities have enforced capital requirements for non-centrally cleared derivatives, known as the credit valuation adjustment (CVA). Margining requirements for non-centrally cleared derivatives will be phased in once the “effective date” is published by Authorities. Margin requirements will be phased in according to the size of the market participant, and as discussed below, it is expected that none of the local OTC derivatives providers (ODPs is the term given to local market makers by the FMA act) notional amounts outstanding will exceed the first, second or third implementation threshold. Thus, margin requirements on non-centrally cleared derivatives are not expected to be mandated for any ODPs until 2023. Central clearing and central trading (if appropriate) have not yet been mandated, and a trade repository has not yet been established in South Africa.

As a G20 member, South Africa has committed to implement market reform in line with the rest of the G20 nations so as to avoid international regulatory arbitrage (National Treasury, 2012a). According to the FSB (2019a:5) *“differences in rule-making could lead to cross-border regulatory arbitrage and a potential build-up of risks in parts of the global financial system that go beyond those addressed by individual national authorities”*. However, not all reform decisions are made at an international level; domestic regulators must take some decisions after considering their market’s unique conditions. One such decision for South African authorities is; how many central clearing counterparties (CCPs) should be licenced, if any, to provide central clearing services in the domestic market. The regulatory landscape itself has changed in South Africa post-crisis. The Twin Peaks framework for financial sector regulation came into effect on 1 April 2018, governed by the *Financial Sector Regulation Act, Act No. 9 of 2017*. Twin Peaks saw the creation of two new regulators, the Prudential Authority (PA) which is housed within the SARB and the Financial Sector Conduct Authority (FSCA) which replaces the Financial Services Board. The PA is responsible for prudential regulation and supervision as well as promoting financial sector stability. The FSCA is responsible for supervising market conduct. Unless otherwise specified, these two regulators, as well as National Treasury, will be referred to as South African “Authorities”.

Authorities indicated in June 2016 that they would allow a global CCP to establish a local office and they would not licence a domestic CCP other than the temporary license given to JSE Clear that would not be renewed (National Treasury, 2016), however as yet a global CCP has still not been licenced. Although the legislation is in place to allow for a global CCP to be licenced, South African Authorities have not yet done so. South Africa has been one of the slowest members of the G20 to implement reforms to the OTC derivatives market.

Following the regulatory push post-crisis towards central clearing Duffie & Zhu (2011), in their seminal work, found that clearing through one CCP is always more efficient and cost-effective than multiple CCPs. Therefore the stated intention of local Authorities to licence only one CCP is supported by Duffie & Zhu (2011) from a market efficiency perspective. Further work by Heller & Vause (2012), Heath, Kelly & Manning (2012) and Duffie, Scheicher & Vuillemeys (2015) found that as the number of CCPs increase, multilateral netting benefits are reduced, and more collateral would need to be posted. Thus, the decision not to licence a domestic CCP minimises cost implications for domestic market participants because many existing foreign counterparties of the local ODPs are already clearing members of global CCPs. Cont & Kokholm (2014) expand on the Duffie & Zhu's model to allow for heterogeneity in risk between products and across dealers, as well as the correlation of positions across products. They find that the central clearing of previously bilaterally traded contracts reduces CCR significantly more when there is heterogeneity of risk across asset classes, as well as the correlation of positions across products. Heterogeneity of risk across asset classes is typical in the real world. For example, an IRS and a CDS with identical notional amounts outstanding and maturity will typically not be subject to the same collateral requirements reflecting differences in risk.

Existing CCPs charge their clearing members initial margin (IM) and variation margin (VM) whilst prior to the Great Financial Crisis bilateral contracts seldom included VM and almost never included IM (International Swaps and Derivatives Association [ISDA], 2014). Since the crisis, however, exchanging VM has become common in bilateral contracts whilst the voluntary use of IM remains rare, this is true of the South African market as well (FSCA & PA, 2019a). Thus, in order to standardise margining on non-centrally cleared derivatives and incentivise central clearing, the Basel Committee on Banking Supervision (BCBS) and International Organisation of Securities Commissions (IOSCO) have developed global

standards for margin requirements for non-centrally cleared derivatives. The BCBS-IOSCO published the policy framework for “margin requirements for non-centrally cleared derivatives” in 2015. The framework allows for two approaches to the calculation of IM for non-centrally cleared derivatives: 1) the traditional risk-sensitive quantitative portfolio margin model (QPMM), or 2) the standardised margin schedule (SMS). Market participants should not be able to use a combination of the QPMM and SMS in an effort to lower IM requirements; they should be consistent in their approach. The QPMM is risk-sensitive and requires a measure of the volatility of the underlying asset. The SMS approach uses a standardised IM schedule and is therefore not impacted by market risk. As a consequence of being risk insensitive, the IM requirements do not change to reflect changes in market risk, meaning requirements are almost always either excessive or insufficient. However, in contrast to the QPMM approach, it is not computationally challenging, and it is not pro-cyclical.

In South Africa, margin requirements on non-centrally traded derivatives were to be slowly phased in, with the first implementation phase starting in 2019, according to a joint statement by the PA and FSCA. However, the implementation schedule published in the 2019 draft document has been delayed by a year due to the Covid-19 crisis. The final implementation schedule for margin requirements for non-centrally cleared OTC derivative transactions was published on 2 June 2020. The implementation will begin from an “effective date” yet to be announced by Authorities. From the effective date to 31 August 2021 only participants belonging to a group with an average month-end gross notional amount outstanding during March, April and May of the previous year exceeding 30 trillion ZAR are required to post IM on non-centrally cleared derivatives when dealing with a participant whose gross notional position also exceeds 30 trillion ZAR. The threshold will continue to decline annually to 23 trillion for 2021/22, 15 trillion in 2022/23, 8 trillion in 2023/24 and finally 100 billion ZAR from 1 September 2024 onwards. These thresholds are set in Euros by the BCBS-IOSCO and converted to rands at a set rate of 1EUR=10ZAR which is subject to change by the South African Authorities. A survey conducted by the PA indicated that as of June 2018, no South African ODP’s total notional amounts outstanding exceeded the 15 trillion ZAR threshold (FSCA & PA, 2019). Thus, as mentioned above, no ODP is

anticipated to be large enough to be subject to mandatory IM posting on non-centrally cleared derivatives until 2023.

The margining requirements on non-centrally cleared derivatives are being phased in, and a grandfathering exemption applies. This means that the new regulations will only apply to new trades after the regulation is applicable, not on existing trades. However, the majority of IRS tend to have short maturities; therefore, the phase-in period would be short. Of the total notional amount outstanding, 46.8% have a maturity of 0-2 years, 23.3% have a maturity of 2-5 years and over 5 years 29.9% (Heller & Vause, 2012).

VM is held to protect against mark-to-market losses on a contract, that is to limit the build-up of current exposure. The market values of derivative contracts vary continuously with the variation in the value of the underlying instrument. At any given moment one party's derivative contract is "in-the-money," i.e. the contract is an asset for the party who holds it, and the counterparty is, therefore "out-of-the-money," i.e. their derivative position is a liability. In a bilateral exchange, the party whose position is a liability transfers the VM straight to the party whose position is an asset, while when a contract is centrally cleared the CCP acts as a middle man, receiving the VM from the one-party and transferring it to the other. In a bilateral contract, both parties exchange IM to protect against potential future exposures (PFE), which is defined as the maximum amount at a given confidence interval an investor could lose on their positions during a pre-specified period of time (Lopez, Mendes & Vikstedt, 2013). In the case of central clearing, IM is one-directional risk cover. Both parties to the initial contract post IM to the CCP, while the CCP does not post IM to its counterparties. IM is the first barrier to protecting a CCP against the default of one of its clearing members.

VM and IM are tools for mitigating CCR; however, it is possible for a counterparty's end of day loss position to exceed the VM and IM collateral its counterparty holds against the contract. The counterparty with the net loss position may then decide to default on its obligation. In the bilateral market, the defaulter's counterparty must then absorb the loss that exceeds the collateral it holds. Under central clearing, the CCP is still responsible for transferring the VM to the counterparty with the profit position, thereby absorbing the loss, as well as for finding a new counterparty to replace the defaulting counterparty. To cover

such potential losses, CCPs demand from their clearing members an additional risk mitigation payment in the form of contributions to a default fund (DF). SwapClear (a subsidiary of LCH.Clearnet Ltd, which specialises in interest rate swaps) mandates that VM must be paid in the currency of the underlying exposure, i.e. ZAR to cover VM on ZAR denominated contracts. However, IM must be posted in GBP, USD, EUR and a few other eligible major currencies, currently excluding ZAR. Collateral can also be received in the form of acceptable securities subject to haircuts determined by LCH.Clearnet Ltd, currently, no ZAR denominated securities are classed as acceptable collateral (LCH.Clearnet Ltd, 2014). In addition, ZAR has been identified by LCH.Clearnet (2015) as one of four currencies that do not demonstrate a stable and/or strong relationship, therefore it is subject to a margin add-on to limit its use. Given the volatility of the ZAR already acknowledged by LCH.Clearnet, it may be deemed imprudent risk management for a foreign CCP, even one with an office in South Africa, to accept IM from its counterparties in ZAR. This would mean that local market participants would need to post collateral in foreign exchange or eligible securities, exposing them to exchange rate risk. In addition to posting margin to a CCP, local clearing members would also need to contribute to the DF. All contributions to SwapClear's DF are payable exclusively in GBP (LCH.Clearnet Ltd, 2013). South African banks are subject to exchange controls; thus, a sizeable increase in the demand for foreign currency to meet collateral requirements may require South African Authorities to adjust foreign exchange regulation.

VM is passed from one counterparty to the other and since it is already common practice in bilateral contracts in South Africa its net aggregate impact on collateral demand in South Africa will be lower than IM and contributions to the DF. VM is also mostly posted in cash which is readily reused by dealers (a more detailed discussion of collateral reuse follows in the literature review, Chapter 2). According to Heath, Kelly & Manning (2012), the impact of IM on collateral demand will be "quantitatively much more important" than the demand as a result of VM. Thus, the effect of VM is beyond the scope of this study. DF contributions to CCPs as well as IM on centrally cleared and non-centrally cleared derivatives will increase the demand for high-quality liquid assets (HQLA).

The first version of BCBS-IOSCO's framework for margining non-centrally cleared derivatives was proposed in 2012, however, it was adjusted following the results of that year's Quantitative Impact Study conducted by the BCBS and the IOSCO which estimated that

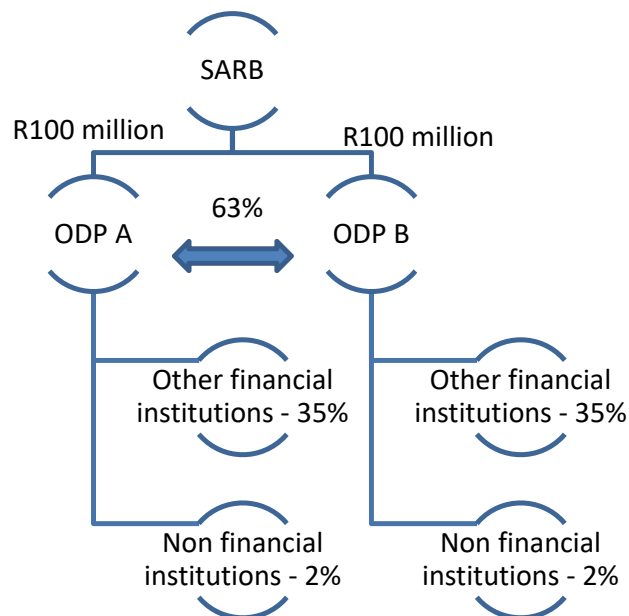
between 0.7 and 1.7 trillion EUR in collateral would be required globally to meet increasing IM demands on non-centrally cleared derivatives. The final policy framework was published by the BCBS-ISOCO in 2015 and included several amendments to reduce the total collateral requirements of margining on uncleared derivatives. Firstly, the expansion of eligible collateral to include high-quality corporate bonds, equities (listed on major stock indices) and gold albeit with higher haircuts in an effort to reduce the pro-cyclical volatility of their value. See table 2.2 for the standardised haircut schedule for collateral posted against non-centrally cleared derivatives published by South African Authorities based on the BCBS-IOSCO's recommendations. Eligible collateral can be denominated in any currency in which payment obligations under the non-centrally cleared derivatives may be made. Secondly, allowing IM to be re-hypothecated once by the IM collector. As discussed in section 2.3.2.1 this means that the velocity of collateral posted against uncleared derivatives is limited to 2 while it is 1 for collateral posted to a CCP. Thirdly, there is no requirement for a covered entity to collect IM below a threshold. The threshold was set at 500 million ZAR by South African Authorities and may be changed from time to time. Lastly, the margin requirements are phased in to lower the liquidity, operational and transition costs of compliance. The phase-in timeline for margin requirements on non-centrally traded derivatives announced by South African Authorities is provided previously in this section. However, these reforms to the OTC derivatives market will still increase the cost of doing business in these markets for dealers which may ultimately be passed on to their clients in the case of non-proprietary trading.

The big five South African banks are the primary market makers (or ODPs) in the country. They typically enter into contracts with foreign counterparties in order to offset risk assumed from local institutional clients or "end-users" (e.g. pension funds, insurance companies, asset managers and non-financial corporates). According to National Treasury (2016), in June 2012, the total OTC derivatives market had a notional amount outstanding of 27.7 trillion ZAR. Of that, 88% or 24.3 trillion ZAR in notionals outstanding represented interest rate derivatives. 10.3 trillion ZAR in notionals were interest rate derivatives traded between ODPs and foreign counterparties, while the balance of 14 trillion ZAR was between local counterparties. Foreign exchange contracts had the next highest notional amount outstanding amounting to 11% whilst the remaining 1% consisted of equity, credit and

commodity derivatives. Nearly all derivative contracts traded between local counterparties are ZAR denominated.

As of end December 2018 the SARB reported an aggregate amount outstanding of 38.2 trillion ZAR, of which 33.6 trillion or 88% are interest rate derivatives (IRD). However, the gross notional amounts outstanding are subject to double-counting when both parties to the contract are reporting dealers. According to the IMF (2015), in the South African OTC derivatives market, 63% of gross notional amounts outstanding are interbank (i.e. interdealer, or between two ODPs) while 35% and 2% respectively are with other financial institutions and non-financial institutions, see figure 1.2. Assume that ODP A and ODP B both report 100 million ZAR in notional amounts outstanding in their balance sheets and in their regulatory filing to the SARB. Therefore, each ODP has approximately 63 million ZAR in notionals outstanding where the counterparty is another ODP and 37 million where the counterparty is another financial or non-financial institution. ODPs are subject to regulatory reporting requirements; therefore, they both report 100 million in outstanding notionals to the SARB, totalling 200 million. However, since 63% of notionals are between two ODPs, this amount is reported twice to the SARB, thus overstated by 31,5%. The actual market size in this simple example is 137 million ZAR (R37m + R37m + R63m).

Figure 1.2: Double counting in gross notional positions reported to the SARB



Source: IMF (2015).

In the bilateral OTC derivatives market structure, the interconnectedness of market participants and lack of counterparty relationship transparency were exposed as sources of systemic risk during the Great Financial Crisis (FSB, 2010). Central clearing increases the transparency of market participant's derivative holdings compared to an opaque bilateral market structure and as a result, reduces systemic risk (Hull, 2010). When a party to a bilateral derivative contract defaults, the counterparty would usually want to replace the contract. However, since default would typically take place under conditions of financial stress with increasing concern over CCR, market liquidity may be reduced and if so, a replacement contract may come at a higher price, or it may not be possible to replace the contract at all in the bilateral market. CCPs are able to reduce this potential for market failure, where a contract cannot be replaced in times of financial stress, by facilitating the calm transfer of contracts from a defaulted clearing member to others by auction. Thus, CCPs can improve liquidity and reduce systemic risk during times when the bilateral market may seize up due to counterparty credit fears. CCPs can curtail price volatility and increases in systemic risk, which would result from the default of a large derivatives dealer in a bilateral market. However, not all derivative contracts are suitable for central clearing. According to the FSB (2010), only standardised products which have liquid markets and whose price is easy to attain and is generally agreed upon by the market are suitable for central clearing. Eligibility for central clearing is discussed further in section 2.1.4.3. If a product is not standardised, and/or does not have a sufficiently liquid market, and/or does not have an acceptable and easily available pricing source, then defaulted contracts are more complicated, if it is possible at all, to replace during times of market stress. Even a CCP would struggle to close out and replace such contracts leading to losses and potentially the failure of the CCP. Large CCPs are themselves systemically important institutions; thus, authorities should not force them to clear unsuitable contracts which could expose them to undue risk. Thus, the G20 only mandated central clearing for "standardised" OTC derivative contracts. Almost all IRD are highly contractually and operationally standardised, making them suitable for central clearing (FSB, 2010). The South African OTC derivatives market is one of the smallest in the G20 with IRD making up 88% of the market (as at end December 2018). Therefore, the initial central clearing mandate is likely to extend only to IRD as the other derivative asset classes in South Africa do not have as liquid markets with high levels of price transparency.

Some domestic trades already clear through foreign CCPs as a result of ODPs transacting with foreign counterparties who are already subject to mandatory central clearing requirements. In January 2013, the first OTC derivative transaction involving a South African bank (Absa) and a foreign counterparty was cleared by LCH.Clearnet Ltd (FSB, 2013). However, no local ODPs are currently clearing members to any CCP; therefore, any transactions being centrally cleared are done so for local ODPs by clearing members offering client clearing services.

SwapClear (a subsidiary of LCH.Clearnet Ltd, registered in the UK) is responsible for the central clearing of the majority of IRDs globally. SwapClear clears six types of IRD product (interest rate swaps, zero-coupon swaps, basis swaps, forward rate agreements, overnight index swaps, and variable notional swaps) in 17 different countries. Thus, given the fact 88% of South African OTC derivatives are IRD and SwapClear clears almost all IRDs globally, it would seem most likely that LCH.Clearnet Ltd will be given a licence to operate its SwapClear service in South Africa to maximise multilateral netting benefits. Another international CCP which could be licenced is the Chicago Mercantile Exchange (CME) which specialises in futures and commodities derivatives; however, it has a separate clearinghouse for IRD.

Dealer banks face higher liquidity requirements than they did before the Great Financial Crisis as a result of OTC derivatives reforms such as higher capital requirements, VM, IM, central clearing fees and trade reporting. This is in addition to the Basel III liquidity coverage ratio (LCR), net stable funding ratio and other post-crisis reforms (Sidanius & Zikes, 2012). Most dealers are large banks which means that higher collateral demands may result in lower credit extension by banks, which could reduce production in the real economy. A collateral shortage in the derivatives market could force dealers to limit market-making activities. Gibson & Murawski (2013) find that increased margin requirements may impact negatively on trading volume in the derivatives market, which could have devastating results for liquidity and the operation of this market. Thus, the ability of dealer banks to meet their increased collateral and liquidity demands has implications for systemic risk in the financial system. Despite the systemic weaknesses highlighted during the Great Financial Crisis, the derivatives market may serve an important role in the financial market by improving risk pricing and allowing for risk transfer (Cecchetti, Gyntelberg & Hollanders,

2009). The FSB (2010) notes that *“OTC derivatives benefit financial markets and the wider economy by improving the pricing of risk, adding to liquidity, and helping market participants manage their respective risks. However, it is important to address the weaknesses in these markets which exacerbated the financial crisis.”*

Participants in a bilateral OTC market are interconnected through a vast network of privately negotiated transactions, dominated by a few large dealers. The failure or default of a market participant can have large systemic risk implications as all of their counterparties attempt to replace their contracts while the market may be less liquid as a result of the default. Thus, market participants who act as dealers may pose a systemic risk to the derivatives market through their interconnectedness with other market participants even if their net positions are equal to zero, i.e. they have a “balanced book”. Conversely, dealers are exposed to systemic risk through their derivatives positions should one of their counterparties default. South African dealers or ODPs are primarily the country’s big five banks; therefore, systemic risk in the derivatives market could spill over into the larger financial system as it did in other countries during the Great Financial Crisis. The World Bank considers total bank assets to GDP as a good measure of the depth of a country’s financial system. Total bank assets as of December 2015 was 4.8 trillion ZAR (SARB, 2015) whilst GDP for 2015 was estimated at 4.5 trillion ZAR. Thus, South African banks’ balance sheets are large in relation to the country’s economy. This makes it important to quantify the collateral required for South African ODPs in the derivatives market to comply with incoming regulations.

In addition, the local market’s exposure to foreign currencies is likely to increase during times of local market stress through the potential depreciation of the ZAR (possibly as a result of a risk-averse flight to reserve currencies or as a result of a deterioration of South African fundamentals). In addition, shocks to global liquidity typically involve large foreign exchange liquidity shortfalls, barring intervention from authorities (Committee on the Global Financial System [CGFS], 2013). These factors of increased demand for collateral and the possible short-term shortages of HQLA in times of volatility could lead to a crippling shortage of liquidity for financial institutions. A shortage of liquidity could result in the bankruptcy of otherwise solvent institutions, in other words, where assets exceed liabilities (see Section 2.2.1). In the case of systemically important financial institutions, their

bankruptcy could result in complete market failure. This then places a burden on the SARB to be prepared to provide liquidity to the market in its function as the lender of last resort. According to van Wyk, Botha & Goodspeed (2019), the lender of last resort function is fulfilled by *“a country’s central bank in extending credit to banks or to other entities in unusual circumstances involving a national or regional emergency, where failure to obtain credit would have a severe adverse impact on the economy.”* This liquidity assistance should only be extended when the failure of the entity poses a systemic threat, and when the entity is otherwise solvent.

1.2 Scope and purpose of the study

Margining requirements on centrally and non-centrally cleared derivatives as well as contributions to a CCPs DF will increase collateral demand for ODPs. The magnitude of the increase depends on whether derivatives are centrally cleared or non-centrally cleared. If centrally cleared, they are dependent on the model inputs of the CCP’s margin model. If non-centrally cleared, they are dependent on whether the requirements are calculated using the QPMM approach or the SMS approach. If calculated using the QPMM approach, they are dependent on the model inputs.

These demands should increase during times of market stress to cover the increasing CCR and PFE; however, the SMS approach breaks this relationship. If the QPMM approach is used, the relationship between market stress and IM and DF requirements is pro-cyclical. A CCP may even choose to increase the number of IM calls it makes during times of increased market risk. Gibson & Murawski (2013) liken increasing margin requirements to a run on a bank, increasing liquidity demands when liquidity is scarce. They find that high margin rates when collateral is scarce increases the risk of default. Thus, when collateral is scarce, margining may increase default risk in contrast to the regulatory objective of reducing systemic risk. The potential sources of collateral scarcity are discussed in section 2.3 below.

A study by the CGFS (2013) found that collateral supply globally is in principle large enough to meet increasing collateral requirements; however, weaknesses in individual markets could result in the temporary immobilisation of collateral in some parts of the system unable to flow freely to deficit units. This market fragmentation was realised during the Q1

Covid-19 crisis of 2020 and is discussed further in section 2.3. A liquidity shortage would be detrimental to the OTC derivatives market function as well as for financial stability in South Africa. In 2012, the SARB had already identified the limited supply of high-quality liquid assets (HQLA) as a possible risk and barrier for local commercial banks to meet Basel III's liquidity coverage ratio (IMF, 2015). In response, the SARB committed to the provision of a "committed liquidity facility" to ensure that banks have a supply of HQLA to meet Basel III's regulatory requirements. According to Anderson & Joeveer (2014), the reforms to the OTC derivatives market is one of the most important changes affecting collateral demand globally. Therefore, South African Authorities must be prepared to meet increasing collateral demands. Given the poor credit rating of South African sovereign debt, these demands would likely fall on the SARB. Therefore, the estimates from this study will serve to prepare the SARB for the increased demand for collateral resulting from IM and DF.

Although the South African Authorities have indicated their intention to mandate central clearing for eligible products, the impact of a decision not to mandate central clearing is considered. South African Authorities may decide to licence a local CCP, an international CCP, both or neither. As discussed in the previous section, increasing the number of CCPs will always reduce multilateral netting benefits and increase collateral costs. Therefore, the potential of licencing both a local and international CCP is not considered as this research seeks to find the most cost-efficient market structure. Therefore, three potential market structure scenarios are considered to inform South African Authorities of the collateral implications. Firstly, licencing a single global CCP and assuming all eligible trades are cleared through that CCP, and the balance remains uncleared however, they are subject to margin requirements calculated using the BCBS-IOSCO's QPMM approach. Secondly, licencing a single global CCP and assuming all eligible trades are cleared through that CCP, and the balance remains uncleared however, they are subject to margin requirements calculated using the BCBS-IOSCO's SMS approach. Thirdly, assuming central clearing is not mandated, and all derivatives remain non-centrally cleared and are subject to margin requirements calculated using the BCBS-IOSCO's SMS approach.

All of these collateral costs will be calculated in ZAR, however, licencing an international CCP exposes ODPs to exchange rate risk if IM and DF contributions are not accepted in ZAR. In addition, existing exchange control rules could restrict ODPs from complying with their

collateral requirements. National Treasury may need to adjust exchange controls to accommodate this increase in demand and the SARB will need to be prepared to provide foreign exchange to the market in the event of a shortage of supply. In addition, ODPs will need to employ risk management techniques against exchange rate volatility, further increasing the cost of doing business in the derivatives market.

1.3 Research objectives

Following the above discussion in section 1.2 a gap in the knowledge was identified to inform South African Authorities of:

The impact of initial margining requirements on collateral demand for ODPs under various potential market structure scenarios and to determine the potential foreign exchange rate risk emanating from licencing an international CCP.

From the identified knowledge gap, three research objectives were identified to contribute to the body of knowledge in this emerging field.

1. Analyse the volatility dynamics of the underlying asset of South African interest rate derivatives and estimate various market stress scenarios as an input for the QPMM approaches used by the BSBC-ISOCO and a CCP.
2. Estimate the collateral demands on South Africa ODPs that will result from the enforcement of IM on non-centrally (using the QPMM and SMS approaches) as well as IM and DF contributions on centrally cleared derivatives (using a CCP's margin model) in the three potential market structure scenarios.
3. Quantify and examine the foreign exchange rate risk that ODPs would be exposed to should an international CCP be licenced by Authorities.

1.4 Research design

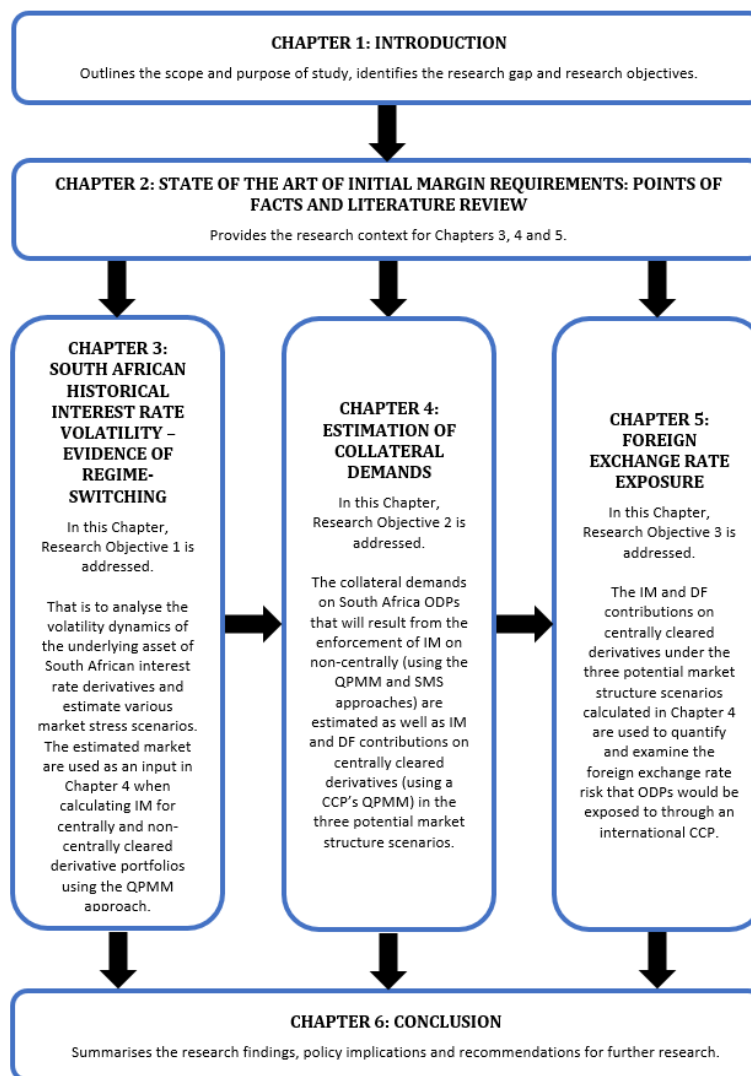
A deductive (or quantitative) approach to the research design is followed within a positive economics framework. The research is conducted using secondary data.

Chapter 2 provides an overview of the state of the art of post-crisis reforms, with a specific focus on bilateral margin requirements and the collateral costs from central clearing. The

chapter then provides context on the costs of regulations and the supply of collateral, as well as a discussion of the pro-cyclicality of IM requirements. Chapter 2 presents the research context within which Chapters 3, 4 and 5 exist. Finally, the conclusion is presented in Chapter 6.

Chapter 3 addresses the first research objective, Chapter 4, the second and Chapter 5 the third. The methodologies employed in Chapters 3 to 5 are informed and supported by a literature review at the beginning of each chapter. The methodologies for Chapters 3, 4 and 5 are applied in a linear fashion with each chapter’s results used as an input for the following chapter, this is illustrated by figure 1.3 below.

Figure 1.3: Overview of Thesis structure



Source: Author’s illustration.

1.5 Other research considerations

1.5.1 Research Ethics

The research used secondary historical time series data available through the researcher's employer's (the University of South Africa) subscription to Bloomberg as well as publicly available information from dealer banks and the SARB. These sources of data did not involve any human subjects, and the data is available in the public domain. The research, therefore, did not have any ethical risks associated with it. The 2020 research ethics policy of the Faculty of Commerce at the University of Cape Town states this that this kind of research does not require an application for ethics clearance. More information can be found following the link below:

<https://www.commerce.uct.ac.za/Downloads/Commerce%20Ethics%20in%20Research%20Handbook%20Nov%202019.pdf>

1.5.2 Plagiarism

The Turnitin report is available upon request, the overall similarity index is 14% and no single source exceeded an individual similarity index of 1%.

Addendum 1A: Covid-19

This study was completed before the global outbreak of the Covid-19 pandemic; thus, all of the data used was collected prior to the outbreak. The notional amounts outstanding per ODP used in Chapter 4 were sourced from each ODP's annual financial statements as at end December 2018. The impact of the Covid-19 crisis on notional amounts outstanding per ODP will only be observed in the December 2020 financial statements which will be published in the first and second quarters of 2021. The interest rate and exchange rate data used in Chapters 3 and 5 spans the period 2001 – 2018. The impact of Covid-19 on the South African derivatives market is beyond the scope of this study and presents an interesting topic for future research.

The Covid-19 pandemic is the most serious global health crisis since the 1918 Spanish flu, and although it is too early to evaluate the long-term economic impact of Covid-19, it is anticipated to result in the highest economic losses of any epidemic in more than a century. (Boissay & Rungcharoenkitkul, 2020). According to a report by the Macroeconomic Policy Analysis Programme (2020), as of 15 May 2020, South Africa had the highest reported total number of infections in Africa and the 8th highest number of infections per capita in Africa. However, this number may be skewed upwards because the testing intensity in South Africa is higher than that in most African countries. Testing intensity is the number of tests that have been conducted relative to the number of positive cases. As of the May report, South Africa had the 17th highest testing intensity in Africa and 78th highest globally. South Africa had the 3rd highest Covid-19 tests per capita in Africa and the 97th highest in the world. Although, those tested may not be representative of the total population because those tested have generally been exposed to an individual who tested positive or are themselves showing symptoms; therefore, the estimates may again be skewed upwards.

The first cases of Covid-19 were identified in China in December 2019, and by 19 February, stress in the global financial market began to show. Global volatility as proxied by the Chicago Board Options Exchange Volatility Index (VIX) began climbing in February and quickly reached 2008 levels. Even the traditionally "safe haven" market for US government debt witnessed extreme volatility and large-scale sell-offs. The market for South African government debt, which suffers from unusually high idiosyncratic risk was especially hard

hit by the external shock. According to Schrimpf, Shin & Sushko (2020), increased volatility increased margins calls which led to a liquidity spiral and rapid downturn in the leverage cycle (see section 2.3.1.2 for more information on liquidity spirals and the leverage cycle).

By mid-March, the global financial market functioning was impaired, necessitating intervention from authorities globally to prevent catastrophic market failure. During the Great Financial Crisis, many central banks (not including the SARB) found themselves constrained by a liquidity trap, necessitating Quantitative Easing (QE). QE refers to the purchase of government bonds and possibly risky assets with newly created central bank reserves in order to provide banks with more liquidity and prevent a deflation spiral while in a liquidity trap. In the aftermath of the Covid-19 outbreak, many central banks in developed economies found themselves once again constrained by the zero lower bound. In response, the Fed (Federal Reserve System) has restarted its QE programme, and the European Central Bank has extended theirs. As of May 2020, the SARB was not inhibited by a liquidity trap as the repo rate remained above zero and inflation had not persistently fallen short of its targets. Therefore, in response to the lower projected GDP growth following the Covid-19 outbreak, the SARB was able to cut the repo rate by 100 basis points on 19 March and 14 April respectively followed by a further 50 basis points on 21 May to reach a 50-year low of 3.75%. Liquidity strains prompted the SARB to increase the frequency and term of repurchase agreements offered to banks. In addition to the standard 7-day repurchase agreements offered weekly, the SARB began offering repurchase agreements on a daily basis for up to three months. Disruptions in the South African financial market prompted an extraordinary unconventional monetary policy response from the SARB. On 25 March the SARB announced that it would take the unprecedented step of purchasing government bonds in the secondary market to inject liquidity directly into the bond market as well as to stabilise the market. Although this action resembles QE, it is not a QE programme because the SARB is not constrained by the zero lower bound, nor is it required to prevent deflation, nor is it designed to drive investors away from government bonds towards riskier assets (SARB, 2020). In addition to this remarkable monetary policy response, the PA has provided regulatory relief for banks in three areas. Firstly, loans to households, small-to-medium sized businesses and corporates that are restructured due to Covid-19 will not be subject to a higher capital charge. Secondly, for the duration of the crisis, the LCR is lowered from

100% to 80%. Thirdly, banks are subject to lower minimum capital requirements, and banks meeting specific criteria may dip into their capital conservation buffer until otherwise specified. The PA has also issued a guidance note “advising banks not to distribute discretionary ordinary dividends during this period” in addition to recommending that bonuses for senior executives be put on hold during the crisis (PA, 2020). These reliefs are designed to help banks use their own capital and liquidity reserves in order to extend credit to and help their clients who are in good standing.

Economically, the Covid-19 pandemic may be a what is referred to in the literature as a “sunspot”. A sunspot is an extrinsic random variable upon which agents coordinate their decisions. Cass & Shell (1983) illustrate how a sunspot activity can lead to excess volatility, while expectations are rational. An extrinsic random variable is unrelated to economic fundamentals; however, it affects economic outcomes such as the allocation of resources and prices in a non-trivial way through excess extrinsic volatility. Sources of sunspots include heterogeneity of probability beliefs, incomplete markets and barriers to market participation (Shell, 2008). Azariadis (1981) finds that an economy may exhibit long-run stationary sunspot cycles when price expectations are self-fulfilling. When referring to volatility in this study, the focus is on intrinsic volatility which occurred during the Global Financial Crisis, rather than extrinsic volatility. However, the Covid-19 crisis highlights the importance of liquidity during times of financial market stress which makes it crucial to estimate the collateral required to comply with incoming reforms to the OTC derivatives market.

The policy interventions by South African and global authorities stabilised local and global financial markets and allowed a quick partial recovery in March, although funding conditions remained tight up until April (Aldasoro et al., 2020). The quick rebound supports the notion that the volatility was caused by sunspot activity rather than intrinsic uncertainty in economic fundamentals. In an April 2020 letter to G20 finance ministers and central bank governors, the chair of the FSB asserted that *“The financial system in the lead-up to the outbreak of COVID-19 has been stronger and more resilient than ever before, and this strength is owed in large part to the sustained efforts of the FSB and the international community”* (FSB, 2020b). Indeed, the banking sector did not amplify the initial shock during the 2020 Q1 Covid-19 crisis as it did during the Great Financial Crisis.

CHAPTER 2

STATE OF THE ART OF INITIAL MARGIN

REQUIREMENTS: POINTS OF FACTS AND LITERATURE

REVIEW

This Chapter provides the research context within which Chapters 3, 4 and 5 exist. It begins with section 2.1, a discussion of each of the G20 regulatory reforms aimed at reducing systemic risk in the OTC derivatives market. Section 2.2 investigates the costs of these regulatory reform measures. Section 2.3 explores possible limitations on the supply of collateral as well as mechanisms to increase collateral availability. The literature review concludes with section 2.4, a discussion of the pro-cyclicality of margin requirements.

2.1 Measures aimed at reducing systemic risk in the OTC derivatives market

The primary goal of post-crisis G20 regulatory reform initiatives is to reduce systemic risk in the international financial system. Systemic risk is not concerned with the failure of an individual financial institution, but rather the risk that the failure of an institution could result in the collapse of a specific financial market or the entire financial system. Nijssens and Wagner (2011) found that OTC derivatives amplified systemic risk during the Great Financial Crisis via direct losses as defaults triggered embedded credit derivatives as well as indirect mark-to-market losses on derivative portfolios through increased CCR. CCR is the risk that the counterparty to a transaction defaults before the transaction is settled; thus it is two-way risk between the two parties to a contract that the counterparty will default (Gregory, 2010). As the Great Financial Crisis unfolded, CCR increased as general market risk factors increased, and this positive correlation is known as wrong-way risk (Canabarro and Duffie, 2003). Defaults and mark-to-market losses increased CCR, which pro-cyclically resulted in further mark-to-market losses (European Commission, 2010). Higher CCR required more collateral to be posted to counterparties further constraining liquidity, and the ensuing liquidity crisis threatened the operation of otherwise solvent institutions

(Blanchard, 2009). In fact, the BCBS noted that approximately two-thirds of CCR losses were due to mark-to-market losses and only one third due to actual defaults (Bank for International Settlements [BIS], 2009). Below follows a discussion of the reform initiatives for the OTC derivatives market and how it is believed they would reduce CCR and thus systemic risk.

2.1.1 Trade reporting

Prior to the Great Financial Crisis, authorities were more focused on the net positions, rather than gross positions, of market participants as a measure of the riskiness of their OTC derivatives portfolios (Cecchetti, Gyntelberg & Hollanders, 2009). However, as the crisis unfolded, a lack of transparency about the exposure of counterparties through their large gross positions created concerns over CCR, which exacerbated losses through mark-to-market adjustments. Trade reporting improves transparency in the market and can lower CCR if the information is properly reported and properly used by authorities and the public. Trade reporting, however, does not eliminate CCR. Reporting would allow regulators to monitor the trade in those derivatives which are not suitable for central clearing, giving authorities a picture of the whole derivatives market. Better trade reporting also enables supervisors to monitor previously unregulated market participants such as insurance firms, hedge funds and large corporates. Trade repositories allow authorities to assess systemic risk, conduct market surveillance, supervise market participants, plan resolution activities, implement monetary policy, conduct research, analyse products, analyse market infrastructure and conduct event studies (FSB, 2018a).

However, differences in reporting requirements and legal barriers to sharing data across jurisdictions have impeded the supervisory benefits of trade reporting (FSB, 2019a). In response, the Committee on Payments and Market Infrastructures (CPMI) and IOSCO were tasked with developing guidelines to enhance data harmonisation so that trade repository data from different nations can be aggregated and compared by supervisors. These include the Unique Transaction Identifier (UTI) and the Unique Product Identifier (UPI). In 2017 the FSB published its conclusions and recommended the implementation of UTI in all member jurisdictions by end 2020. Following further consultations on the governance arrangements for the UTI and UPI, the implementation deadline was delayed to the third quarter of 2022

(FSB, 2019b). In a follow up to its 2015 recommendations to limit legal barriers to trade reporting, the FSB, (2018b) reports that there has been significant progress in adopting the 2015 recommendations in most jurisdictions.

The successful sharing of information has been achieved in the EU, the European Securities and Markets Authority's (ESMA) TRACE system aggregates data from eight trade repositories to better assess systemic risk across the region (FSB, 2018a). Section 6c of the FMA provides the legislative framework for South African Authorities to establish supervisory cooperative agreements with authorities in equivalent jurisdictions. From June 2019, South Africa was the only member jurisdiction of the G20 without comprehensive trade reporting requirements in force (FSB, 2019c).

2.1.2 Margin requirements

CCPs demand IM from their clearing members on a one-way basis to cover PFE. VM is demanded from the counterparty whose position is in-the-money and transferred to the counterparty whose position is out-of-the-money; therefore, the CCP does not hold onto VM. An additional risk mitigation payment is demanded from clearing members in the form of a contribution to the CCP's DF¹.

Prior to the Great Financial Crisis, the use of margining in the bilateral OTC derivatives market was varied and inconsistent. VM was sometimes exchanged whilst IM was almost never required. Generally margining was insufficient prior to the crisis and the increase in CCR during the crisis lead to large increases in margin calls exacerbating pro-cyclicality. A well-known example is AIG, who prior to the crisis, sold credit protection through credit default swaps (CDSs). They were required to post almost no initial collateral due to their AAA credit rating, allowing them to create a highly leveraged position. When AIG suffered a credit ratings downgrade its counterparties demanded collateral which created a cycle of further downgrades and higher collateral demands, which would have bankrupted AIG if it had not been for government assistance (Hull, 2010). According to the ISDA (2014), many parties still did not post VM in 2014.

¹ Not all CCPs require contributions to a DF, for example US securities CCPs who mutualise margin rather than having a DF.

At the direction of the G20, the BCBS-IOSCO set margin requirements for non-centrally cleared derivatives in an effort to incentivise central clearing and reduce CCR. This is because central clearing imposes costs in the form of margin requirements and contributions to a CCP's DF. Therefore, margin requirements on non-centrally cleared derivatives were designed to remove this relative cost advantage. Margining may have an external benefit on risk-taking activities, encouraging participants to internalise the cost of their risk-taking (BCBS-IOSCO, 2015a). Margining may also help prevent excessively leveraged positions. The implementation schedule set by the BCBS-IOSCO requires covered entities (entities which are defined as "covered" and those which are excluded by South African Authorities are listed in table 2.1) The BCBS-IOSCO's original implementation plan required covered entities with aggregate non-centrally cleared derivatives positions in excess of 3 trillion EUR to post IM from 1 September 2016 and for VM exchange to be mandatory from 1 March 2017. However, according to the FSB in August 2016, only three of its twenty-four member jurisdictions were ready to implement these reforms (FSB, 2016). South Africa is among the twenty-one nations who missed the initial deadlines. According to the FSCA & PA (2019b), all new contracts entered into after 1 March 2020 were to be subject to VM exchange in South Africa. However, as with IM requirements, implementation of VM requirements has been delayed to "an effective date" not yet announced due to the Covid-19 crisis. The exchange of VM will be required on all new contracts entered into from 6 months after the effective date. The FSB (2019c) highlights that the staggered implementation of margining requirements throughout its member jurisdictions is a source for regulatory arbitrage. A staggered implementation allows market participants to design contracts in a way that avoids complying with the higher cost of regulations. This circumvention of regulations may also lead to market fragmentation (FSB, 2019a).

The initial thresholds mean that in practice it will still be years before the major market participants in South Africa would be required to post IM on non-centrally cleared derivatives. The total South African market size reported by the SARB as of end December 2018 was just over 38 trillion ZAR. From the effective date to 31 August 2021, only market participants with an average of 30 trillion ZAR in notional outstanding are required to post IM. The threshold will continue to decline annually to 23 trillion ZAR for 2021/22, 15 trillion ZAR in 2022/23, 8 trillion ZAR in 2023/24 and finally 100 billion ZAR from 1 September 2024

onwards (FSCA & PA, 2020). The single largest domestic ODP reported notionals of 9 trillion ZAR as of end December 2018, therefore margining would only be required from 2023. All covered entities are subject to IM and VM requirements above the threshold. The second half of table 2.1 contains a list of entities that are exempt from the margining requirements.

Table 2.1: Covered and uncovered entities as defined by South African Authorities

“Covered entity” refers to the following financial institutions

- an authorised user,
- a bank, bank controlling company or branch as defined in terms of the Banks Act,
- a financial services provider authorised to provide financial services in derivative instruments,
- an insurer licensed or deemed to be licensed to conduct life insurance business in terms of the Insurance Act,
- an insurer licensed or deemed to be licensed to conduct non-life insurance business in terms of the Insurance Act,
- a manager of a collective investment scheme registered in terms of the Collective Investment Schemes Control Act, 2002 (Act No. 45 of 2002),
- a private equity fund,
- a person outside the Republic who is authorised by a supervisory authority to perform a service or services similar to one or more of the services referred to in the definition of a provider or the services performed by an authorised user; or is registered, licensed, recognised, approved or otherwise authorised to conduct the business of a bank or to render services of a business referred to in paragraphs (d), (e) or (f) by a supervisory authority with functions similar to those of the Authority referred to in the legislation listed in paragraphs (d), (e) or (f),
- any other person declared by the Authority, with the concurrence of the Prudential Authority, to be a covered entity.

The following institutions are exempt from margin requirements

- sovereigns,
- central banks,
- multilateral development banks,
- the Bank for International Settlements,
- transactions such as repurchase agreements and security lending transactions that are not derivatives but share some attributes with derivative instruments; and
- indirectly cleared OTC derivative transactions that are intermediated through a clearing member on behalf of a non-member client, if (i) the non-member client is subject to the margin

requirements of the relevant clearing house; or (ii) the non-member client provides margin, consistent with the margin requirements of the relevant corresponding clearing house.

Source: (FSCA & PA, 2020).

2.1.3 Capital requirements

Capital requirements are only applicable to OTC derivatives market participants who are also commercial banks. Basel III introduced interim standards in 2012 for additional capital requirements, such as the CVA, as an incentive to centrally clear derivatives as well as mitigate CCR in non-centrally cleared derivatives. CVA protects against the probability-weighted loss given default; therefore, it is an additional capital requirement which takes account of the credit quality of counterparties. South African ODPs have been fully compliant with CVA requirements since 1 April 2015 (National Treasury, 2016). Capital requirements are a “survivor-pay” risk mitigation strategy whilst margining is a “defaulter-pay” strategy. The final Basel III standards are in the process of implementation and comprise of the standardised approach to CCR, which is a holistic approach to mitigate CCR (FSB, 2018a). These final standards ascribe the smallest capital requirements to a qualified CCP followed by a non-qualifying CCP (the difference between qualifying and non-qualifying CCPs is based on whether it has been granted equivalence, this is discussed in section 2.1.4.4.1). This reflects the recognition that CCPs have a low risk of default however the risk does exist (see section 2.1.4.2 for a discussion of the systemic importance of CCPs and the resultant regulatory response to ensure these market infrastructures are more robust to market stress). Non-centrally cleared derivatives are subject to the highest capital requirements, reflecting the higher CCR of the counterparty.

2.1.4 Central clearing

Although currently enforced in many G20 jurisdictions, South African Authorities have not yet mandated central clearing. This section begins with an examination of the private and social benefits of central clearing as compared to bilateral trading. Followed by a discussion of the systemic importance of CCPs, the eligibility criteria for central clearing, an examination of the different CCP licencing frameworks available to South African Authorities and finally a review of the incentives for central clearing.

2.1.4.1 Potential benefits of central clearing

Cecchetti, Gyntelberg & Hollanders (2009) identify the potential benefits of wider use of central clearing in the OTC derivatives market as a reduction in CCR, multilateral netting of exposures and the increased market transparency of outstanding contracts and prices. In addition, centrally cleared derivatives are subject to lower capital requirements.

2.1.4.1.1 Reduced CCR

Cecchetti et al.'s assertion that central clearing may be a method to reduce CCR and thus, systemic risk is intuitive. A CCP interposes itself between the two parties (for example A and B) to a derivative contract becoming the seller to the buyer and the buyer to the seller. The original contract is torn up, and two new contracts with the CCP as counterparty to each of the original two parties are created, this process is known as novation. Through novation, the original two parties are no longer exposed to each other's CCR; instead, they are both now exposed to the CCP. Therefore, in times of financial stress, like those conditions seen during the Great Financial Crisis, the default of party A would result in losses for the CCP and not for party B. The CCP thus insulates the other clearing members from the default of a counterparty (assuming it maintains adequate risk management practices), thereby reducing the risk of CCR soaring as it did during the crisis. Reducing CCR can reduce systemic risk because in times of market stress a few defaults in a bilaterally cleared market could spark a chain of defaults and losses which could threaten the solvency of many interconnected OTC derivatives market participants. Loon & Zhong's (2014) research supports this theory, and they found that the relation between CDS spreads and the contract's original parties CCR weakens after central clearing. In addition, they found that the liquidity of cleared reference entities improved with central clearing, thereby improving market efficiency. This implies that central clearing had reduced CCR for these CDSs, and therefore, systemic risk was reduced. According to Duffie and Zhu (2011), effective central clearing reduces systemic risk by reducing CCR, reducing the probability of fire sales and solvency problems during a crisis. However, central clearing is only effective if the lost bilateral netting benefits are smaller than the multilateral netting benefits gained by clearing. Duffie and Zhu find that as the number of CCPs increase, multilateral netting benefits are reduced. Cont & Kokholm (2014) expand on the Duffie & Zhu's model to allow for heterogeneity in risk between products and across dealers, as well as the correlation of

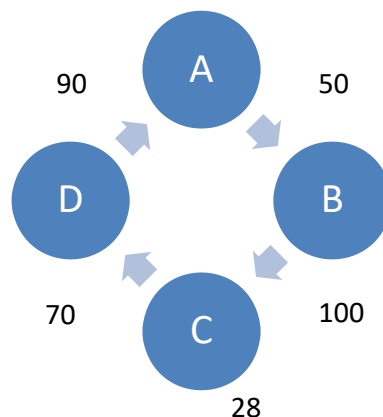
positions across products. They find that the central clearing of previously bilaterally traded contracts reduces CCR significantly more when there is heterogeneity of risk across asset classes, as well as the correlation of positions across products. Heterogeneity of risk across asset classes is typical in the real world. For example, an IRS and a CDS with identical notional amounts outstanding and maturity will typically not be subject to the same collateral requirements reflecting differences in risk.

2.1.4.1.2 Multilateral netting

Prior to the Great Financial Crisis, multi-product bilateral netting was commonly practised on non-centrally cleared derivatives. According to Cont & Kokholm (2014), bilateral netting could allow a party to net a fixed income position with an interest rate swap (IRS), for example. Bilateral netting is the offsetting of contracts between two counterparties in all contracts and products so that only one IM or VM payment is made (Heath, Kelly & Manning, 2012). Bilateral netting is beneficial to the surviving party in the case of default because of “close-out netting”, whereby the defaulting party would be unable to avoid payment on out-of-the-money contracts while still collecting on in-the-money contracts.

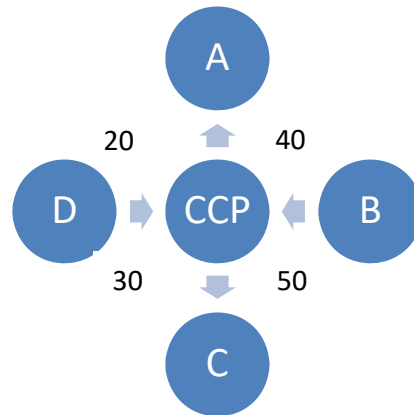
Central clearing or central trading allows for the multilateral netting across multiple clearing members within individual product types. Multilateral netting allows for balance sheet netting, which reduces overall counterparty exposure. All the clearing member’s positions are netted to a final net position between each member and the CCP; it is this final net position that needs to be collateralised. To contrast bilateral and multilateral netting benefits, compare figures 2.1 and 2.2 below. In this example, the move from bilateral netting in figure 2.1 to multilateral netting in figure 2.2 reduces total collateral demand by 170 from 310 to 140.

Figure 2.1: Illustration of bilateral netting benefits



Source: Author's illustration.

Figure 2.2: Illustration of multilateral netting benefits



Source: Author's illustration.

As under Basel III, the BCBS-IOSCO rules do not allow derivative positions between different risk categories to be offset when calculating IM. Thus, bilateral netting benefits have been reduced by Basel III and the BCBS-IOSCO rules. Any remaining bilateral netting benefits are eliminated through central clearing. The ISDA notes that reducing bilateral netting benefits in non-centrally cleared derivatives markets could lower risk management incentives for dealers, possibly leading to negative externalities (The International Swaps and Derivatives Association [ISDA], 2014b). However, it has had a major impact on incentivising the central clearing of derivatives (FSB, 2018c).

Multilateral netting may result in private benefits by reducing market exposure as well as social benefits in reducing market complexity. The extent to which a transition to multilateral netting can reduce the total collateral demand depends on the market structure as well as the extent of bilateral netting already in practice. In the simple example illustrated above in figures 2.1 and 2.2, the transition from bilateral netting to multilateral netting results in reduced market complexity and exposure (represented by total collateral demand). However, this simple example assumes that a single CCP clears the entire market. Duffie & Zhu (2011) find that multilateral netting benefits are maximised when there is a single CCP clearing all products globally. Alternatively, if not a single CCP, then multiple CCPs that are linked together. Linking CCPs would reduce the cost of multiple CCPs operating in a market; however, this creates an exposure between CCPs. According to Anderson & Joveer

(2014), these netting benefits can reduce total collateral exposure. However, in practice, regional CCPs dominate markets typically clearing only one derivative product type. According to Gregory (2020), this is due to bifurcation on the regional as well as product level. Market participants (and in some cases regulators) view it as important to have a CCP in their local region and CCPs tend to operate with vertical structures (specialising in certain product types). This significantly reduces the benefits of multilateral netting. Concerningly, Marshall, Ruffini & Anene (2018) find that networks with low benefits from multilateral netting receive less financial stability benefits from the movement to central clearing. Therefore, networks without large redundancies in gross exposures, i.e. those that may have gone through trade compression, benefit less from the movement to central clearing.

2.1.4.1.3 Market transparency

A source of systemic risk in the pre-financial crisis OTC derivatives market was the deficiency of counterparty relationship transparency (FSB, 2010). According to Acharya & Bisin (2010), a lack of trade position transparency results in a negative CCR externality which can lead to excessive default and market failure. They find that the negative CCR externalities from information asymmetries could potentially be eliminated through central clearing or central trading. This is because trade positions can be disseminated to market participants whom themselves set trades conditional on that information. Central clearing increases transparency in a previously opaque market and allows supervisors to monitor the build-up of risks in the market.

2.1.4.1.4 Reduced capital requirements compared with bilateral trading

As discussed in section 2.1.3, exposures to a qualified CCP are subject to the lowest capital requirements under Basel III followed by a non-qualified CCP.

2.1.4.2 Systemic importance of CCPs

The current clearing market is dominated by a few large CCPs each clearing specific asset classes for an international member base. Mandatory central clearing has increased the size and interconnectedness of CCPs. Tucker (2014) points out that this increased concentration of systemic risk in CCPs and could not have been the intention of G20 leaders. In addition, many of the largest OTC derivatives dealers, and as such the largest counterparties to CCPs, have been identified as globally systemically important banks (G-SIBs). Borovkova & Lalaoui

El Mouttalibi, (2013) find that for heterogeneous financial networks (a characteristic of any real-life financial system), the presence of a CCP increases the probability of contagion defaults, particularly for smaller financial firms. Different financial network structures were considered by varying the number and size of market participants as well as their capitalisation. They found that in the most realistic structure, the core-periphery network, a default by a large clearing member is propagated through the system affecting small counterparties in the periphery worse than in a bilateral market.

The reduced CCR from central clearing may introduce an asymmetric information problem as parties are no longer incentivised to consider the creditworthiness of their counterparty or the riskiness of contract they are entering into because they know their eventual counterparty will be the CCP. Akerlof (1995) predicts that this behaviour will push “peaches” (i.e. low-risk counterparties or products) out-of-the market in favour of “lemons” (i.e. high-risk counterparties or products). In a recent study, Antinolfi, Carapella & Carli (2021) find that the presence of adverse selection limits the ability of CCPs to effectively provide risk-sharing because the CCP creates a lack of incentives to acquire information about heterogeneous counterparties. The result is a higher average collateral requirement or higher average default rate in comparison to bilateral trading.

Koepl (2013) establishes a relationship between clearing, market liquidity and collateral requirements when collusive moral hazard is present. He finds that in the presence of collusive moral hazard, a CCP is forced to charge collateral levels associated with the worst counterparty quality on all its transactions, thus raising collateral requirements. Increasing capital requirements increase trading costs which may result in lower market liquidity, and lower market liquidity increases capital charges as the ability to replace contracts is reduced. He concludes that central clearing is most effective in sufficiently liquid markets and where CCPs take counterparties risk level into account when setting collateral requirements. Pirrong (2011) finds that the collateral required by CCPs depends on the product risk characteristics and does not depend on the counterparty’s risk level. CCR is dependent on both the product and counterparty risk level; therefore, CCPs may under-price the risk of less creditworthy clearing members creating the opportunity for moral hazard where less creditworthy counterparties trade more and vice versa.

Thus, because large CCPs are themselves systemically important financial institutions, regulators and supervisors have an interest in ensuring they employ robust risk management practices to survive extreme market stress. In response to the increased systemic risk centralised within CCPs, the CPMI-IOSCO published the “Principles for Financial Market Infrastructures” (PFMIs) in 2012. The twenty-four principles are designed to ensure that systemically important financial market infrastructures are robust and can withstand the failure of a clearing member and other financial shocks, even in periods of market stress. Thus, their resilience to and recovery from financial stress is of paramount concern to authorities. In 2017 the CPMI-IOSCO published more detailed guidance on five key principles of the PFMI focusing on financial risk management for CCPs. These are governance, stress testing for both credit and liquidity exposures, coverage, margin, and a CCP’s contribution of its own financial resources to losses. Supervisory stress tests are conducted regularly in some jurisdictions, and CCPs themselves conduct daily stress tests.

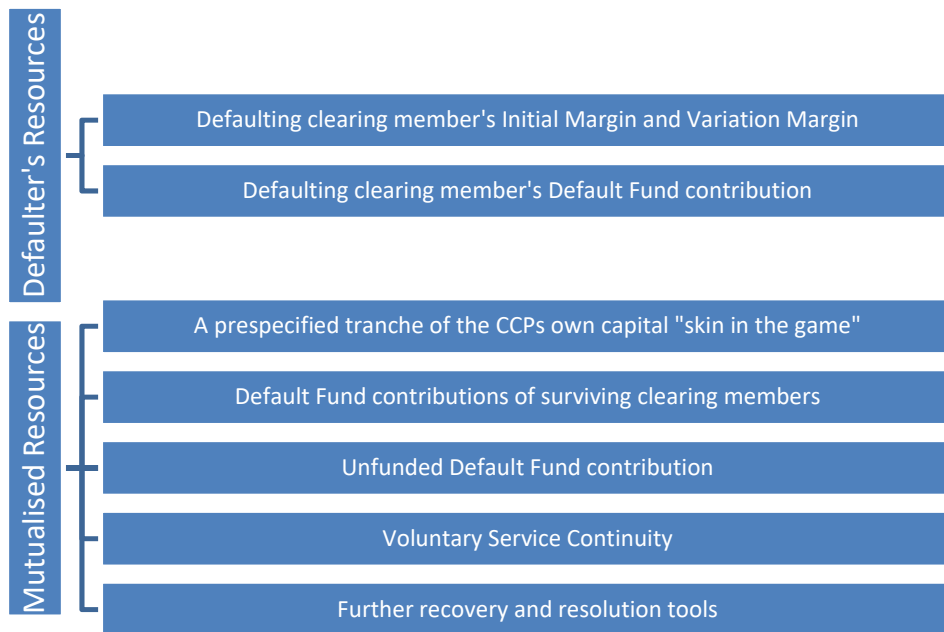
The “too big to fail” phenomenon was highlighted as a weakness in the international financial system during the Great Financial Crisis. Some systemically important institutions, such as AIG, were bailed out by the US government because their failure would have exacerbated the crisis. The premise for a bailout is that the bankruptcy of the institution would cause greater economic losses than the cost of the bailout. An institution that is “too big to fail” may suffer from a moral hazard problem as the institution is incentivised to take higher risks. This is because a government bailout is essentially a socialisation of an institution’s losses (because taxpayers pay the institution’s losses) while profits are privatised.

Since the Great Financial Crisis, international regulators have focused on ending “too big to fail” by identifying systemically important institutions and requiring them to create resolution plans. A resolution plan is essentially an institution’s “living will”, laying out the plan for an orderly wind-down of the business in order to limit the contagion effect. The FSB published “Guidance on Central Counterparty Resolution and Resolution Planning” in 2014 (revised in 2017) to provide direction on credible resolution plans for CCPs. The FSB (2018c) finds that the financial resources available to CCPs have increased in recent years, lowering systemic risk. However, the FSB notes that progress is still needed in recovery planning and liquidity stress testing. The FSB (2020a) released further draft guidance on assessing the

adequacy of financial resources to absorb losses and approaches to the treatment of CCP equity.

According to Levitin (2012), a significant benefit of a well-capitalised CCP over dealer banks is its ability to diffuse losses across their membership. CCPs have a net-zero risk position under normal circumstances; however, the default of a clearing member exposes the CCP to market risk while a replacement counterparty is found. The default waterfall of a CCP illustrates how losses will be absorbed in the event of default; a typical default waterfall is illustrated in figure 2.3.

Figure 2.3: The default waterfall for a typical CCP



Source: Budding & Murphy (2014).

In a common example, first, the defaulting member's resources are used, followed by the CCPs mutualised resources. The "skin in the game" capital exposes the CCP's owners to losses and can provide appropriate incentives to owners to ensure that the CCP is properly risk-managed. According to CPMI-IOSCO (2017), putting the CCP's own capital before the DF contributions of non-defaulting clearing members in the default waterfall will increase members confidence in the risk management of the CCP. If the losses exceed the DF, the CCP may demand "unfunded" DF contributions from members, up to a maximum of each member's DF contribution at the time of default. If losses exceed the maximum unfunded DF contributions, the CCP could ask non-defaulting members to make voluntary

contributions. If all other resources have been exhausted, central banks could consider granting systemically important CCPs direct access to liquidity or indirect access by lending to its clearing members; otherwise, the CCP would go into recovery and then possibly into resolution (Pirrong, 2011).

By the beginning of 2020, the largest derivatives jurisdictions had implemented central clearing regulations which concentrated CCR and systemic risk in the few dominant global CCPs. The financial market turbulence resulting from the Covid-19 outbreak from February to April has been the largest test for this post-Global Financial Crisis reform to the OTC derivatives market. As authorities intended, CCPs functioned well and remained resilient during the initial financial market volatility and the operational challenges caused by Covid-19 (FSB, 2020c) & (Huang & Takáts, 2020).

2.1.4.3 Eligibility for central clearing

Not all derivative contracts are suitable for central clearing because they could expose the CCP to market movements that are difficult to margin accurately. For example, the default of a counterparty whose contracts are exotic (non-standard) and challenging to replace exposes the CCP to higher market risk as a replacement counterparty might take long to find or might not be found at all. The absence of generally accepted pricing sources for non-standard derivatives further complicates their replacement due to disputes about the market value of a contract. As the market risk increases, the ability of a CCP to replace exotic contracts further decreases. The forced central clearing of non-standard derivatives could also lead to a moral hazard problem as the original counterparties no longer have the incentive to manage CCR. For these reasons, the G20 only mandated central clearing for “standardised” OTC derivative contracts.

The FSB (2010) issued the following criteria for authorities and CCPs to identify whether a derivative product is standardised and therefore eligible for central clearing;

- 1) The degree of standardisation of a product’s contractual terms and operational processes,
- 2) The depth and liquidity of the market for the product,
- 3) The availability of fair, reasonable and generally accepted pricing sources.

As not all contracts can be centrally cleared, a bilateral market for exotic contracts will continue to exist.

2.1.4.4 Potential central clearing frameworks for the South African market

Duffie & Zhu (2011), Heller & Vause (2012), Heath, Kelly & Manning (2012) and Duffie, Scheicher & Vuillemeys (2015) find that the most efficient clearing model is for one global CCP to clear all trades and all products. They find that as the number of CCPs increase, multilateral netting benefits are reduced, and more collateral would need to be posted. According to former Minister of Finance, Nhlanhla Nene, South African banks trade extensively with foreign banks, with around 60% of South African interbank derivatives traded with foreign banks. Thus, multilateral netting benefits would be maximised if authorities licenced only the largest global CCP to clear the market. However, foreign exchange rate risk would be introduced to the market and national regulatory and supervisory control over a CCP would be sacrificed as well.

As central clearing has not yet been mandated, the CCP licencing decisions to be made by South African Authorities will have implications for the efficiency, cost, foreign exchange rate risk and systemic risk in the cleared OTC derivatives market. Authorities could choose to licence only a local CCP (section 2.1.4.4.1), only a global CCP (section 2.1.4.4.2), both a local and global CCP (2.1.4.4.3), allow a link between CCPs (section 2.1.4.4.4) or not licence any CCP (section 2.1.4.4.5).

2.1.4.4.1 Licencing only a domestic CCP

The FMA allows for South African Authorities to licence only a standalone domestic CCP. This structure allows the domestic Authorities the greatest degree of supervision and control over the clearing platform. Also, domestic infrastructure providers may have a commercial interest in offering clearing services (Anderson, Dion & Saiz, 2013). The CCP would be tailored to meet domestic needs in line with the South African legal system. However, since a large proportion of interbank trades are with foreign registered ODPs, the decision to recognise only a domestic CCP would limit multilateral netting benefits and increase costs. Forcing foreign ODPs to clear through a domestic CCP would possibly reduce their trade with South African ODPs and would also require equivalence.

“Equivalence” is the recognition by a national authority that a foreign registered CCP’s supervisory and regulatory regime is equivalent to the domestic regulatory regime, allowing market participants supervised by the national authority to use the services of the foreign based CCP. According to the FSB (2019b) when appropriate, equivalence (or deference to another national authority) encourages market efficiency and financial stability by reducing market fragmentation. Market participants who clear through a CCP who has not been granted equivalence will be subject to higher capital requirements because their trades will be not be recognised as “centrally cleared” by their national authorities.

JSE Clear (formally known as SAFCOM) is South Africa’s only domestic clearing house. On 27 January 2016, JSE Clear was granted equivalence by the ESMA. Previously, JSE Clear cleared only exchange-traded derivatives and other standardised products. With the equivalence granted by the ESMA, local Authorities amended the FMA in February 2018 to allow JSE Clear to clear the local OTC derivatives market until 31 December 2021 (FSB, 2018a). From 1 January 2022, only an “independent” registered CCP will qualify to clear the South African OTC derivatives market according to the FMA. JSE Clear is not considered independent because it is wholly owned by the JSE, the ESMA has suggested that the connectedness of an exchange and a CCP could be a source of additional risk (IMF, 2015). This is because the risks faced by an exchange and a CCP differ and could spill over from one to the other. JSE Clear relies heavily on four of its ten existing clearing members for liquidity, which makes it extremely vulnerable should one of the big four banks fail. Other risks of a CCP owned by a formal exchange include monopolisation and barriers to new entrants.

A significant advantage to licensing only a domestic CCP is that the foreign exchange rate risk associated with VM, IM and DF contributions to a foreign CCP is eliminated. The local currency would be accepted as collateral, and it is possible that certain local assets (that would not be accepted by a foreign CCP) would be accepted by a domestic CCP. However, the FSB (2019b) warns against national authorities mandating certain transactions denominated in the local currency to be cleared locally as this may increase market fragmentation, reduce multilateral netting benefits, increase margining costs and increase systemic risk.

2.1.4.4.2 Recognising only a foreign CCP

South African Authorities can decide to recognise only a foreign CCP. The Authorities would need to grant equivalence to the foreign CCP and allow it to register as an external company or registered office in terms of section 23 of the Companies Act. South African Authorities would have little say over the supervision and control of the foreign CCP, deferring authority to the foreign supervisors.

Since most of the interbank derivatives transactions in South Africa are conducted with foreign banks, the use of foreign CCPs seems a natural choice to increase multilateral netting benefits, but the use of foreign CCPs would require South African entities to post collateral to offshore accounts. Current exchange controls limit South African entities from investing more than 25% of their liabilities offshore, and collateral requirements to foreign CCPs mean this limit may need to be reconsidered. The same supervision and access to data limitations that apply to a foreign TR also apply to a foreign CCP, but even more so because CCPs are more systemically important. It would be far harder for South African Authorities to assist a foreign CCP in trouble than a domestic CCP and the failure of a foreign CCP would have large direct and indirect consequences for South Africa. However, a global CCP would also have more clearing members and therefore less reliance on the small number of large South African banks whose share of the global derivatives market is small. Owing to economies of scale, a global CCP reduces costs for clearing members and allows for greater netting benefits, which is highly desirable.

2.1.4.4.3 Licencing both a domestic and global CCP

There are costs and benefits to both the domestic only CCP or global only CCP approaches, but the FMA allows for both domestic and global CCPs to operate in the market. A benefit of this mixed approach is that important domestic products that are not cleared by foreign CCPs can be centrally cleared locally, while contracts with foreign counterparties can be cleared globally. However, multilateral netting opportunities are reduced when there are multiple CCPs, increasing collateral requirements for IM and DF. Conversely, forcing foreign participants to use a South African CCP would increase their costs and possibly reduce their participation in the market, resulting in a smaller market and less liquidity in the market. The fragmentation of the market would make supervision and regulation more difficult for local Authorities (Cecchetti, Gyntelberg & Hollanders, 2009).

2.1.4.4.4 Linking CCPs

The CPMI-IOSCO broadly identified two types of CCP links in its PFMI. The first type is a “peer-to-peer” link whereby two or more CCPs exchange margin and other resources on a reciprocal basis even though the CCPs are not subject to each other’s normal clearing members rules. The second is a “participant” link whereby one CCP becomes a clearing member of a “host” CCP. It will be subject to the same collateral requirements as any other normal clearing member of the host CCP. As with other clearing members, risk protection is one-directional, i.e. the participant CCP posts collateral to the host CCP to cover its CCR however the host CCP does not post collateral to the participant CCP (CPMI-IOSCO, 2012). A report by the ESMA highlights that the peer-to-peer link implies reciprocity whereby CCPs agree to multilaterally net exposures across their combined membership; however it does not follow that a participant CCP would be able to clear any of the host CCP’s member’s trades with its own members (ESMA, 2016). Therefore, in addition to the higher costs and higher CCR for a participant CCP in contrast to a peer CCP, there would also be reductions in netting benefits. Thus, linking has benefits for netting, and these are the largest when clearing is reciprocal; however, these are reduced in the case of a participant link. In some literature, the terms “linking” and “interoperability” are used interchangeably; however, the ESMA argues that participant link arrangements cannot be referred to as interoperability because it is not a reciprocal relationship.

Other possible benefits of linking include increased market competition possibly leading to lower fees as well as reduced operational and legal risks for domestic clearing members who would otherwise have to become clearing members in the global CCP directly. Increased costs include the operational and legal risks faced by a participant or peer CCP but the most crucial cost is the higher CCR faced by the domestic CCP through its exposure to the global CCP. Anderson et al. (2013) investigated the benefits of a peer-to-peer link for a domestic CCP to a global CCP. They found that when the number of domestic clearing members is small relative to the number of foreign clearing members (the ratio of domestic to foreign participants being less than 1/3), it is less efficient to establish a link between domestic and foreign CCPs than it is for domestic trades to clear through a domestic CCP and for trades including a foreign counterparty to clear through a global CCP. According to their approach, the benefits of interoperability (i.e. increased netting) are weighed against

the cost of the domestic CCP's increased CCR exposure to the global CCP. Thus, the higher the importance domestic Authorities attach to a domestic CCP's CCR, the higher the number of domestic market participants needed to make interoperability more beneficial than an unlinked scenario. Anderson et al. investigate a peer-to-peer link and the corresponding benefits for the domestic market participants; it follows that a participant link would be even less beneficial for the domestic CCP due to a reduction in netting benefits and an increase in CCR exposure. From an oversight perspective, domestic Authorities would likely not have regulatory or supervisory powers over the global CCP; thus, from a supervisory perspective, the hybrid approach is similar to recognising both a domestic and a foreign CCP.

The global CCP most likely to link with a South African CCP is LCH.Clearnet. It is a large CCP, both in the number of clearing members and in the notional size of trades. Such a large global CCP would be unlikely to agree to a peer-to-peer arrangement with a South African CCP because it would forfeit clearing fees or other profits that would be earned from clearing with domestic market participants directly. Such peer-to-peer arrangements for the central clearing of derivative contracts have few examples in practice. For example, the only interoperability link that existed in the EU zone was between UK based LCH.Clearnet and Swiss CCP X-Clear (ESMA, 2016). On the other hand, a large global CCP would likely still receive these fees if it was a host CCP in a participant arrangement with the domestic CCP, however from the above discussion this would not be in the interests of the domestic CCP. National Treasury (2015) notes that this hybrid approach is complicated and could be too costly to implement.

While interoperability between a domestic CCP and a global CCP is unlikely and linking between a domestic CCP and a global CCP is potentially too costly, interoperability or linking of domestic CCPs does not suffer from the same limitations and may increase efficiencies. An example is Brazil's B3 which was created in 2017 with the consolidation of domestic CCPs. B3 is able to maximise efficiencies because it has only one DF, risk calculation, cross margin benefits etc. B3 offers across-product netting which lowers hedging costs in the local currency. The netting benefits accrue to the local CCPs which can be transferred to local clients through lower prices. These lower prices make it difficult for foreign CCPs to compete

in the Brazilian market. The dominance of local CCPs also reduces demands for foreign currency when domestic counterparties are out-of-the money with foreign counterparties.

2.1.4.4.5 Not licencing a CCP

It may not be beneficial for small domestically oriented market participants to become clearing members directly. Client clearing services allow market participants who are not direct clearing members to centrally clear their derivatives. Clearing membership is restricted to sufficiently well-capitalised participants who contribute resources to the CCP's default waterfall. The majority of market participants are not direct clearing members, either because they are too small to qualify as a clearing member or the cost of membership is too high. For these market participants, the principal-to-principal and agency-based models of client clearing are possible. In the principal-to-principal model, there are two trades, firstly between the client and the clearing member, which is then matched by a trade between the clearing member and the CCP. In this case, the client has no direct contractual relationship with the CCP, and the clearing agent is held accountable to the CCP. In the agency model, only one trade is executed between the client and the CCP directly, which is guaranteed by the clearing member.

In the bilateral OTC derivatives market structure, the interconnectedness of market participants was exposed as a source of systemic risk during the Great Financial Crisis (FSB, 2010). Policymakers promote central clearing as a way to decrease the interconnectedness between financial institutions. However, market participants who are not direct clearing members must make use of client clearing services to adhere to a clearing mandate. Heath, Kelly & Manning (2012) find that client clearing is a new source of interconnectedness in financial markets because a clearing member is involved in the transaction between the client and the CCP, which could increase systemic risk. Client clearing services are offered by a small and concentrated group of the largest clearing members. In the US, UK and Japan, the top five clearing members provided more than 80% of client clearing services for IRS (FSB, 2018c). This high concentration of client clearing services increases systemic risk. The default or withdrawal of services of a major provider would amplify CCR unless client positions and collateral are quickly ported to another client clearing service provider (FSB, 2018a).

A broader offering of client clearing services would reduce systemic risk; however, some of the regulations aimed at reducing systemic risk, such as the leverage ratio and the G-SIB determination may have reduced incentives to provide client clearing services. The BCBS, CGFS, CPMI, FSB and IOSCO convened the Derivatives Assessment Team (DAT). 64.7% and 44% of client clearing service providers reported to the DAT survey that the leverage ratio and G-SIB has a significant negative impact on their ability to offer client clearing services respectively. Acosta-Smith, Ferrara & Rodriguez-Tous (2019) conducted a difference-in-difference study using confidential transaction and portfolio level data from UK CCPs after the introduction and posterior tightening of the leverage ratio in the UK. They found that the leverage ratio does have a disincentivising effect on client clearing in terms of both the number of clients and the volume of transactions. This is primarily driven by a reduction in new clients accepted.

The BCBS's Basel III framework introduced the leverage ratio as a non-risked based measure of the ratio of tier 1 capital to the bank's total exposure. The derivatives portfolio is included in the total exposure, irrespective of whether it is the institution's own trades or those provided as client clearing services. However, the leverage ratio methodology does allow IM holdings to reduce total exposure. The leverage ratio has the same effect, whether an agency-based model or principal-to-principal model is used. Client clearing services are predominantly provided by the largest banks who are designated as G-SIBs. G-SIBs are subject to higher capital requirements due to the systemic risk they pose.

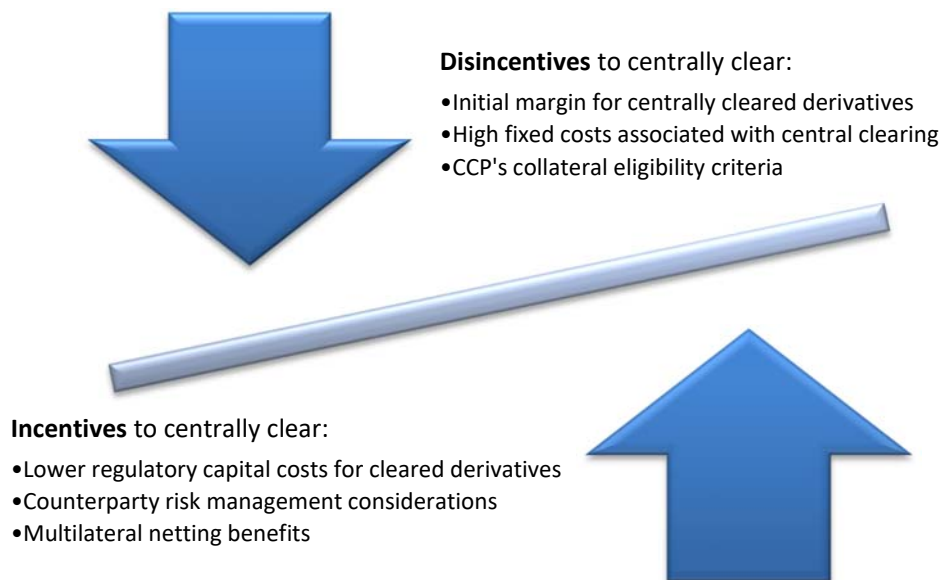
The disincentives to client clearing may result in higher fixed costs for end-users and reduced access to client clearing services. Indeed, 68% of clients in the DAT survey reported challenges in accessing client clearing services. The ISDA finds that the higher relative cost of central clearing for small end-users has forced some to shift to cheaper hedging instruments which imperfectly address their risk management needs (ISDA, 2016). Access to central clearing for end-users in emerging markets may be even more restricted due to market fragmentation (FSB, 2019a). These unintended and undesirable consequences of regulation are being investigated by the BCBS, who published a consultative document in 2018 on the leverage ratio treatment of client cleared derivatives.

2.1.4.5 A review of incentives to centrally clear derivatives

The G20's intention when imposing margining as well as the higher capital requirement on non-centrally traded derivatives was to incentivise the central clearing of standardised derivatives. Collateral requirements have to be high enough to encourage central clearing while not being so high as to encourage banks to try to centrally clear derivatives which are not suited for central clearing in order to take advantage of the arbitrage opportunities. All of the post-crisis G20 reforms taken have changed the private and social costs and benefits of both central clearing and bilateral trading when considered in totality. Thus, in 2017 the BCBS, CGFS, CPMI, FSB and IOSCO reconvened the DAT to review the incentives to centrally clear OTC derivatives (FSB, 2018c). The DAT conducted a quantitative survey using proprietary information from the largest OTC dealers and trade repositories, as well as a qualitative survey of the opinions of dealers and end-users.

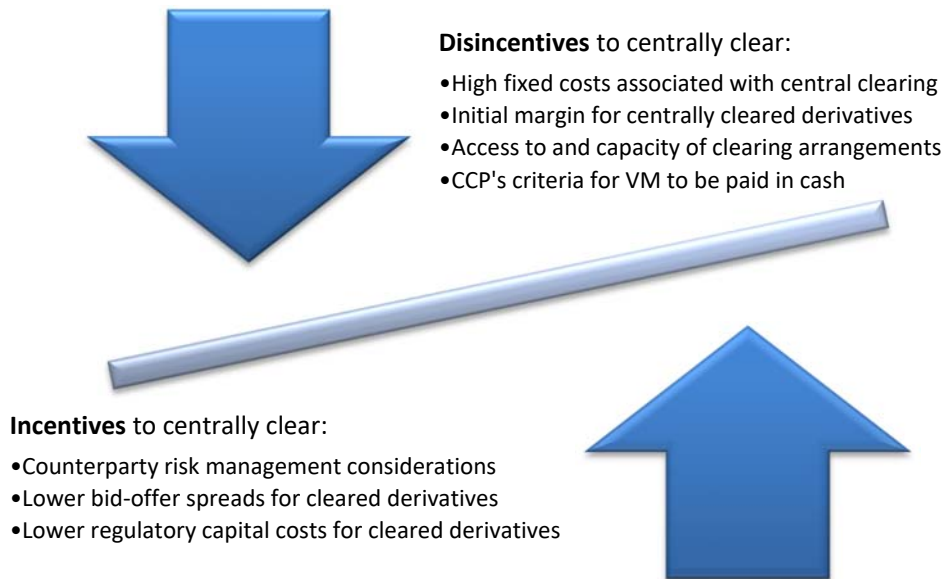
Assuming the absence of a central clearing mandate, the DAT found that incentives to centrally clear have largely been successful, especially for the largest and most systemically important market participants. However, the incentive structure varied across different market participants. See figures 2.4 and 2.4 for the top incentives and disincentives reported by dealers and end-users when the clearing mandate is not in effect.

Figure 2.4: Dealer incentives and disincentives to centrally clear (assuming no clearing mandate)



Source: FSB (2018c).

Figure 2.5: End-user incentives and disincentives to centrally clear (assuming no clearing mandate)



Source: FSB (2018c).

Many jurisdictions have already enforced mandatory central clearing requirements for certain products, including the largest jurisdictions by market size. Therefore, it is not surprising that both dealers and end-users reported to the DAT that the primary overall driver for central clearing was the mandate itself. Market liquidity was reported as the second overall driver by both dealers and end-users, indicating that in certain markets for certain products, a critical mass of participants centrally clearing has increased market liquidity for cleared trades. The DAT reports a bifurcation (the separation into two) of market liquidity into centrally cleared and uncleared pools based on participant size. With larger end-users preferring the increased liquidity, lower bid-offer spreads and lower regulatory capital costs involved in central clearing whilst smaller end-users with more directional portfolios prefer to transact in the bilateral market when possible. Smaller end-users cite the relatively higher fixed costs of central clearing to the DAT, such as minimum clearing fees which result in higher per trade clearing fees for less active end-users. Haynes & McPhail (2017) find that less connected clients (those who deal with smaller and less connected dealers) on average face higher transaction costs to centrally clear their trades. In many jurisdictions, smaller, less active end-users are not subject to mandatory central clearing and fall below the threshold for margins on non-centrally cleared derivatives. These

include non-financial counterparties and pension funds. The DAT notes that these smaller, less active end-users pose a significantly lower systemic risk than the larger end-users and dealers.

Overall the DAT found that incentives to centrally clear have been effective in creating an overall incentive to centrally clear for dealers and larger end-users. In particular, the capital and margin requirements for non-centrally cleared derivatives. The central clearing of mandated products as well as voluntary central clearing has increased since the Great Financial Crisis. For IRD, only 24% of notional amounts outstanding were centrally cleared in 2009, compared to 62% in 2017 (FSB, 2018c).

Mandatory clearing is not yet in force in South Africa at the time of writing. As a result, South African market participants are not yet driven by the clearing mandate (except for trades with counterparties already subject to the clearing mandate). Thus, they still have a degree of a choice between cleared or uncleared trading, incentives for end-users and dealers in South Africa are assumed to be similar to those presented in figures 2.4 and 2.5.

2.1.5 Central trading

The main advantage that central trading holds over central clearing is in the pre-trade transparency of pricing. Under central clearing, pre-trade prices are binding quotes, and actual transaction prices are published (Cecchetti, Gyntelberg & Hollanders, 2009). However, central trading allows for less customisable products. A survey of end-users in the IRS market showed that pre-trade price transparency is satisfactory (National Treasury, 2012a). Therefore, central clearing has been prioritised over central trading by most authorities. In addition, central trading may affect the functioning of an illiquid derivatives market. Thus, the central trading of derivative transactions is not seen as an immediate concern and is not covered by the FMA. Further regulation would be needed should authorities find that central trading of standardised derivatives transactions is desirable. South African Authorities have made no determination as yet on whether to adopt and enforce central trading (FSB 2018a).

2.2 The cost of regulatory reform measures

The primary social benefit of derivatives is their use to manage risk. A well-functioning derivatives market allows for the efficient transfer of risk, which reduces the cost of hedging and improves price discovery. While acknowledging the failure of the pre-crisis regulatory approach to the OTC derivatives market, Lee & Martin (2016) warn against policies that limit the operation of the derivatives market. According to them, derivatives can create wealth for society by turning the risk and volatility of future financial flows into present-day assets. Derivatives allow the transformation of volatility and uncertainty into manageable risks. This allows risk-averse parties to shift risk and volatility to those who are willing to accept the risk in pursuance of profit-making.

The various measures discussed in section (2.1) above are aimed at reducing systemic risk; however, they will also increase the cost of doing business in the OTC derivatives market. The following sections will explore the costs of regulatory reform from an increase in the demand for collateral (section 2.2.1), potential price increases (section 2.2.2), potentially reduced trading activity (section 2.2.3) in addition to some direct costs (section 2.2.4).

2.2.1 Collateral demand

Margin and capital requirements on non-centrally cleared derivatives, as well as margin and DF requirements on centrally cleared derivatives, will structurally increase the demand for collateral in global financial markets. Collateral is defined as financial assets pledged to secure counterparty exposures. Collateral posting reduces the degree of leverage financial participants can take up and protects against CCR. According to regulators, collateral should be safe and liquid; thus, only HQLA qualifies to be used as collateral.

The European Systemic Risk Board (ESRB, 2014) found that increased collateral demands could be a source of systemic risk and contagion. Heath, Kelly & Manning (2012) find that increased collateralisation in the derivatives market increases the risk of contagion because dealers' balance sheets are less liquid. They argue that there is a trade-off between illiquidity (when margin requirements cannot be met with HQLA) and insolvency (when equity is depleted or assets no longer exceed liabilities) as collateral demand increases. The increased collateral demand is intended to increase financial stability by reducing the risk of

insolvency; however, liquidity strains may trigger defaults. IM and DF requirements, in particular, may be pro-cyclical if they increase with market volatility to cover increased CCR (discussed further in section 2.4).

2.2.2 Price increases

Johannes & Sundaresan (2011) find that the practice of margining increases swap rates, thus increasing prices in the market. Using data from a Brazilian trade repository, Araujo & Leao (2016) find that the increase in regulatory costs in the Brazilian OTC derivatives market was in some part transferred to the non-financial end-users (those derivative end-users not in the financial sector, such as non-financial corporates) in the form of increased spreads. The study found that costs for non-financial end-users doubled.²

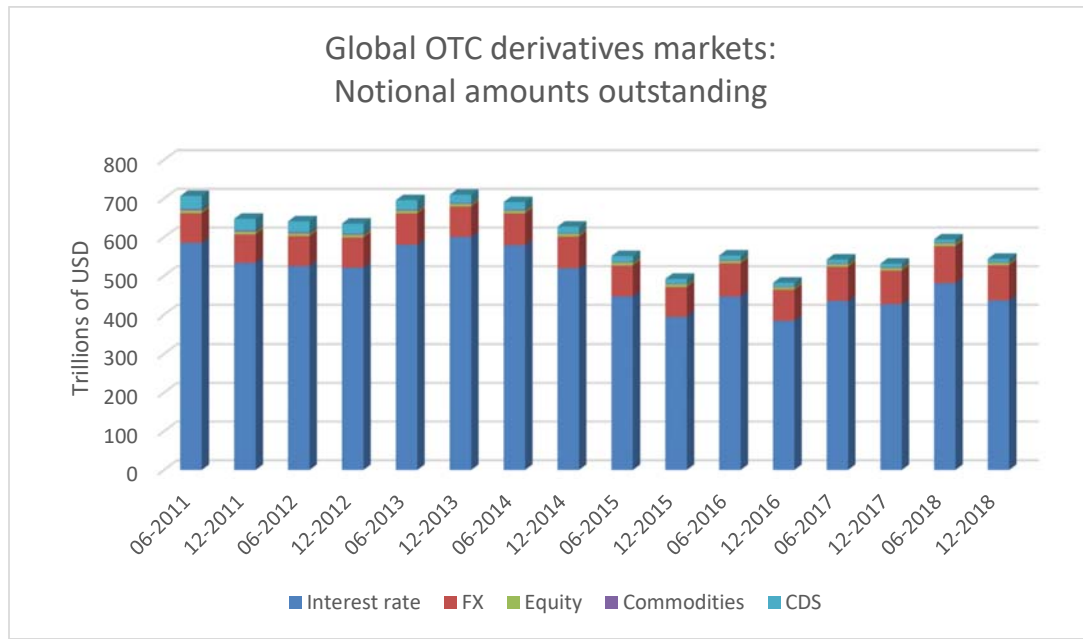
2.2.3 Trading volume and market size

The derivatives market provides end-users with a valuable mechanism to hedge or speculate in the underlying market. A decline in derivatives market activity could result in negative externalities as participants struggle to shift risk. Hardouvelis & Kim (1995) find a significant negative causal relationship between IM and market participation on the New York Commodity and Mercantile Exchange and the Chicago Board of Trade. They find that both trading volume and the total notional amounts outstanding decreased as a result of the increased IM. According to Aldasoro, Gatti & Faia (2016), increasing liquidity costs reduces systemic risk and the contribution of each bank to it. However, they also found that it decreases market efficiency in terms of reduced non-liquid asset investment. The reforms could lead to a decline in market structure and overall market functioning (Heath, Kelly & Manning, 2012). Overall the DAT found that most respondents reported that the G20 reforms had not had an impact on trading liquidity while a minority reported a decrease in trading liquidity (FSB, 2018c). However, most respondents to the survey were large market participants. The effect on market liquidity may be different in smaller, less connected markets such as South Africa. Anecdotally, the total global derivatives market has recently seen a downward trend in both notional amounts outstanding (figure 2.6) as well as gross

² Araujo & Leao's study took place before the creation of Brazil's B3.

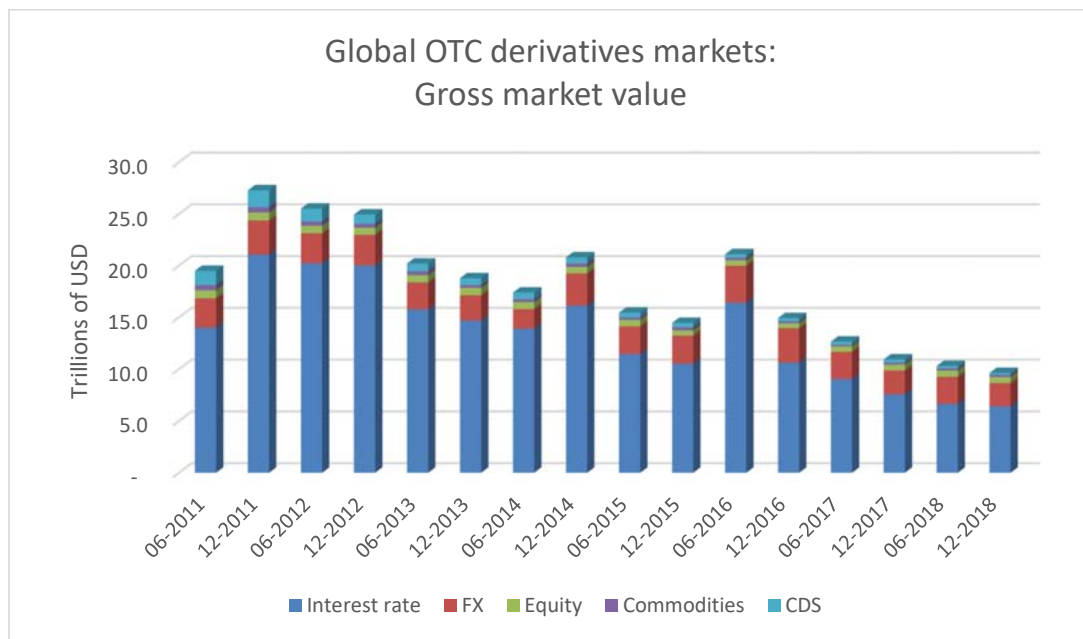
market value (figure 2.7). The figures differentiate between the five derivative asset classes. Central clearing in the two largest jurisdictions, the EU and the US, were mandated in 2016 and 2013, respectively (FSB, 2016).

Figure 2.6: Notional amounts outstanding in the global OTC derivatives market (2011-2018)



Source: Data sourced from the BIS Quarterly Review, June 2019.

Figure 2.7: Gross market value in the global OTC derivatives market (2011-2018)



Source: Data sourced from the BIS Quarterly Review, June 2019.

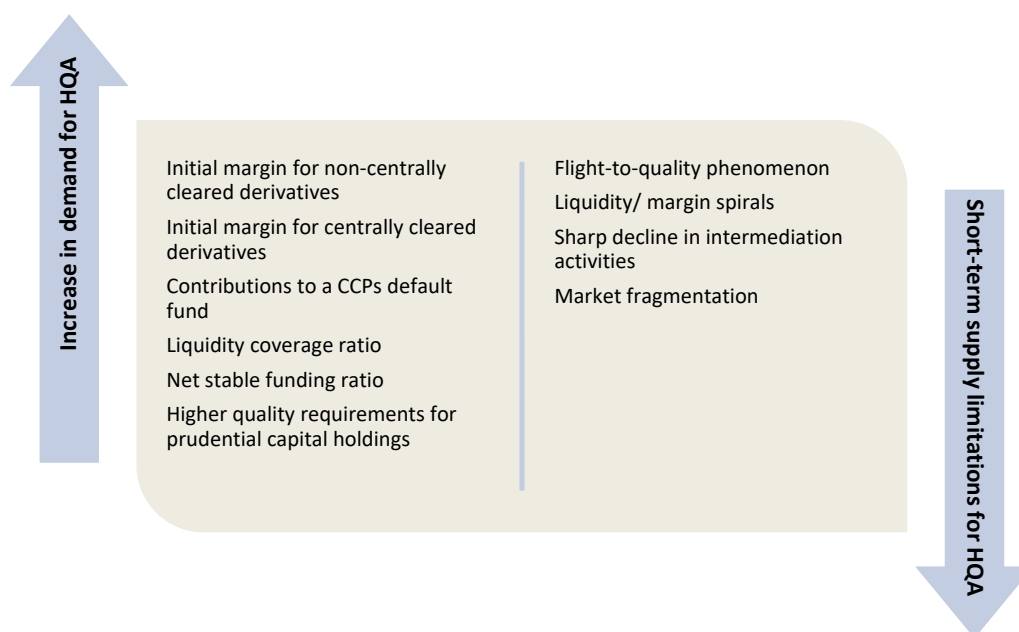
2.2.4 Direct costs resulting from the implementation of IM requirements

In addition to the above, South African Authorities acknowledge that the implementation of IM requirements will result in direct costs ODPs and end-users. These include costs associated with custodian held IM accounts, legal and compliance, system enhancements, human resources and reporting requirements (FSCA & PA, 2019).

2.3 The supply of collateral in South Africa

Reforms to the OTC derivatives market as well as other post-crisis reforms will lead to a permanent structural increase in the demand for collateral, specifically HQLA. In the absence of supply constraints, price adjustments should correct any temporary mismatch in the demand and supply of collateral. However, sharp temporary shocks to collateral supply were observed during the Great Financial Crisis as well as at the beginning of the Covid-19 pandemic. During both of these shocks, there was a concurrent increase in collateral demand and shortage in collateral supply. If the increase in the global demand for collateral is not met, it could have disastrous implications for the functioning of financial markets, see Di Maggio & Tahbaz-Salehi (2015) and Koepl, (2013). In South Africa, the SARB acts as the lender of last resort and can act as the main supplier of liquidity in a crisis. The post-crisis reforms have altered and increased vulnerabilities in the collateral market (Aguiar et al., 2016), see figure 2.8.

Figure 2.8: Sources of increases in demand for HQLA and potential short-term limitations in supply for HQLA



Source: Author.

The CGFS (2013) found that globally the aggregate supply of HQLA is more than sufficient to cover the expected increased collateral demand stemming from the structural changes to financial regulation. The expected increase in HQLA demand due to post-crisis regulatory reform was estimated at 4 trillion USD while the supply had increased by 10.8 trillion between 2007 and 2012. They note, however, that individual market's frictions could lead to temporary supply shortages in some nations. Anderson & Joeveer (2014) also assert that despite a sufficient overall collateral supply, bottlenecks could prevent collateral from reaching credit-worthy borrowers. Under the assumption that there is no aggregate shortage of HQLA, Heath, Kelly & Manning (2012) emphasise that some jurisdictions could face temporary liquidity shortages.

The CGFS (2013) makes special mention of potential market frictions in countries where outstanding sovereign debt is low or is perceived as being risky by market participants and therefore, does not qualify as HQLA. On 3 April 2017, the major rating agencies Fitch and S&P downgraded South African sovereign debt to non-investment grade, also known as junk status. Moody's was the last major credit-rating agency to downgrade South Africa to junk status on 27 March 2020. LCH.Clearnet does not currently accept any non-investment grade sovereign debt as collateral, and according to the BCBS-IOSCO IM rules, only "high-quality"

government debt should be accepted. The “draft margin requirements for non-centrally cleared OTC derivative transactions” published by the South African Authorities in 2019 confirms that only high-quality government and central bank debt securities are eligible to serve as collateral for IM and are still subject to haircuts based on residual time to maturity, see table 2.2. Levels & Capel (2012) consider assets rated BBB- and above as HQLA. As of May 2020, South African sovereign debt had a BB- credit rating from S&P, BB from Fitch and Ba1 from Moody’s (Trading Economics, 2020). As a result of its poor credit rating, LCH.Clearnet does not list RSA bonds as acceptable IM collateral (LCH.Clearnet Ltd, 2016). Thus, it is probable that South African sovereign debt would not qualify to serve as collateral for centrally and non-centrally cleared derivatives, thereby eliminating a large source of HQLA in the country (78 billion USD at the start of the first quarter of 2020). This leaves central bank securities, high-quality corporate debt, high quality foreign sovereign debt, high-quality equities, gold and eligible foreign currencies for DF contributions and IM on centrally cleared derivatives. There are limitations to the use of foreign collateral as it is subject to both exchange rate risk and an additional haircut of 8% on the value of the collateral, see table 2.2. Whilst corporate debt and equities could be exposed to higher margin haircuts during times of market volatility.

2.3.1 Possible limitations on collateral supply

The following discussion is a partial analysis of factors that could limit collateral supply during times of market stress. Aldasoro, Gatti & Faia (2016) find that the initial shocks to the market sparked the Great Financial Crisis through three contagion channels. Firstly, through direct cross-exposures in the interbank market (discussed in section 2.3.1.3). Secondly, through fire-sale externalities (section 2.3.1.2) and lastly the precautionary behaviour of intermediaries (section 2.3.1.3) leading to a decline in intermediation activity. In addition, the impact of the “flight-to-quality” phenomenon (section 2.3.1.1) and market fragmentation (section 2.3.1.4) which are particularly relevant for developing markets are considered. These factors of increased demand for collateral, and the possible short-term shortages of HQLA in times of volatility, could lead to a crippling shortage of liquidity for systemically important financial institutions

2.3.1.1 Flight to quality

Krishnamurthy & Vissing-Jorgensen (2012) find that the relative safety of US Treasury Bills as well as their liquidity make them highly desirable and push their price below that of the “true” riskless rate. According to them, the true riskless rate is “the rate that can meaningfully be compared to the riskless rate from a model that ignores the convenience benefits of Treasuries”. In their model, agents derive utility from the convenience benefits of US Treasuries, arising from their liquidity and safety attributes. They find that demand spiked during the Great Financial Crisis, supporting the existence of the flight-to-quality phenomenon. During the crisis, the demand for and price of HQLA increased while the value of higher risk assets plummeted as prices declined or haircuts increased. Therefore, the demand for HQLA is pro-cyclical, increasing substantially during periods of market stress. The higher demand for collateral due to post-crisis reforms will permanently increase the demand for HQLA and decrease the demand for riskier and/or illiquid assets.

2.3.1.2 Liquidity spirals

Brunnermeier & Pedersen (2008) analyse the effects of margins on collateral prices in a competitive equilibrium model. They find that under certain conditions price declines in an asset used as collateral, or haircuts resulting from a credit-rating downgrade or similar event could trigger a liquidity spiral as market participants sell assets to be able to meet margin and liquidity buffers, resulting in further margin calls. Through this channel, a decline in funding liquidity can have negative implications for market liquidity and market functioning during times of extreme stress. That is to say that during periods of extreme stress, a decline in the ease with which market participants can obtain funding can negatively impact the ease with which assets are traded.

A bank’s ability to meet its collateral requirements depends on the market value of its equity, debt and the required capital ratio under mark-to-market accounting. In a crisis, the market value of debt reduces, the market value of equity reduces, and the required capital ratio (other than the countercyclical capital buffer component) remains unchanged. This creates a need for additional liquidity, which is likely met through the sale of assets. The market-wide sale of assets may lead to sharp declines in asset prices, which given the balance sheet constraints, necessitates further asset sales. These losses can lead to successive rounds of deleveraging, creating an asset valuation spiral (FSB, 2013). This

concept is linked to what Geanakoplos (2010) described as the “leverage cycle” which can affect any market participant, not just banks. In times of low volatility, asset prices rise, and margins shrink. Low margins allow large leveraged positions to develop, further increasing asset prices and lowering margins. The process continues until a sudden increase in market volatility forces the sale of assets in order to meet increased margin demands. As a result, prices continue to fall, and margins continue to increase until volatility decreases.

During the Great Financial Crisis, the initial loss in the net worth of some financial institutions exposed to securitised assets resulted in an increase in margins and haircuts, which reduced the maximum attainable leverage necessitating the fire sale of some assets. This devolved into a loss spiral where asset sales increased volatility which further increased margins and haircuts necessitating further fire sales to restore liquidity buffers. While at the same time, interdealer bilateral repo (repurchase agreement) haircuts resulting from increased CCR led to a collapse in short-term secured lending (Di Maggio & Tahbaz-Salehi, 2015). Mitchell & Pulvino (2012) illustrate that a rapid reduction in leverage prevented arbitrageurs (such as hedge funds) from taking advantage of low-risk highly profitable arbitrage strategies. The limited power of arbitrage resulted in a diversion in the price of “substantially similar” assets, violating the law of one price during the Great Financial Crisis. Gorton & Metrick (2012) found that fears over the market liquidity for bonds (used as collateral in repo transactions) increased haircuts which triggered a “repo run” during the Great Financial Crisis. Oehmke (2013) finds that even a perceived increase in the likelihood of fire sales can lead to an increase in margins.

The haircut on an asset represents the potential loss in the value of the collateral. A haircut is subtracted from the market value of an asset in order to reflect its risk-adjusted value. For example, if the required risk-adjusted collateral is 100 ZAR, a 10% haircut means that an asset with a value of 110 ZAR must be posted. Thus, haircuts protect against the fluctuations in the price of the collateral should the counterparty default. The standardised margin haircut schedule published by the FSCA (See table 2.2) is intended to provide minimum haircuts in the bilateral market to avoid the margin spirals witnessed during the Great Financial Crisis. The policy goal of the standardised collateral haircut schedule is to restrict securities borrowing against assets which are subject to pro-cyclical volatility in their value in order to reduce the potential for the excessive leverage to build-up (FSB, 2013).

Table 2.2: Standardised haircut schedule for collateral posted against non-centrally cleared derivatives

Asset class	Haircut (% of market value)
Cash in same currency	0%
High-quality government and central bank debt (as specified in writing by the FSCA and the PA):	
Residual maturity ≤ 1 year	0.5%
Residual maturity ≥ 1 year ≤ 5 years	2%
Residual maturity > 5 years	4%
High-quality corporate bonds (as specified in writing by the FSCA and the PA):	
Residual maturity ≤ 1 year	1%
Residual maturity ≥ 1 year ≤ 5 years	4%
Residual maturity > 5 years	8%
Equities included in major stock indices	15%
Gold	15%
Additional haircut on asset which is denominated in a different currency than the derivatives obligation	8%

Source: (FSCA & PA, 2020).

CCPs have the unilateral right to increase haircuts on collateral posted with them against IM and DF.

2.3.1.3 Decline in intermediation activity

Kirk et al. (2014) find that dealer banks are highly efficient at matching collateral supply and financing demands (through intermediation activities) during normal market conditions, however, they can experience abrupt and significant disruptions in periods of market stress. Baranova, Liu & Noss (2016) assume that most end-users of collateral do not transact directly with the suppliers but that a large network of leveraged financial institutions acts as broker-dealers. They find that as market stress increases, the intermediation capacity of financial institutions to transfer collateral from ultimate end-suppliers to ultimate end-users decreases. This could be due to increased perceptions of CCR and market wide deleveraging. They suggest that when market volatility is high enough collateral will get “blocked in the network of dealer balance sheets”, leading to a temporary collateral shortage.

Di Maggio & Tahbaz-Salehi (2015) find that there is a cumulative moral hazard problem over chains of dealers through which small shocks to the liquidity of collateral can lead to large spikes in haircuts and a potentially sharp collapse in the system's dealer capacity. This was observed when the interdealer market seized after Lehman Brothers failed. Risk-averse precautionary hoarding by financial institutions with a surplus led to a freeze in the interbank market. While simultaneously on the demand side, increases in CCR increased haircuts.

Aguiar et al. (2016) find that post-crisis reforms, such as the leverage ratio, discourage banks from acting as intermediaries in collateral markets, this disincentive effect was discussed in section 2.1.4.5.

2.3.1.4 Market fragmentation

The FSB (2019b) describes market fragmentation in terms of fragmentation based on geography, product type or participant. The FSB identifies the main sources of market fragmentation as differences in national regulations and differences in the timing and substance of implementation of international standards. The shock to the SA government bond market at the start of the Covid-19 crisis is an example of short-term market fragmentation and may occur again as the crisis evolves. The staggered implementation of BCBS-IOSCO margining requirements across jurisdictions has created market fragmentation and the opportunity for regulatory arbitrage. Locally, South African Authorities have noted issues with the treatment of cross-border transactions (FSB, 2018a). Some market fragmentation may be the result of domestic regulatory mandates, for example, data protection and the resulting issues with cross-border trade reporting.

In some instances, market fragmentation may decrease market efficiency while having a positive impact on systemic risk by limiting the contagion effect. In this way, market fragmentation acts as a natural capital flow management measure; these measures are discussed further in section 2.3.3.3. Thus, in some instances, market fragmentation may be beneficial in reducing the cross-border spillover of systemic risk. In other cases, market fragmentation decreases market efficiency while also increasing systemic risks. For example, fragmented capital, a lack of liquidity and "thin" markets may result in diversions in the price of substantially similar assets. Peck & Shell (1991) refer to "thin" markets as those

where few trades take place while “thick” markets are characterised by a large volume of trades. Market fragmentation can also reduce cross-border risk management opportunities, increasing costs for end-users.

The misallocation of capital and liquidity at a global level, due to a reduction in cross-border flows of capital that would otherwise occur to meet demand, is a prime source of systemic risk. According to the FSB, this can amplify divergent economic and financial conditions, negatively affecting economic growth and development in some jurisdictions.

2.3.2 Possible mechanisms to increase collateral availability

In this section, two possible mechanisms to increase collateral availability are discussed; these are re-hypothecation and collateral transformation services. However, both may increase systemic risks. The final resort should be an intervention by authorities; however, this may increase moral hazard.

2.3.2.1 Re-hypothecation of collateral

Reuse of pledged collateral is commonly referred to as re-hypothecation, but technically this term only refers to the re-pledging or re-investing of collateral. Prior to the Great Financial Crisis, any margins received were typically re-hypothecated. Clients who allow the re-hypothecation of their collateral are generally compensated, for example through lower fees. Other sources of collateral for reuse are repurchase agreements and securities lending (Anderson & Joeveer, 2014).

Singh (2011) found that it is common practice in bilateral contracts for suppliers of collateral such as hedge funds, securities lenders and commercial banks to allow large dealers to reuse posted collateral, particularly prior to the Great Financial Crisis. Using data from six US investment banks, eight European global banks and one global Japanese bank, he estimated that in 2007 10 trillion USD in collateral was supported by approximately 3.3 trillion USD. Singh likens this recycling of collateral to the way in which central bank reserves circulate through the banking system supporting much higher deposits. He estimated the “velocity of collateral” to be 3. This means that each unit of collateral is used to serve as three units of collateral in the system. The velocity of collateral means that if the collateral is no longer reused, there will be a dramatic increase in its demand.

Gibson & Murawski (2013) suggest that the reuse of pledged collateral could preserve the welfare benefits of margining whilst reducing the costs of margining. However, many regulators argue that the reuse of collateral increases leverage and pro-cyclicality in the market heightening systemic concerns (Lopez, Mendes & Vikstedt, 2013). For instance, the ultimate end-suppliers may be willing to allow the re-hypothecation of their collateral during normal market conditions in the search for yield but reluctant during times of market stress (Anderson & Joeveer, 2014). However, in light of the large collateral demands projected, the BCBS-IOSCO has permitted the reuse of VM and the limited re-use of IM in its final margining rules. South African Authorities have followed the lead of the BCBS-IOSCO, allowing for the re-hypothecation of VM while IM can only be reused once (FSCA & PA, 2020). As IM on non-cleared derivatives can only be re-hypothecated once, the velocity of collateral is limited to 2. CPPs do not allow for the reuse collateral; therefore, the velocity of collateral posted to CCPs is equal to 1. Thus, if an identical amount of IM is required to post against a contract whether it is centrally cleared or traded bilaterally, the effective demand for IM on the bilateral contract is half that of central clearing. Sidanius & Zikes (2012) find that the relative collateral efficiency of central clearing is reduced if the BCBS-IOSCO rules allow for collateral to be reused. This may create an incentive to continue to trade on a bilateral basis as opposed to moving to central clearing, in violation of the objectives of the G20 reforms. According to the BCBS-IOSCO (2015), the objectives of margin requirements on non-centrally cleared derivatives primarily to reduce systemic risk and secondly to promote central clearing.

2.3.2.2 Collateral transformation services

Collateral can be transformed in terms of its maturity, liquidity and credit risk. These services could mitigate shortages of collateral (Lopez, Mendes & Vikstedt, 2013). For example, the credit transformation of collateral is the “upgrade” of assets not deemed eligible to qualify as HQLA. The service provider exchanges HQLA (which either they had in their inventory or borrowed, for instance from the repo market) for an asset that does not meet either the maturity, liquidity or credit risk requirements for eligible collateral. The service provider adds a haircut to the asset received from the client as well as charges a fee. This allows the client to meet collateral requirements without having to hold eligible assets on their balance sheet.

Maturity mismatches could expose the transformation service provider to interest rate and rollover risk (Kirk et al., 2014). Rollover risk is the possibility that the collateral contract expires and cannot be replaced before the maturity of the underlying derivative contract. This could occur if the asset held by the transformation provider is subject to a haircut larger than the one charged to the client or during times of market stress when liquidity dries up.

Collateral transformation adds additional complexity to meeting collateral demands. In addition, collateral transformation increases the interconnectedness of financial institutions, and CCR could be concentrated with a few financial institutions, possibly contributing to systemic risk. Aldasoro, Gatti & Faia (2016) find that increasing interconnectedness might increase risk-sharing and liquidity; however, it also increases the exposure of each institution to shocks. Thus, interconnectedness may be a source of contagion during market stress.

Heath, Kelly & Manning (2012) find that financial stability is negatively affected if end-users only have indirect access to HQLA through collateral transformation transactions with dealers. Prior to the Great Financial Crisis, large dealer banks specialised in collateral management; however, regulatory constraints are eroding their competitive advantage (Anderson & Joeveer, 2014). The impact of the leverage ratio is discussed under section 2.1.4.5. As a result, CCPs and other non-bank competitors are entering the market. The FSB notes that collateral transformation could lead to an excess build-up of leverage outside the banking system, beyond the reach of regulations (FSB, 2013).

2.3.2.3 Intervention from the authorities

In the event of a severe shortage of collateral, a government or central bank bailout should be the last resort. Heath, Kelly & Manning (2012) recommend that central banks monitor liquidity conditions and be ready to inject liquidity into the system to avoid any market disruption. The FSB (2013) recommends that authorities must capture “granular and timely” information on the composition and evolution of underlying collateral in order to monitor the build-up of risks. The SARB could provide liquidity through open market operations or the discount window. However, these conventional monetary policy responses may not always be sufficient, for instance in the event of a fire sale of less liquid assets in which case QE or the direct purchase of assets may be necessary.

In the event of large capital outflows due to a crisis, authorities could use capital flow management measures (CFMs) to stem the flow. The IMF (2019) defines CFMs as measures that are designed to limit capital flows. They may either be residency-based measures affecting cross-border financial activity between residents and non-residents, or other measures which do not discriminate based on residency. CFMs are an unorthodox monetary policy measure which is designed to reduce systemic risk stemming from capital flows. The IMF (2012) notes that CFMs are only justifiable in the event of a crisis and as part of a broader macroeconomic policy approach to address the root causes of the crisis.

2.4 Pro-cyclicality of margin requirements

Pro-cyclicality is defined by the CGFS (2010) as the “mutually reinforcing interactions between the financial and real sectors of the economy that tend to amplify business cycle fluctuations and cause or exacerbate financial instability”. Brunnermeier & Pedersen (2008), the European Commission (2012), Heller & Vause (2012), Murphy, Vasios & Vause (2014), Lin & Surti, (2015) and Glasserman & Wu (2018) among others note that margin demands are pro-cyclical. This is intuitive because as market volatility increases, margin requirements should be higher to protect against rising CCR. However, if margin requirements increase excessively when the supply of collateral is constrained, margining could increase systemic risk. Margin calls on centrally cleared derivatives are always made at the end of the day and sometimes made intra-day, margin must be posted quickly after the call (Murphy, Vasios & Vause, 2016). Margins on non-centrally cleared contracts are also made regularly as per the bilateral agreement, resulting in quick increases in collateral demand. Thus, this particular regulatory attempt aimed at reducing CCR could increase liquidity risk. Therefore, risk-sensitive margin requirements, principally IM margin requirements, present a trade-off between microprudential and macroprudential goals. Given the pro-cyclical nature of IM demands, it is important to consider variations in demand under a variety of volatility scenarios. In response, the BCBS-IOSCO developed the SMS approach to IM requirements for non-centrally cleared derivatives which is not sensitive to changing market risk. The variances in quantitative estimates under the SMS and risk-sensitive QPMM approaches to IM requirements for non-centrally cleared derivatives is a key research objective examined in Chapter 4.

The discussion of liquidity spirals and the leverage cycle under section 2.3.1.2 provides the theoretical foundation for the systemic risk implications of the pro-cyclicality of margin requirements. In addition to liquidity spirals and the leverage cycle, competitive behaviour by CCP's provides a potential source of pro-cyclicality. In markets with multiple CCPs clearing the same products, inter CCP competition could result in lower than socially optimal margin demands during normal market conditions to attract more customers (Abruzzo & Park, 2016). This so-called "race to the bottom" increases pro-cyclicality because margin levels are too low in normal market conditions and could increase sharply in times of market stress as CCPs try to protect their own solvency. The ISDA also highlights that while thresholds on IM and VM on non-centrally cleared derivatives make margining more affordable for small market participants during normal conditions, demands can spike above the threshold during volatile conditions increasing pro-cyclicality. Based on empirical evidence from the Chicago Mercantile Exchange (A US CCP), Abruzzo & Park (2016) find that margin demands rise quickly following volatility spikes; however, the decrease following volatility declines is slower. This asymmetric response to margin setting implies that the pro-cyclicality of margin requirements is more of a concern in recessions than it is in expansions. In addition, an increase in volatility is more likely to be disruptive after a long period of low volatility, after institutions have had a long time to increase leverage.

Pro-cyclical capital requirements can exacerbate economic downturns by depressing lending, which is why Basel III introduced the countercyclical capital buffer (Repullo & Suarez, 2012). In this same way, pro-cyclical margin requirements can lead to deleveraging by increasing funding and liquidity risk (Brunnermeier & Pedersen, 2008). In response, Article 28 of EMIR specifies three tools to limit pro-cyclicality; all CCPs in the EU must use at least one. These are; a countercyclical margin buffer, stressed observations and a margin floor to limit pro-cyclicality. Murphy, Vasios & Vause (2016) find that these tools do mitigate pro-cyclicality; however, the extent of which depends on the weight the CCP places on minimising over-margining during periods of low volatility. O'Neill & Vause (2018) find that both quantity and price based regulatory approaches could eliminate the pro-cyclicality of IM demands. The quantity-based approach is an additional IM amount that acts as a countercyclical buffer, releasing during periods of high margin demands. The price-based approach is a proportional tax on derivative positions. Both approaches require regulators

to have significant information on the market to be successful. The real time market positions and liquid-asset holdings of all market participants, as well as a distribution of potential market shocks, would be required.

As expected, CCPs responded to the increased market volatility and losses experienced between February and April of 2020 by increasing their margin requirements and collateral haircuts (FSB, 2020c). Examples include the doubling of IM requirements on US equity futures, the doubling of IM requirements on Nikkei futures by JSCC (the largest Japanese CCP) and the sharp increase in IM on benchmark oil contracts (Huang & Takáts, 2020). An undesirable market response, partly in anticipation of increased margin calls, was increased precautionary liquidity hoarding by banks between the end of February and early April (Huang & Takáts, 2020).

Despite this large increase in liquidity demand, clearing members and end-users remained resilient to the demands of CCPs, primarily due to the quick response of authorities in many countries who pumped liquidity into various markets. The Covid-19 crisis in early 2020 underscores the balance between the microprudential and macroprudential goals of central clearing. The natural microprudential response of CCPs to increase their IM demands due to increased CCR, in addition to the many other demands on liquidity, created a strain on liquidity globally. The impact of Covid-19 on financial markets is not yet over, and volatility may spike again, necessitating an agile response from authorities.

CHAPTER 3

SOUTH AFRICAN HISTORICAL INTEREST RATE VOLATILITY - EVIDENCE OF REGIME-SWITCHING

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3.1 Introduction

In this Chapter, research objective one is addressed. That is to analyse the volatility dynamics of the underlying asset of South African interest rate derivatives and estimate various market stress scenarios as an input for the QPMM approaches used by the BSBC-ISOCO and a CCP. The estimated market stress scenarios are used as an input in Chapter 4 when calculating IM for centrally and non-centrally cleared derivative portfolios using the QPMM approach.

The value of a financial asset may be considered a function of the expected variances and means of its rate of return (Engle, 1982). Various models have been created for the purpose of valuing interest rate derivatives; these include the Vasicek (1977), Cox-Ingersoll-Ross (1985) and Hull-White (1990) models. All of these models price interest rate derivatives as a function of the yield curve with volatility and mean reversion as inputs to the model. Accordingly, estimates of volatility (the square root of variance) and mean reversion may be relevant to value derivative instruments and other securities. The valuation of financial assets under a variety of potential volatility scenarios is essential for their risk management from the perspective of all economic stakeholders. According to the Bank of England (2016), a severe but plausible period of financial stress must be included in the scenario testing. The stakeholders include the institution itself who seeks to minimise capital holdings, the

institution's counterparties who seek to minimise CCR, and regulatory supervisors who are concerned with minimising systemic risk. Longstaff & Schwartz, (1992) advocate the use of a generalised autoregressive conditional heteroskedasticity (GARCH) process over options-price implied volatility to extract the volatility estimates of an interest rate. GARCH models are able to capture the volatility clustering phenomenon, which is the grouping of periods of high volatility together rather than being equally spaced (Dueker, 1997). Interest rate data sometimes exhibits a mean reversion characteristic, returning to the long-run average rate over time (Holilal, 2011). Mean reversion for the purpose of valuing derivative instruments is commonly modelled using an AR(1) process where the next periods change depends linearly on the current level (Venter, 2010).

In the risk management of a portfolio of financial assets, it is important to generate scenarios of what could actually happen, thus using historical data is appropriate to capture features of the process (Venter, 2010). The CPMI-IOSCO's (2017) principles for CCP resilience advocates that "one of the most direct ways to derive a set of extreme but plausible market conditions is to use historical scenarios". In South Africa, the 3-month Jibar (Johannesburg interbank average rate) is typically used as the benchmark interest rate for ZAR denominated IRS (West, 2008; Du Preez, 2011; SARB, 2018). The 3-month Jibar is the average mid of the 3-month Negotiable Certificates of Deposit (NCD) rates quoted by several local and foreign banks (excluding the two highest and lowest rates). Thus, it is a variable used to extract estimates of volatility and mean reversion for short-term interest rates. This study shows that fitting a GARCH (1,1) to the differenced Jibar 3-month data results in estimates of highly persistent conditional variance. Persistence in variance is the degree to which the past volatility of a variable explains its current volatility. The 1 Month, 6 Month and 12 Month Jibar interest rates also exhibit highly persistent variance, indicating a common feature in South African interest rates in general over the observed period.

According to Gray (1996), GARCH models of the short-term interest rate often imply highly persistent conditional variance due to unaccounted for regime-switching. He identifies possible causes for changes in the conditional variance of the Fed funds rate between January 1970 – April 1994 as the change in monetary instrument targeted by the Fed, the OPEC (organisation of petroleum exporting countries) oil crisis, the Black Monday 1987 stock market crash and various wars involving the US. Thus, this study investigates the

presence of regime-switching in the conditional variance by fitting Markov-switching GARCH models of varying specifications to the data. The period under study in this paper starts close to the inception of the 3-month Jibar in 2001 until 2018. The justification for the long period under study is to attain a clear picture of shifts in the historical volatility of the Jibar 3-month data. Attaining more accurate estimates of historical volatility allows various stakeholders to analyse the impact of realistic (as they have occurred during the period under study) volatility scenarios on the value of and regulatory capital requirements for derivatives. The Markov-switching GARCH model allows the conditional variance to shift regimes, capturing various historical volatility scenarios.

The standard ARCH (autoregressive conditional heteroskedasticity) and GARCH models do not allow for an asymmetric effect in the data. Asymmetry occurs when positive and negative shocks have different impacts on heteroscedasticity either all the time or some of the time. An asymmetric effect occurs when conditional volatility increases when there is negative market information while having a different reaction to positive market information. Various extensions of the GARCH model were created in order to assess the asymmetric effect. This study will investigate the in-sample accuracy of the ARCH, GARCH, E-GARCH, GJR-GARCH and T-GARCH models for up to four regimes and six conditional distributions. Thus, 120 GARCH-type volatility models are tested to determine which model, distribution and number of states best fit the Jibar 3-month data in order to extract the most accurate estimation of historical volatility. The mean-reverting rate is captured through an AR(1) process.

3.2 Theoretical Underpinnings

In the ARCH model of Engle (1982), the conditional variance depends on the lagged squared change in the variable. The GARCH model of Bollerslev (1986) extends the ARCH model to allow conditional variance to depend on its own past values as well. The standard GARCH(p,q) model regresses on lagged terms of squared returns (p) and variance (q).

The empirical findings of Engle, Ng & Rothschild (1990), Gray (1996), Koedijk et al., (1997) Hillebrand (2005), Bauwens, Preminger & Rombouts (2010) and Olweny (2011) report a high degree of persistence in the variance for a variety of financial assets, including interest

rates, when only a single regime is considered. In a GARCH(1,1) model persistence in the variance occurs when the sum of the $\alpha_1 + \beta$ parameters are close to or exceed 1 (see section 3.4 below for the full equation). The process is variance-covariance unstable if the sum of $\alpha_1 + \beta$ parameters exceed 1 (Bollerslev 1986).

To account for this empirically observed persistence in variance, Engel and Bollerslav introduced the I-GARCH in which shocks to variance do not decay over time. The sum of the ARCH and GARCH parameters are restricted to equal 1. According to Lamoureux & Lastrapes (1990), the I-GARCH model lacks theoretical motivation because it does not allow asset prices to follow a random walk; instead, prices are almost entirely explained by their past observations. They argue that the presence of structural shifts in the unconditional variance bias the persistence estimates upwards. Thus, structural or regime shifts are mistaken for periods of volatility clustering. A single regime model assumes that the conditional mean and conditional variance remain fixed throughout the sample period. However, the economic mechanism that generates the variable may change over time, for example, changes in monetary policy or a financial crisis.

Using dummy variables to indicate structural shifts, Lamoureux & Lastrapes (1990) report decreases in the persistence of variance. Therefore, they demonstrate that ignoring structural shifts can result in an overestimation of the persistence of variance. Cai (1994) and Hamilton & Susmel (1994) demonstrate the benefits of a Markov-switching ARCH model over the dummy variable technique used by Lamoureux & Lastrapes (1990). A Markov chain assumes the current value of a state variable depends on its immediate past value. It allows for frequent switching between states at random times, and its transition probabilities determine the persistence of each regime (Hamilton, 2016). The regimes are not directly observed; however, probabilistic statements can be made about the time-varying transition probabilities, and thus the relative likelihood of being in each state. Thus, the regimes are probabilistic and determined by the data; no prior classification is necessary as required by the dummy variable method employed by Lamoureux & Lastrapes.

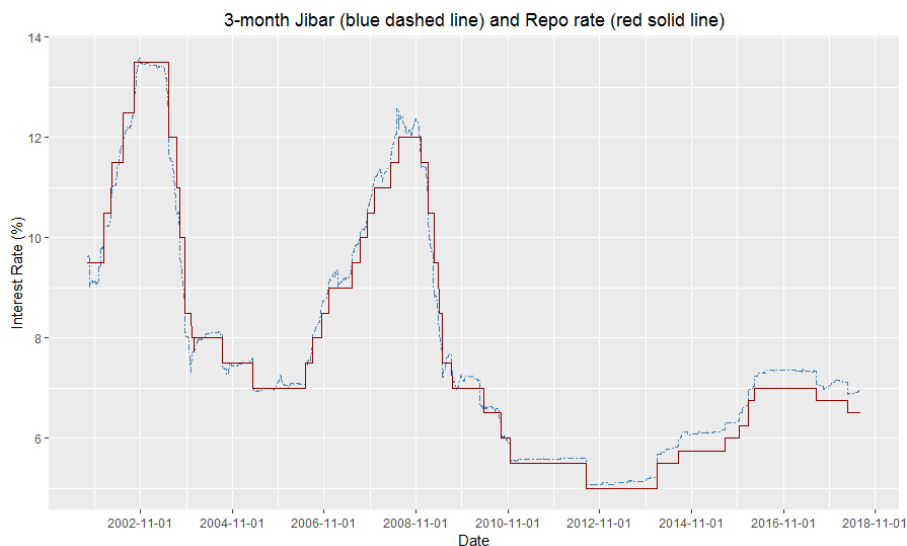
Extending Markov-switching to a GARCH model renders the estimation intractable because it requires integration over unobserved regime paths which increases exponentially as the sample size increases. I.e. the conditional variance at time t depends on the entire sequence

of regimes up to $t-1$. Gray (1996), Dueker (1997), Klaassen (2002) made successive improvements to the estimation and overcame the computational difficulties in estimating Markov-switching (MS) GARCH models using an approximating method which collapses the past regime specific conditional variances. Haas, Mittnik & Paoletta (2002) further improved the estimation of MS-GARCH models by allowing the GARCH process to evolve independently of those in other states; therefore, the model does not face the path-dependency problem.

3.3 Data

The data analysed consists of 877 weekly observations of 3-month Jibar in total, spanning from week 36 in 2001 to week 28 in 2018. The data was sourced from Bloomberg. In South Africa, the SARB controls the Repo rate in pursuance of its goal to achieve and maintain price stability within the inflation-targeting band of 3-6%. The Repo rate is the benchmark interest rate used by financial market participants, thus changes in the Repo rate result in changes in market interest rates, including Jibar. Figure 3.1 presents a clear positive relationship between the Repo rate and Jibar, confirming that Jibar does closely follow movements in the Repo rate.

Figure 3.1: 3-month Jibar and Repo rate - absolute level



Source: Created by Author using data from Bloomberg.

Since the adoption of inflation targeting during 2000 there have been two periods where the inflation rate exceeded the upper target limit of 6% by a sizable amount and for a prolonged period of time, see figure 3.2. The first was during 2002 when supply-side shocks such as a depreciation of the rand coupled with increases in global food and oil prices caused inflation rates to soar above the inflation target band (Nell, 2018). The second was in the wake of the global financial crisis of 2007/2008. Although South Africa did not experience a domestic financial crisis, it was one of the worst affected emerging economies according to the FSB. The South African stock market fell by 36% between May and December 2008, and the economy suffered the loss of almost one million jobs (FSB, 2013). A sharp depreciation as foreign investment was withdrawn from the country following the crisis caused inflation to rise.

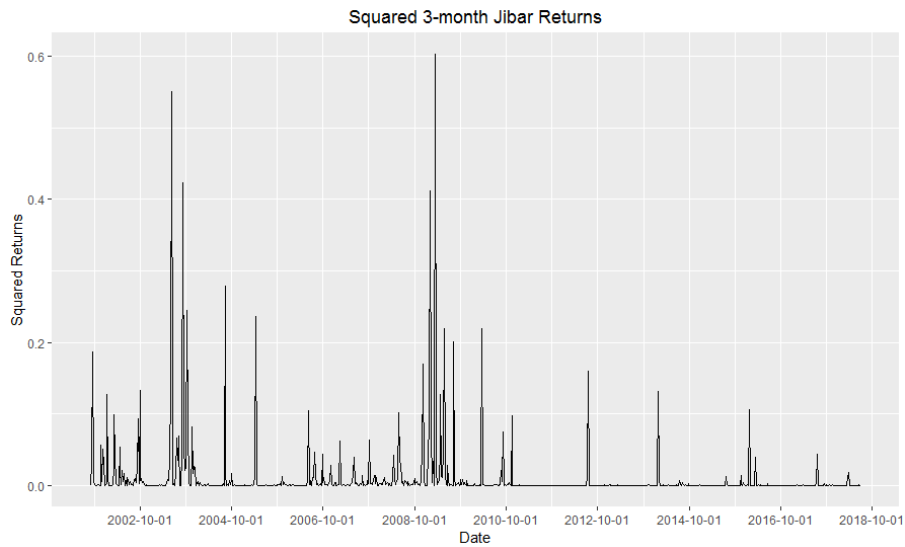
Figure 3.2: South African inflation rate. Period 2001/09/07 - 2018/07/11



Source: TradingEconomics.com [Accessed on 2019/03/29].

In response to both of these periods of prolonged high inflation, the SARB employed contractionary monetary policies as can be seen in figure 3.1. These changes in monetary policy support the presence of regime-switching in the data. Figure 3.3 illustrates the spikes in squared returns around the 2002 and 2008 shocks, providing intuitive insights of shifts in conditional variance due to changing economic circumstances.

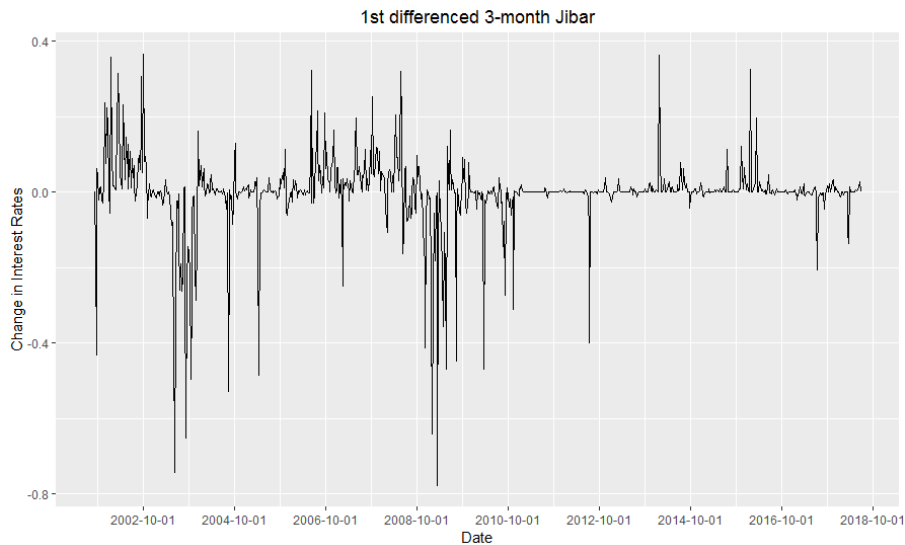
Figure 3.3: Evidence of Regime Switching in the conditional volatility of the 3-month Jibar interest rate data



Source: Created by Author using data from Bloomberg.

The Augmented Dickey-Fuller and Phillips Perron unit root tests both indicated that the differenced 3-month Jibar data is stationary, a requirement for the AR and Markov-switching GARCH models. GARCH models require stationarity, because if the $\alpha_1 + \beta$ parameters exceed 1 the process is variance-covariance unstable. According to Cheung & Erlandsson (2005) it is not advisable for a Markov-switching model to be employed on non-stationary data as the model may misidentify the trend (due to unit root persistence) as regime-switching behaviour. The 1st differenced data, illustrated in figure 3.4, consists of 876 observations.

Figure 3.4: 1st differenced 3-month Jibar data



Source: Created by Author using data from Bloomberg.

Following Engle (1982) and Bollerslev (1986), the Lagrange multiplier (LM) test for autoregressive conditional heteroscedasticity (ARCH) is performed to test for the presence of ARCH effects. The LM test detected ARCH effects for the weekly averaged 3-month Jibar, however, the daily data did not present an ARCH effect. Rejecting the null hypothesis for the weekly 3-month Jibar data allows for a GARCH model to be fitted.

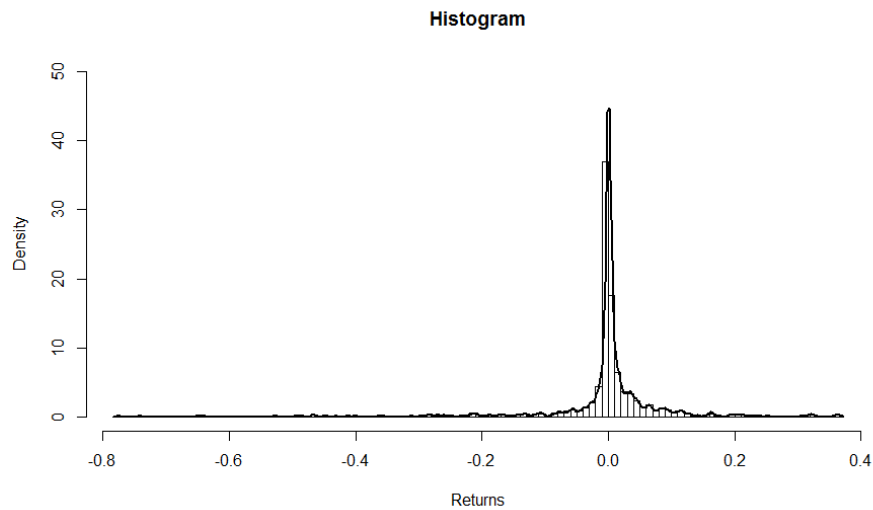
Table 3.1: Statistics for the first four moments of the differenced weekly averaged 3-month Jibar

Statistics for the first four moments of the 3-month Jibar	
Mean	-0.003
Standard deviation	0.1
Skewness co-efficient	-2.73
Kurtosis co-efficient	18.26

Source: Author's calculations.

The skewness and kurtosis coefficients indicate that the conditional distribution is not normally distributed, in addition, the null of normality is rejected by the Jarque-Bera test. The histogram in figure 3.5 illustrates the highly leptokurtic nature of the data with a long left tail.

Figure 3.5: Histogram for 3-month Jibar



Source: Created by Author using data from Bloomberg.

3.4 Methodology

3.4.1 Econometric Model for Mean Reversion

A typical model of the behaviour of interest rates is captured by the following AR(1) process:

$$r_t = c + br_{t-1} + e_t$$

Equation 3.1: Mean equation

where r_t is the differenced interest rate, c is the constant, br_{t-1} is the first order autoregressive process and e_t is the residual.

The mean reversion rate Alpha (α), which can simply be calculated as: $\alpha = 1 - b$

3.4.2 Econometric Models for Volatility

Four core GARCH type models and an ARCH model are estimated for one to four states using six conditional distributions. A total of 120 models are estimated using the maximum likelihood method and compared using the Akaike information criterion (AIC) and Bayesian information criterion (BIC) for the goodness of fit and parsimony.

3.4.2.1 Conditional volatility models

Ardia et al. (2018) assume that r_t has zero mean and is not serially correlated. Therefore the mean equation for the differenced interest rate is adjusted for autocorrelation using an AR(1) process denoted by equation 3.1 above: $r_t = c + br_{t-1} + e_t$.

Following Ardia et al. (2018) the general Markov-switching GARCH specification employed is:

$$r_t | (s_t = k, I_{t-1}) \sim D(0, \sigma_{k,t}^2, \xi_k)$$

Equation 3.2: Markov-switching GARCH specification

where $D(0, \sigma_{k,t}^2, \xi_k)$ is a continuous distribution with zero mean, $\sigma_{k,t}^2$ is the state and time-varying variance and ξ_k captures the additional shape parameters. The integer-valued stochastic state variable s_t is defined on the discrete space $\{1, \dots, k\}$, is assumed to evolve according to a first-order ergodic homogeneous Markov chain with transition probability matrix $\Sigma\{P_{i,j}\}^k = 1$ with $p_{i,j} = P[s_t = j | s_{t-1} = i]$. I_{t-1} is the information set observed up to time $t-1$.

$$\text{Transition probability matrix: } P \equiv \begin{bmatrix} p_{1,1} & \cdots & p_{1,k} \\ \vdots & \ddots & \vdots \\ p_{k,1} & \cdots & p_{k,k} \end{bmatrix}$$

Following Haas, Mittnik & Paoletta (2002) the conditional variance is a function of past observations of the variable as well as a regime-dependent vector of parameters, overcoming the path dependency problem.

The standardised innovations are allowed to follow one of six conditional distributions, discussed in section 3.4.2.2.

All of the GARCH type models follow the above Markov-switching specification however the conditional volatility process differs, as discussed in this section. The standardised innovations are defined as:

$$\eta_{t,k} \equiv \frac{r_t}{h_{k,t}^{1/2}} \sim iid D(0, 1, \xi_k)$$

Equation 3.3: Standardised innovations of the Markov-switching volatility models

The ARCH model of Engle (1982) is given by:

$$\sigma_{k,t}^2 = \alpha_{0,k} + \alpha_{1,k}r_{t-1}^2$$

Equation 3.4: ARCH (1)

where $\sigma_{k,t}^2$ is the time-varying variance of a variable for period t, $\alpha_{0,k}$ is the constant and r_{t-1}^2 is the squared percentage change in the differenced interest rate. To ensure a positive conditional variance estimate the following must hold: $\alpha_{0,k} > 0$ and $\alpha_{1,k} \geq 0$. Covariance-stationarity in each regime requires $\alpha_{1,k} < 1$

Bollerslev's 1986 GARCH(1,1) model expands on the ARCH model to include the previous period's variance ($\sigma_{k,t-1}^2$).

$$\sigma_{k,t}^2 = \alpha_{0,k} + \alpha_{1,k}r_{t-1}^2 + \beta_k\sigma_{k,t-1}^2$$

Equation 3.5: GARCH (1,1)

To ensure positivity the following must hold: $\alpha_{0,k} > 0$, $\alpha_{1,k} > 0$ and $\beta_k \geq 0$. The persistence of the volatility is equal to $\alpha_{1,k} + \beta_k$. Covariance-stationarity in each regime requires $\alpha_{1,k} + \beta_k < 1$

Nelson's (1991) Exponential GARCH (E-GARCH) specifies the conditional variance in a logarithmic form allowing big shocks to have a greater impact on variance than GARCH.

$$\ln(\sigma_{k,t}^2) = \alpha_{0,k} + \alpha_{1,k}(|\eta_{k,t-1}| - E[|\eta_{k,t-1}|]) + \alpha_{2,k}r_{t-1} + \beta_k \ln(\sigma_{k,t-1}^2)$$

Equation 3.6: E- GARCH (1,1)

This specification accounts for the asymmetric or leverage effect where past negative observations have a larger influence on the conditional volatility than past positive observations; $\alpha_{1,k}$ captures the sign of the asymmetric effect, and $\alpha_{2,k}$ captures the size of the asymmetric effect. Positivity of the conditional variance is ensured by specifying the log of the variance, thus coefficients can have negative values. The persistence is captured by β_k . Covariance-stationarity in each regime requires $\beta_k < 1$. The expectation of the standardised residuals $E[|\eta_{k,t-1}|]$ is taken with respect to the distribution conditional on regime k.

The GJR-GARCH of Glosten, Jagannathan & Runkle (1993) reflects the asymmetric nature of responses by defining the conditional variance as a linear piecewise function.

$$\sigma_{k,t}^2 = \alpha_{0,k} + (\alpha_{1,k} + \alpha_{2,k}\mathbb{I}\{r_{t-1} < 0\}) r_{t-1}^2 + \beta_k \sigma_{t-1}^2$$

Equation 3.7: GJR-GARCH (1,1)

where $\alpha_{1,k}$ captures the sign effect, and $\alpha_{2,k}$ indicates the degree of asymmetry. $\mathbb{I}\{\cdot\}$ is an indicator function which takes the value 1 if $\{r_{t-1} < 0\}$, otherwise it takes the value 0. The persistence is captured by β_k . To ensure positivity the following must hold: $\alpha_{0,k} > 0$, $\alpha_{1,k} > 0$, $\alpha_{2,k} \geq 0$ and $\beta_k \geq 0$. The persistence is captured by $\alpha_{1,k} + \alpha_{2,k}E[\eta_{k,t}^2\mathbb{I}\{\eta_{k,t} < 0\}] + \beta_k$. Covariance-stationarity in each regime requires $\alpha_{1,k} + \alpha_{2,k}E[\eta_{k,t}^2\mathbb{I}\{\eta_{k,t} < 0\}] + \beta_k < 1$

Zakoian's Threshold GARCH (T-GARCH) was developed in 1994. The conditional volatility is the dependent variable instead of the conditional variance.

$$\sigma_{k,t} = \alpha_0 + \alpha_{1,k} r_{t-1} \mathbb{I}\{r_{t-1} \geq 0\} + \alpha_{2,k} r_{t-1} \mathbb{I}\{r_{t-1} < 0\} + \beta_k \sigma_{t-1}$$

Equation 3.8: T-GARCH (1,1)

To ensure positivity the following must hold: $\alpha_{0,k} > 0$, $\alpha_{1,k} > 0$, $\alpha_{2,k} > 0$ and $\beta_k \geq 0$. The volatility persistence is captured by $\alpha_{1,k}^2 + \beta_k^2 - 2\beta_k(\alpha_{1,k} + \alpha_{2,k})E[\eta_{t,k}\mathbb{I}\{\eta_{t,k} < 0\}] - (\alpha_{1,k}^2 - \alpha_{2,k}^2)E[\eta_{t,k}^2\mathbb{I}\{\eta_{t,k} < 0\}] + \beta_k$. Covariance-stationarity in each regime requires $\alpha_{1,k}^2 + \beta_k^2 - 2\beta_k(\alpha_{1,k} + \alpha_{2,k})E[\eta_{t,k}\mathbb{I}\{\eta_{t,k} < 0\}] - (\alpha_{1,k}^2 - \alpha_{2,k}^2)E[\eta_{t,k}^2\mathbb{I}\{\eta_{t,k} < 0\}] + \beta_k < 1$

The effect of the previous period's differenced interest rate on the conditional variance depends on its sign. It is α_1 when r_{t-1} is positive, and when negative it is $\alpha_1 + \alpha_2$. Therefore α_2 is positive when a leverage effect is present.

According to Gray (1996), the estimation of regime-switching has typically been done through Maximum Likelihood, this method is applied in this Chapter to estimate the volatility models.

3.4.2.2 Conditional distributions

Each distribution is standardised to have a zero mean and a unit variance as well as a skewness parameter ξ_k . When $\xi_k = 1$ the distribution is symmetric however when $\xi_k \neq 1$ the distribution is skewed.

The probability density function (PDF) of the standard normal conditional distribution is represented by:

$$f_N(\eta) \equiv \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\eta^2}, \eta \in \mathbb{R}$$

Equation 3.9: Normal distribution

The PDF of the standardised Student's t conditional distribution is represented by:

$$f_S(\eta; \nu) \equiv \frac{\Gamma\left(\frac{\nu+1}{2}\right)}{\sqrt{(\nu-2)\pi}\Gamma\left(\frac{\nu}{2}\right)} \left(1 + \frac{\eta^2}{(\nu-2)}\right)^{-\frac{\nu+1}{2}}, \eta \in \mathbb{R}$$

Equation 3.10: Student's distribution

where ν is constrained to exceed 2 in order to ensure that the second-order moment exists.

The kurtosis of the distribution is higher for a lower ν . $\Gamma(\cdot)$ is the Gamma function.

The PDF of the standardised generalised error distribution (GED) is represented by:

$$f_{GED}(\eta; \nu) \equiv \frac{\nu e^{-\frac{1}{2}|\frac{\eta}{\lambda}|^\nu}}{\sqrt{\lambda 2^{(1+\frac{1}{\nu})}} \Gamma\left(\frac{1}{\nu}\right)}, \quad \lambda \equiv \left(\frac{\Gamma\left(\frac{1}{\nu}\right)}{4^{1/\nu}\Gamma(3/\nu)}\right)^{\frac{1}{2}}, \eta \in \mathbb{R}$$

Equation 3.11: GED distribution

where $\nu > 0$ is the shape parameter.

The MSGARCH packaged in R by Ardia et al., (2018) also allows for skewed normal, skewed student's t and skewed GED conditional distributions.

3.4.2.3 Model evaluation criteria

Following Chu et al. (2017), in-sample model selection criterion AIC and BIC are used to select the most appropriate model in terms of the trade-off between goodness of fit and parsimony. The BIC imposes a greater penalty on the number of parameters than the AIC, however theoretical arguments often favour the AIC over the BIC (Fabozzi et al., 2014). Both the AIC and the BIC are calculated to identify whether the criterion agree on the selection of the best performing model. The model with the smallest AIC and BIC is preferred as it minimises the loss of information in the data.

Akaike's (1974) AIC is represented by:

$$\text{AIC} = 2\chi - 2\ln L(\hat{\Theta})$$

Equation 3.12: AIC

where χ is defined as the number of unknown parameters, Θ is the vector of unknown parameters and $\hat{\Theta}$ their maximum likelihood estimates.

The BIC of Schwartz (1978) is represented by:

$$\text{BIC} = \chi \ln n - 2\ln L(\hat{\Theta})$$

Equation 3.13: BIC

where n is the number of observations.

3.5 Empirical Analysis

3.5.1 Mean Reversion

The autoregressive effects are removed using an AR(1) process. The Ljung-Box test returns a p-value of 0.096, which is non-significant at the 95% level, rejecting the null of serial correlation.

Table 3.2: Results of the autoregressive model

Coefficients	AR(1)
c	0
b	0.4664
α	0.5336
Log-likelihood	905.56
AIC	1807.11
BIC	1797.57

Source: Author's calculations.

The Pearson correlation coefficient of r_t and r_{t-1} is -0.03587804, suggesting that r_t is in fact mean-reverting. The mean reversion rate is 0.5336.

3.5.2 Markov-Switching GARCH

As mentioned above, this study investigates the in-sample accuracy of the ARCH, GARCH, E-GARCH, GJR-GARCH and T-GARCH models for up to four regimes and six conditional distributions. A total of 120 models were estimated with the results presented in Appendix A.

The overall preferred in-sample model according to both AIC and BIC is the 4-State T-GARCH with Student's t distribution and the second best overall model is the 2-State T-GARCH with Student's t distribution. Table 3.3 summarises the two overall best performing models as well as the preferred model for each GARCH-type model. The AIC and BIC selection for each of the models in table 3.3 was consistent except for the GARCH model. The single state models are to a large extent, outperformed by the multiple state models. The results suggest that there is indeed evidence of regime-switching in the historical interest rate volatility.

Table 3.3: Best in-sample performing combination of state and distribution for each of the GARCH-type models

Model			AIC	BIC
4-State	T-GARCH	Student's t	-8153.5823	-8000.7706
2-State	T-GARCH	Student's t	-7230.7734	-7173.469
2-State	E-GARCH	Student's t	-6317.0747	-6259.7703
4-State	GARCH	GED	-6002.6079	-5868.8977
4-State	GARCH	Skewed Student's t	-6005.3204	-5852.5087
2-State	E-GARCH	Student's t	-6317.0747	-6259.7703
2-State	GJR-GARCH	Skewed GED	-5885.9502	-5819.095
4-State	ARCH	Student's t	-5731.6621	-5617.0533

Source: Author's calculations.

The Normal and Skewed Normal distribution results suggest the worst fit, thus confirming a fat-tailed distribution is preferred. This is in accordance with expectations given the highly leptokurtic nature of the data. The kurtosis coefficient reported in section 3.3 above is 18.26, while the kurtosis coefficient of a normal distribution is 3. For all five models types, the selection criteria favour the Student's t, Skewed Student's t, GED and Skewed GED distributions, confirming the presence of fat tails. The majority of the preferred models favour an un-skewed distribution.

Table 3.4 presents the estimates from the selected model and a single state T-GARCH as well as a simple 1-State GARCH with the same distribution.

Table 3.4: Details of the 4-State T-GARCH, 1-State T-GARCH and 1-State GARCH

Coefficients	4-State T-GARCH		1-State T-GARCH		1-State GARCH Student's t	
	Student's t		Student's t			
$\alpha_{0,1}$	0.0000001	(2.00E-15)	0.00107351	(1.55E-04)	0.0000001	(2.00E-15)
$\alpha_{1,1}$	0.9997895	(6.63E-24)	0.56488167	(9.11E+01)	0.5222659	(8.54E-21)
$\alpha_{2,1}$	0.0001004	(4.09E-26)	0.43501790	(1.59E-04)	-	
β_1	0.0104750	(2.72E-21)	0.48528445	(7.15E-05)	0.4775062	(2.38E-25)
ν_1	2.1000310	(7.31E-26)	2.51934933	(1.37E+00)	2.5917760	(3.81E-21)
$\alpha_{0,2}$	0.0000012	(2.27E-29)	-		-	
$\alpha_{1,2}$	0.8569539	(4.99E-22)	-		-	
$\alpha_{2,2}$	0.1302990	(5.27E-24)	-		-	
β_2	0.5188921	(2.43E-22)	-		-	
ν_2	2.1000310	(6.57E-26)	-		-	
$\alpha_{0,3}$	0.0179356	(7.21E-21)	-		-	
$\alpha_{1,3}$	0.7716386	(4.79E-21)	-		-	
$\alpha_{2,3}$	0.1289264	(6.97E-22)	-		-	
β_3	0.5863053	(1.49E-22)	-		-	
ν_3	2.1000310	(1.80E-25)	-		-	
$\alpha_{0,4}$	0.0507341	(3.54E-21)	-		-	
$\alpha_{1,4}$	0.4584096	(7.80E-21)	-		-	
$\alpha_{2,4}$	0.3530546	(1.53E-22)	-		-	
β_4	0.6429577	(2.83E-23)	-		-	
ν_4	2.1000310	(3.61E-26)	-		-	
σ_1 Mean	0.009105		0.020791		0.0338402	
σ_1 Maximum	0.1702		0.200787		0.2661557	
σ_2 Mean	0.01886		-		-	
σ_2 Maximum	0.2024		-		-	
σ_3 Mean	0.06345		-		-	
σ_3 Maximum	0.24165		-		-	
σ_4 Mean	0.1642		-		-	
σ_4 Maximum	0.3230		-		-	
Log-likelihood	4108.7912		2527.645		2535.9746	
AIC	-8153.5823		-5045.289		-5063.9492	
BIC	-8000.7706		-5021.412		-5044.8477	

Source: Author's calculations. Standard errors are in brackets. All of the coefficients are significant at the 1% level.

The estimated volatility from the simple 1-State GARCH and the 1-State T-GARCH is in effect an average of the four volatility estimates from the 4-State T-GARCH, failing to represent the lowest and highest volatility regimes. Therefore the 4-State T-GARCH is better at capturing the volatility clustering in the data.

The persistence of the simple 1-State GARCH is calculated by summing $\alpha_1 + \beta$ which equals 0.999. The persistence for each state of a T-GARCH is calculated as follows:

$$\alpha_{1,k}^2 + \beta_k^2 - 2\beta_k(\alpha_{1,k} + \alpha_{2,k})E[\eta_{t,k} \mathbb{I}\{\eta_{t,k} < 0\}] - (\alpha_{1,k}^2 - \alpha_{2,k}^2)E[\eta_{t,k}^2 \mathbb{I}\{\eta_{t,k} < 0\}] + \beta_k$$

where, $E[\eta_{t,k} \mathbb{I}\{\eta_{t,k} < 0\}] = 0.5$ for an unskewed distribution (see Ardia et al., 2018)

Table 3.5: The persistence in volatility per state of the 4-State T-GARCH Student's t

Volatility persistence of each state of the 4-State T-GARCH Student's t	
State 1	0.739320174
State 2	0.151004597
State 3	0.266472973
State 4	0.080423857

Source: Author's calculations.

The single regime GARCH and T-GARCH models return similar AIC and BIC values which are much higher than the values for the preferred model, indicating the presence of multiple regimes. For all four of the states, the persistence is lower than the persistence of the 1-State GARCH indicating that the high persistence in the single-regime GARCH model is indeed spurious. The 1-State T-GARCH, on the other hand, has an incredibly low volatility of only 0.036893.

State 1 is the low volatility state with a high volatility persistence indicating that in this tranquil market state, there were no significant economic events which caused increased volatility. The asymmetry parameter in this state is extremely small indicating that with no significant economic events occurring in this state, the leverage effects are minimal.

States 2 and 3 are both moderate market volatility states with a similar leverage effects. State 3 is more persistent than state 2 and exhibits higher mean and maximum volatility within the state.

State 4 is characterised by the highest volatility and very strong leverage effects. This period of extreme market stress also exhibits a low volatility persistence indicating that more weighting is given to more recent data as well as a quick reversion to the mean.

Recall from section 3.4.2 that the shape parameter ν is constrained to exceed 2 for the Student's t distribution in order to ensure that the second-order moment exists and the kurtosis of the distribution is higher for a lower ν . The ν of all the states is 2.1 once again confirming that the data is highly leptokurtic.

Table 3.6: The transition probability matrix of the 4-State T-GARCH Student's t

	t+1 k=1	t+1 k=2	t+1 k=3	t+1 k=4
t k=1	0.52329418	0.01834748	0.4529629	0.00539542
t k=2	0.51544280	0.18835601	0.0845859	0.2116153
t k=3	0.20857706	0.03624498	0.7463898	0.00878816
t k=4	0.03699331	0.03481171	0.1621211	0.76607385

Source: Author's calculations.

The probability matrix represents the probability of moving from one state to another. For example, the probability of transitioning from State 1 in time t to State 4 in time $t+1$ is 0.00539542 or 0.5%; thus, it is highly unlikely to jump from the 1st State directly to the 4th State in one time period. While in States 1, 3 and 4 in time t it is more likely to remain in the initial state in $t+1$ than it is to change states. The exception is State 2, which is more likely to transition back to State 1 in $t+1$. Interestingly, the high volatility State 4 is characterised by an extremely low volatility persistence of 0.08 and a high probability of remaining in State 4 at $t+1$. Indicating that a large shock will likely result in a transition to State 4, with a high probability of remaining in this state at $t+1$. Thus, the main source of volatility clustering in State 4 is due to the persistence of the regime itself.

3.6 Conclusion

The study finds that there is indeed regime-switching evident in South African historical interest rate volatility which is of consequence for the valuing of financial assets. Thus, standard single regime GARCH(1,1) and T-GARCH(1,1) models are insufficient to capture the underlying volatility dynamics of interest rates. The four states identified represent tranquil,

normal and extreme market volatility conditions. The data was also found to have an asymmetric effect to past negative observations. The asymmetric effect increases as the volatility conditions increase, suggesting that the bigger the negative information shock, the higher the volatility response.

The high volatility regime is characterised by low volatility persistence while the low volatility regime is characterised by high volatility persistence. An interesting finding is that the volatility clustering in State 4 is due to the regime's persistence.

Recommendations for further research include using out of sample forecasts to compare the goodness of fit. Although Wu (2010) finds that the maximum likelihood estimate for the T-GARCH is unbiased and normally distributed for modest sample sizes given stationarity, a further area of research is the comparison of other estimation techniques such as the Bayesian Markov Chain Monte Carlo estimation technique. At the time of writing, proposals on the reform of the Jibar calculation as well as proposals for potential new benchmarks are being considered by South African Authorities, the potential impact on derivatives pricing of a new benchmark interest rate is, therefore, an additional area for future research.

CHAPTER 4

ESTIMATION OF COLLATERAL DEMANDS

4.1 Introduction

Research objective two is addressed in this Chapter. Which is to estimate the collateral demands on South Africa ODPs that will result from the enforcement of IM on non-centrally (using the QPMM and SMS approaches) as well as IM and DF contributions on centrally cleared derivatives (using a CCP's margin model) in the three potential market structure scenarios.

As a member nation of the G20, South African Authorities have committed to reforming the country's OTC derivatives market. The focus of this Chapter is on the enforcement of IM requirements to protect against CCR and the resulting cost to the South African ODPs. In the event of a counterparty default, IM is intended to cover PFE that may arise from future changes in the mark-to-market value of a derivative contract during the time it takes to close out and replace the contract. PFE is defined as the maximum amount at a given confidence level an investor could lose on their positions during a pre-specified period of time through the default of their counterparty (Lopez, Mendes & Vikstedt, 2013).

IM is exchanged in a bilateral contract to protect both parties against PFE. In the case of central clearing, IM is one-directional risk cover. VM is intended to cover changes in the mark-to-market value of the contract; in other words, it protects against current counterparty exposures. VM exchange is one-directional, flowing from the counterparty whose net position is out-of-the-money to the counterparty whose net position is in-the-money. VM is exchanged between parties to a bilateral contract, and in the case of central clearing, the CCP transfers the full amount from one party to the other. In the event of a counterparty default, the CCP is still liable for transferring VM to the in-the-money counterparty, which it must do from its own funds until a counterparty is found to replace the contract. It may take some time to find a replacement counterparty, particularly in periods of market stress when the market is likely to be less liquid. CCPs, therefore, demand additional protection against PFE in the form of contributions to a DF. Any losses not

covered by VM and IM are first recovered from the defaulting member's contribution to the CCP's DF. Thereafter a prescribed amount of capital and reserves belonging to the CCP are used to cover losses and finally the remaining DF contributions. This process for a CCP to absorb defaults is known as the risk waterfall and is discussed in more detail in Chapter 2 (section 2.1.4.2). Large and active CCPs, such as SwapClear, use their own internal risk-sensitive QPMM models to determine IM requirements. The IM requirements are dependent on the model inputs of the CCP's margin model.

PFE rises in times of market stress, and thus IM requirements should rise in times of market stress. According to the BCBS-IOSCO (2015a: 13): *"the use of [QPMM] models is intended to produce appropriately risk-sensitive assessments of potential future exposure so as to promote robust margin requirements."* However, as discussed in section 2.4, this procyclicality of margin demands may increase systemic risk. Thus, IM requirements that are sensitive to market risk may favour the microprudential goal of reducing CCR over the macroprudential goal of reducing systemic risk. At the 2011 G20 summit in Cannes, the G20 instructed the BCBS-IOSCO to "develop, for consultation, consistent global standards for these [non-centrally cleared] margin requirements" (BCBS-IOSCO, 2015a: 2). According to the BCBS-IOSCO (2015a: 3) "the effectiveness of margin requirements could be undermined if the requirements were not consistent internationally" therefore the BCBS-IOSCO's framework was designed with cross-border consistency in mind to ensure that opportunities for regulatory arbitrage are limited, although the exact implementation of the framework is at the discretion of local authorities. The framework allows for two approaches to the calculation of IM for non-centrally cleared derivatives: 1) the traditional risk-sensitive QPMM, or 2) the SMS. The BCBS-IOSCO advises authorities that market participants should not be able to use a combination of the QPMM and SMS in an effort to lower IM requirements on non-centrally cleared derivatives. Therefore, a market participant should use either the QPMM or the SMS approach to calculate IM requirements on non-centrally cleared derivatives.

This Chapter presents an estimation of the potential magnitude of collateral demands on South Africa ODPs that will result from the enforcement of IM on non-centrally cleared derivatives (using the QPMM and SMS approaches) as well as IM and DF contributions on centrally cleared derivatives (using a CCP's margin model). Although the South African

Authorities have indicated their intention to mandate central clearing for eligible products, the impact of a decision not to mandate central clearing is considered. Thus, three market structure scenarios are considered; these are illustrated in figure 4.1.

Figure 4.1: Potential market structure scenarios under consideration

Market structure scenario 1	Market structure scenario 2	Market structure scenario 3
<ul style="list-style-type: none"> • Central clearing is mandated by authorities. • 75% of derivatives are eligible for central clearing (collateral requirements calculated using a CCP's margin model) • 25% of derivatives remain non-centrally cleared (collateral requirements calculated using the BCBS-IOSCO's QPMM) 	<ul style="list-style-type: none"> • Central clearing is mandated by authorities. • 75% of derivatives are eligible for central clearing (collateral requirements calculated using a CCP's margin model) • 25% of derivatives remain non-centrally cleared (collateral requirements calculated using the BCBS-IOSCO's SMS) 	<ul style="list-style-type: none"> • Central clearing is NOT mandated by authorities. • 100% of derivatives remain non-centrally cleared (collateral requirements calculated using the BCBS-IOSCO's SMS)

Source: Author.

The SMS approach is specified by the BCBS-IOSCO and is only sensitive to changes in the net-to-gross ratio. The QPMM approach, on the other hand, is computationally complex with a sensitivity to a range of model inputs. These model inputs include the volatility of the underlying asset (calculated in Chapter 3), the risk measure (either VaR or ES), confidence level (the risk tolerance metric) and the decay factor (controls the weighting given to more recent data). IM requirements calculated using a QPMM model will vary based on the choice of the model inputs discussed above, in this way the IM requirements are sensitive to the variability of model inputs. The BCBS-IOSCO's QPMM approach contains a prescriptive rule for the confidence level (enforcing the use of a 99% confidence level internationally), however, it is not prescriptive regarding the choice of the other variable inputs. Any QPMM model must first be approved by local authorities before it may be used; thus, it is important to determine the sensitivity of IM requirements to these model inputs. These inputs are briefly discussed below.

Chapter 2 (section 2.4) discusses the pro-cyclical nature of IM demands, to this end, the market volatility estimates derived in Chapter 3 are used to examine the impact of varying volatility conditions on IM demands estimated using the risk-sensitive QPMM approach. Chapter 2 of this thesis examines at length the potential consequences of increased HQLA demand. These include increases in swap prices, decreases in trading volume and market liquidity, altering market behaviour (for instance, increased precautionary behaviour may lead to a decline in intermediation activity, see section 2.3.1.3) and a shortage HQLA can result in an increase in systemic risk. The latter is due to the pro-cyclical nature of margin requirements, increasing as market volatility increases or during an economic downswing, thus increasing the demand for HQLA during the moment its availability becomes scarcer.

Using the QPMM approach, IM and DF demands are calculated using the traditionally popular Value at Risk (VaR) measure as well as the more conservative Expected Shortfall (ES) risk measure which has gained popularity with regulators and international standard setters post-crisis. VaR captures the maximum portfolio loss with a pre-specified confidence level; however, it does not give any information about the severity of the loss beyond the threshold. ES is the weighted average of all losses past the threshold, thus capturing the tail risk. As a result, ES estimates are always higher than VaR estimates given the confidence level. Margining models used by CCPs are often described as using a VaR/ES type methodology, the weighting assigned to each is confidential, proprietary information. The BCBS-IOSCO's QPMM approach does not specify which risk measure must be used, thus calculating both provides an upper and lower bound for HQLA demands.

In addition to using two different risk measures when using the QPMM approach, a sensitivity analysis is conducted with respect to three key model parameters. The volatility, confidence level and the decay factor model parameters are varied to evaluate the impact on the behaviour of the IM margin model, specifically with regards to the pro-cyclicality of IM. Next, the different IM re-hypothecation rules for centrally and non-centrally cleared derivatives are applied to estimate the IM HQLA demand. Finally, the DF contributions for the two centrally cleared portfolios (assuming 90% and 99% direct hedging) are calculated.

4.2 Literature Review

Several studies have been undertaken by academics and international bodies to determine the IM collateral costs of central clearing as well as the IM collateral costs of non-centrally cleared derivatives after margin requirements are enforced using the risk-sensitive QPMM approach, however, none have been conducted for the South African market. In addition, this analysis is expanded to include a comparison of the margin requirements for the uncleared portfolio using the traditional QPMM approach with the prescriptive SMS approach introduced recently by the BCBS-ISOCO. Duffie & Zhu (2011) presented a pioneering model which has been used and built upon by most of the studies referred to in this literature review. They used data collected by the OCC (Office of the Comptroller of the Currency) from the six largest US derivatives dealers (by notional amounts outstanding). They then included six other dealers with the same notional exposures by the class of asset as a proxy for the non-US dealers for whom they did not have data. Duffie & Zhu contrast the benefits of multilateral netting gained from central clearing with bilateral netting across asset classes from bilateral netting. They found that clearing different classes of derivatives through different CCPs is less efficient than a single CCP and always increases CCR. This was an important finding given the existing institutional landscape whereby different CCPs in different geographic regions usually clear one class of derivative. Duffie, Scheicher & Vuillemeys (2014) used confidential, proprietary data on bilateral CDS exposure aggregated by the US depository trust and clearing corporation (DTCC). They estimate collateral increases for a network of dealer banks and end-users due to IM and VM allowing for varying degrees of collateral re-hypothecation and changes in the number of CCPs. The Bank of England's Sidanius & Zikes (2012) used data on the global CDS market from DTCC and from TriOptima for the total IRS market. They estimate the total IM needed for dealers and non-exempt end-users for the percentage of contracts they assume will be cleared as well as the remainder which will remain uncleared and subject to BCBS-IOSCO IM rules. Sidanius and Zikes assumed zero collateral re-hypothecation for non-centrally cleared derivatives, although the final BCBS-IOSCO rules allow for IM to be re-hypothecated once. They found that the element of derivative reform for OTC derivatives that would have the greatest impact on collateral demand is the imposition of IM in bilateral trade among financial institutions, assuming zero re-hypothecation. They find that central clearing reduces IM

requirements because of multilateral netting benefits for dealer's positions when IM requirements on both cleared and uncleared trades are not allowed to be re-hypothecated. They admit that allowing re-hypothecation in non-centrally cleared derivatives may make central clearing relatively more costly because re-hypothecation reduces the overall demand for HQLA (see section 2.3.2.1).

In a working paper for the BIS, Heller & Vause (2012) estimate the amount of collateral required if all IRS and CDS contracts of the Group of 14 largest global derivatives dealers (G14) were centrally cleared. The G14 dealers publish only their total notional amounts outstanding per derivative class; more detailed information is proprietary and not available to the public. Therefore, Heller & Vause simulate long and short portfolio positions for each dealer using publicly available information and a set of assumptions aimed at capturing the key characteristics of the dealers' actual portfolios. They then estimate a distribution of potential changes in market values of the simulated portfolios by fitting a GARCH model to historical data of the underlying instrument. With these simulated long and short portfolio positions and the distribution of potential changes in market values, they are then able to determine a joint probability distribution of portfolio gains and losses under different market volatility scenarios in order to calculate collateral against VM and IM. Lin & Surti (2015) expand on the Heller-Vause model by exploring the sensitivity of collateral demands by CCPs to changes in model inputs. They find that the collateral requirements, and in turn, the size of a CCP's risk buffers, vary considerably depending on the CCP's internal model calibrations regarding risk tolerance metric (confidence level), look-back period and netting across multiple risk factors. They advise authorities to take a more prescriptive approach to CCP's internal modelling in order to reduce systemic risk.

The above-cited studies focus on the effect of collateral increases on internationally large dealer banks; however, South African ODPs are at the periphery of this dealer market. Some South African ODPs may require client clearing services which reduce the multilateral netting benefits from central clearing. Heath, Kelly & Manning (2012) analyse the derivatives market in terms of a network structure. They identify two types of agents, banks at the core of the structure and investors at the periphery. They show that collateral demands resulting from the new regulations are less severe for dealers than for end-users.

This could result in liquidity shortages for end-users who drive market activity because they are the ultimate buyers and sellers of protection.

The rise of popularity of ES over VaR for measuring market risk, apart from its important ability to capture the left tail risks, is that it is conceptually superior. The seminal work by Artzner et al. (1999) formalised the desirable properties of risk measures. Desirable properties include coherence, comonotonic additivity, law invariance, robustness and elicibility. VaR lacks subadditivity in general; therefore, it does not satisfy the property of “coherence” in many cases. Subadditivity refers to the benefit that should be achieved with portfolio diversification. ES does satisfy the property of coherence and its use instead of VaR was proposed by Artzner et al. (1997). Despite research indicating that ES does not satisfy the property of elicibility, Lazar & Zhang (2019) find that ES outperforms VaR in backtesting and forecasting.

Van den End (2011) studied two hundred years of annual interest rate data for the Netherlands, Germany, the USA and Japan, finding evidence of mean reversion. He found that although long-term interest rates can deviate from their long-term average value, short-term interest rates and the yield curve tend to revert back to their long-term average value. He also found that short-term interest rates and the yield curve have a stronger tendency to revert to their long-term average value than long-term bond yields. Suggesting that interest rate backed derivatives are more sensitive to mean reversion than bonds.

4.3 Derivative Portfolios

Local ODPs report their derivatives holdings to the SARB who then publishes only the aggregated data. Detailed data on the portfolio holdings of derivatives dealers like that used by Duffie & Zhu (2011), Duffie, Scheicher & Vuillemeys (2015) and Sidanius & Zikes (2012) is not available for South African ODPs, due to the absence of a trade repository. Lack of information about local end-users also prevents a network study like the one conducted by Heath, Kelly & Manning (2012). Thus the methodology for the risk-sensitive QPMM approach follows the methodology developed by Heller & Vause (2012) and expanded on by Lin & Surti (2015). According to this theoretical framework, the first step is to simulate each South African ODP’s notional long and short positions outstanding in order to establish their

market exposure. This is done by combining available data on market size, the gross notional positions reported by dealer banks in their annual financial reports and assumptions about these positions to create the constraints. Given the model assumptions summarised in table 4.1 below, the long and short outstanding notional amounts per remaining maturity for each ODP as at end December 2018 are derived.

Table 4.1: Model assumptions

Model assumptions	
All OTC derivatives are interest rate derivatives (IRD)	As at end December 2018, 88% of South African OTC derivatives were interest rate derivatives (IRD), therefore for market pricing, all OTC derivatives are assumed to be IRD.
75% of derivatives will be centrally cleared	Following the findings of the BIS's 2016 Triennial Central Bank survey which found that 75% of dealers outstanding interest rate derivatives were centrally cleared (BIS, 2016)
25% of total IRD remain uncleared	The remainder of IRD are assumed to remain uncleared.
100% of interest rate derivatives are IRS	Lin & Surti assume that the product division of IRD is 86% IRS and 14% overnight interest swaps (OIS) based on information from SwapClear; however, a rand OIS market has not been established because a South African Overnight Index Swap is still in development (Mminele, 2013). Therefore, the only product type considered is the IRS.
Time to maturity for contracts	In order to simulate portfolios, the time to maturity (TtM) of the outstanding contracts must be known. Assumptions about the percentage of contracts in each of the maturity buckets follow the assumptions of Heller & Vause (2012) for IRS, see table 4.4 for more details.
Cleared contracts clear through SwapClear	SwapClear is responsible for the central clearing of almost all IRDs globally. According to its website, SwapClear clears "more than 90% of the overall cleared OTC interest rate swap market and more than 50% of all OTC interest rate swaps" (LCH.Clearnet Ltd, 2021). Given the fact 88% of South African OTC derivatives are IRD and SwapClear clears almost all IRDs globally, it would seem most probable that LCH.Clearnet Ltd would be licenced to operate its SwapClear service in South Africa to maximise multilateral netting benefits. According to LCH.Clearnet in the second quarter of 2015, ZAR denominated IRD cleared at SwapClear had a gross notional outstanding amount of 12.7 trillion ZAR.
All cleared and uncleared contracts are ZAR denominated	According to the IMF (2015), ZAR denominated OTC derivative contracts are traded extensively off-shore, particularly in the UK (where SwapClear is registered) and contracts between local counterparties are almost exclusively ZAR denominated.
Regulations for non-centrally cleared derivatives are assumed to be fully phased in	The IM requirements for non-centrally cleared derivatives are being phased in between the effective date in 2021 and September 2024 in South Africa. From September 2024 covered entities with an average month-end gross notional amount outstanding exceeding 100 billion ZAR will be required to post IM on non-centrally cleared derivatives when dealing with a participant whose gross notional position also exceeds 100 billion ZAR. See Chapter 1,

<p>Two assumptions for the degree of direct hedging in the cleared model: 90% and 99%</p>	<p>section 1.1 for more information on the phasing in of IM requirements for non-centrally cleared derivatives in South Africa.</p> <p>Based on data published by the Reserve Bank, ODPs mainly act as dealers with minimal banking book or proprietary derivatives trading. Only 3% of notionals reported in December 2018 were recorded in the banking book; the balance was recorded in the trading book. Assuming that ODPs act mainly as dealers with largely balanced portfolios and minimal proprietary derivatives trading, thus long and short positions must sum to similar values. 100% direct hedging is where long and short positions are equal in identical maturity and currency for each instrument. Long positions are pay fixed/ receive floating interest rate payments, and conversely, short positions are pay floating/ receive fixed interest rate payments. The degree to which contracts cleared by SwapClear are directly hedged is unknown however Lin & Surti (2015) estimated that in order to simulate actual IM and DF amounts held by SwapClear in their end year 2011 report, the degree of direct hedging would be between 99% and 99.5%. However, they find that when comparing actual data for the clearing member's ratios of swaps assets to swaps liabilities actually fits a degree of direct hedging of 84% to 93%. I make two assumptions concerning the degree of direct hedging in the cleared model to assess the impact of portfolio design in IM demands: 90% and 99%.</p>
<p>Collateral re-hypothecation</p>	<p>According to the final margin requirements for non-centrally cleared derivatives published by the South African FSCA & PA in 2020: "Any cash or non-cash collateral collected as initial margin may be rehypothecated, re-pledged or re-used (collectively referred to as re-hypothecated, unless specifically otherwise stated) only once by the initial margin collector". Therefore, IM posted on non-centrally cleared derivatives may be re-hypothecated only once; in other words, the velocity of collateral is limited to 2 by regulation.</p> <p>The model for centrally cleared derivatives does not allow for collateral reuse by ODPs because under central clearing IM posting is one-directional from clearing members to the CCP. See Chapter 2, section 2.3.2.1 for more information about the re-hypothecation of collateral.</p>
<p>Zero netting across risk categories</p>	<p>The BCBS-IOSCO rules do not allow derivative positions between different risk categories to be offset when calculating IM. The degree to which CCPs offset is not certain, according to Lin & Surti (2015). However, since only IRD are considered, this distinction is not important for the purposes of this study.</p>
<p>Zero netting between risk categories</p>	<p>The degree of netting between IRS is unknown; therefore, zero netting is assumed. This provides the upper bound for margin demands.</p>
<p>Day count convention</p>	<p>The day count convention in South Africa is 365 days.</p>
<p>The portfolio is adjusted for 31.5% double counting.</p>	<p>The gross notional amounts outstanding reported by the SARB are subject to double-counting when both parties to the contract are reporting dealers. According to the IMF (2015), in the South African OTC derivatives market, 63% of gross notional amounts outstanding are interbank (i.e. interdealer, or between two ODPs) while 35% and 2% respectively are with other financial institutions and non-financial institutions. If 63% of trades are between reporting dealers, then these trades are counted twice, to account for this, the portfolio is adjusted downward by 31.5%. See Chapter 1, section 1.1 for a discussion of double counting.</p>

Source: Author.

In order to determine the IM requirements, the market value of the outstanding positions needs to be established. In a plain vanilla IRS one party contracts to pay a fixed interest rate while its counterparty contracts to pay a floating interest rate at pre-determined payment intervals over an agreed-upon duration based on a specified notional amount. The value of an IRS depends on its fixed rate, which is the relevant rate on the day that the contract was originated, and the prevailing floating rate. Given the simulated IRS long and short outstanding notional amounts per remaining maturity bucket for each ODP, the origination dates can be determined. At the origination date, the value of the pay-fixed and pay-floating legs will be equal, i.e. at the origination of the agreement the swap has a zero value to both parties.

$$PV_{fix} = PV_{fl}$$

Equation 4.1: At the origination date of a swap agreement

The floating rate is usually linked to some market reference rate; in South Africa, the 3-month Jibar is typically used as the reference floating interest rate for ZAR denominated IRD (Du Preez, 2011). In order to ensure that the swap has a zero value at origination, the fixed-rate equates the present value of the fixed cash flow stream to the present value of the floating cash flow stream. The fixed-rate remains constant throughout the life of the swap and depending on the prevailing market value of the floating rate, one party will be in-the-money, and the other party will be out-of-the-money. The fixed rate of an existing swap can be calculated by setting the price of the swap at $t=0$ to 0.

Thus, the origination date ($t=0$) of the contract is needed to determine the fixed rate. The available data from TriOptima provides only the remaining time to maturity (TtM) of outstanding positions across the seven maturity buckets (0-2 years, 2-4 years, 5-10 years, 10-15 years, 15-20 years, 20-30 years and 30 plus years). However, using the methodology followed by Heller & Vause, (2012) and Lin & Surti, (2015), it is possible to calculate the age of the contracts and therefore, the origination dates. Origination dates are calculated by constructing a distribution of contracts by original TtM that is consistent with the distribution of contracts by remaining TtM within the seven maturity buckets following a symmetrically weighted distribution (see table 4.2). For instance, 100% of contracts with an original TtM of 2 years must have a remaining TtM of 0-2 years whilst contracts with an

original TtM of 5 years could have a remaining TtM of 0-2 years or 2-5 years. The age of the contracts is then derived by subtracting the remaining TtM from the original TtM (See table 4.3).

Table 4.2: Mapping Original TtM into Maturity Buckets

Remaining maturity buckets (years)	Remaining TtM	Original TtM (years)						
		2	5	10	15	20	30	50
0 – 2	1	100	40	20				
2 – 5	3.5		60	30				
5 – 10	7.5			50	50			
10 – 15	12.5				50	50		
15 – 20	17.5					50		
20 – 30	25						100	
30 +	35							100

Source: Lin & Surti (2015).

Table 4.3: Mapping Origination Dates for IRS Portfolio

Original maturity (years)	Remaining TtM	Age of contracts (years) x share of original TtM (percent)						
		2	5	10	15	20	30	50
2	1	1x 100	4x 40	9x 20				
5	3.5		1.5x 60	6.5x 30				
10	7.5			2.5x 50	7.5x 50			
15	12.5				2.5x 50	7.5x 50		
20	17.5					2.5x 50		
30	25						5x 100	
30 +	35							15x 100

Source: Author's calculations.

The percentage distribution of notional amounts across maturity buckets follows the assumptions of Heller & Vause (2012), see table 4.4.

Table 4.4: Maturity bucket distribution

Maturity in years	Share of total notional amounts
0-2	46.8%
2-5	23.3%
5-10	20%
10-15	3.2%
15-20	2.2%
20-30	4%
30+	0.5%

Source: Heller & Vause (2012).

Using the total gross positions of each dealer and the following distribution assumptions of holdings across the seven maturity buckets, an iterative proportional fitting algorithm can fill in the unknowns and present a matrix of long and short positions for each ODP. The iterative proportional fitting algorithm operates as follows, index derivatives by i and j so that:

$$m \equiv \{IRS\}, \quad i = 1, \dots, N_m \text{ and } j = 1, \dots, ODP_m$$

where m is the South African OTC derivatives market, i represents the maturity buckets and ODP_m the number of ODPs in the market. In this study $i = 7$ and $j = 6$ (the big five South African banks plus the sum of foreign dealers).

The long and short positions are required to have a specified degree of overlap, this is the degree of direct hedging (k_j). In this study, k_j takes the value 90% and 99% for the cleared and uncleared portfolios respectively resulting in four portfolios. The degree of overlap is evaluated on the basis of the following similarity metric:

$$k_j = \frac{\sum_i \min(L_{ij}, S_{ij})}{\frac{1}{2} \sum_i (L_{ij} + S_{ij})} \quad \forall i \in \{1, \dots, N_m\}$$

Equation 4.2: Degree of direct hedging calculation

The aggregate long and short positions can be disaggregated according to age and clearing type and degree of direct hedging resulting in four portfolios for each ODP (see table 4.5).

Table 4.5: Final portfolios

Portfolio	Clearing type	Degree of direct hedging
1	Centrally cleared	99%
2	Centrally cleared	90%
3	Uncleared	99%
4	Uncleared	90%

Source: Author's calculations.

4.4 Methodology

The methodology to calculate IM for cleared and non-centrally cleared derivatives using the QPMM approach is sensitive to portfolio construction (i.e. the degree of direct hedging assumed) as well as model inputs including volatility, risk measure, confidence level and decay factor. These model specifications for the QPMM approach to calculate IM and DF requirements are detailed in sections 4.4.1 - 4.4.4. The methodology to calculate IM requirements on non-centrally cleared derivatives using the SMS approach is relatively simple and is detailed in section 4.4.5.

To determine the IM required using the QPMM approach against the four portfolios listed in table 4.5; first, the portfolios' market value must be determined because the IM and DF

requirements fluctuate with the price of the underlying instrument. As the underlying instrument is an interest rate, the term structure of interest rates is needed to value the portfolios. The representation of the term structure of interest rates is commonly called a yield curve or a swap curve. This study uses the terminology “Swap Zero curve” to distinguish it from a forward curve. The Swap Zero curve is used to mark-to-market the portfolios; section 4.4.1 describes the derivation of the Swap Zero curve.

The sensitivity of the IM estimates to changes in the decay factor (λ), volatility (σ) and confidence level parameters are analysed. The two different decay factors are based on the popular RiskMetrics model as well as the decay factor used by SwapClear. The different market volatility estimates derived in Chapter 3 are used in the pricing of the derivative contracts to determine the pro-cyclical effect on IM demands. The confidence levels are prescribed by the BCBS-IOSCO’s QPMM approach for non-centrally cleared derivatives and SwapClear’s QPMM approach for centrally cleared derivatives.

This methodology will be used firstly to estimate the ZAR value of collateral for IM on a portfolio of products that are likely to be subject to mandatory central clearing, secondly to estimate the DF contributions of ODPs. Thirdly, to estimate the ZAR value of collateral for IM on derivatives that will likely not be subject to mandatory central clearing either because they are not standardised or the market for them lacks the necessary liquidity. Fourthly, to estimate the ZAR value of the collateral if the entire market remains uncleared and is subject to the BCBS-IOSCO’s SMS approach. The final estimates for the uncleared portfolios account for the re-hypothecation allowed by the draft South African regulations. The VaR and ES risk measures serve as the lower and upper bounds for the QPMM estimates.

4.4.1 Portfolio market valuation for the QPMM approach

The mark-to-market value of an IRS with a short position is the difference between the present value of the receive-fixed and pay-floating legs. Conversely, the mark-to-market value of an IRS with a long position is the difference between the value of the receive-floating and pay-fixed legs. The equation for the market value of a short position presented by Lin & Surti (2015) is as follows:

$$MV = PV^{receive-fixed\ leg} - PV^{pay-float\ leg}$$

$$PV^{receive-fixed\ leg} = \sum_{n=1}^N e^{-t_n r_{tn}} (t_n - t_{n-1}) r$$

$$PV^{pay-floating\ leg} = \sum_{n=1}^N e^{-t_n r_{tn}} (t_n - t_{n-1}) r_{t_{n-1}, t_n}^f$$

Equation 4.3: Market value of an IRS with a short position

Where $e^{-t_n r_{tn}}$ is the discount factor using zero rates to discount to present value, N is the number of payments, r is the fixed-rate, r_{tn} is the floating rate and r_{t_{n-1}, t_n}^f is the forward rate between two payment dates ($t_n - t_{n-1}$).

In order to value the IRS, floating rates up to the residual maturity of the contract are needed. The Swap Zero curve is constructed in order to price the portfolios listed in table 4.5. “The nominal swap curve represents the zero-coupon yields at which interbank funding can be placed or obtained” (Johannesburg Stock Exchange, 2012). The Swap Zero curve is derived by the bootstrap and interpolation of various liquid market instruments with similar credit properties over varying time horizons. The relevant business-day count convention is used for South Africa. The Swap Zero curve can be divided into three maturity sections following the methodology outlined by Ron (2000). The short-term maturity section is composed of interbank deposit rates, the medium-term by forward rate agreements and the long-term maturity section is derived using swap rates. The benchmark instruments used to form the South African Swap Zero curve are listed in table 4.6.

Table 4.6: Inputs for the Swap Zero Curve

Term	Instrument	Description
<i>Overnight</i>	The South African benchmark overnight rate (SABOR)	The overnight interbank funding rate.
<i>1 month</i>	1 month Jibar	The 1-month Jibar is the average mid of the 1-month Negotiable Certificates of Deposit (NCD) rates quoted by a number of local and foreign banks (excluding the two highest and lowest rates).
<i>3 month</i>	3-month Jibar	The 3-month Jibar is the average mid of the 3-month Negotiable Certificates of Deposit (NCD) rates quoted by a number of local and

		foreign banks (excluding the two highest and lowest rates).
6 and 9 month	Forward rate agreements (FRAs)	FRAs with maturities of 6 and 9 months.
1-30 years	Swaps	Vanilla IRS with maturities from 1-30 years.

Source: Author.

Treasury Bills are used to construct yield curves in many developed countries. In South Africa however, Treasury Bills have an illiquid secondary market because they are generally held to maturity, and they are typically only auctioned once a week making them unsuitable as an input (du Preez, 2011).

In practice, the Swap Zero curve (or any yield curve) tends to be upward sloping, possibly reflecting the liquidity preference theory, according to Hull (2011). The theory states that there is a liquidity mismatch between investors who prefer to preserve their liquidity and invest for shorter time periods and borrowers who prefer to borrow for longer periods. As a result, forward rates tend to be higher than expected future zero rates. This is reflected in the fact that forward margins tend to be positive. When current volatility is above the long-term volatility the Swap Zero curve will be downward sloping (or inverted).

The evolution of the Swap Zero curve in the future is governed by a term structure model. In practice, the Hull-White (1990) single-factor model is commonly used by South African banks (Holilal, 2011). Other models which could be used to value interest rate derivatives include the Vasicek (1977) and Cox-Ingersoll-Ross (1985) models. The Hull-White model defines the evolution of the short rate as follows:

$$dr = [\theta(t) - ar]dt + \sigma dz$$

Equation 4.4: Hull-White (one-factor) model

where dr is the change in the short rate (r) after a small change in time (dt). a is the mean reversion rate, and σ is the annualised volatility rate. α and σ are model inputs that are estimated in Chapter 3. Section 4.4.2 further describes the volatility scenarios selected for analysis. dz is a Weiner process and the drift function, $\theta(t)$ is defined as:

$$\theta(t) = F_t(0, t) + \alpha F(0, t) + \frac{\sigma^2}{2\alpha}(1 - e^{-2\alpha t})$$

Equation 4.5: Drift function of the Hull-White model

Where $F(0, t)$ is the instantaneous forward rate at time t , $F_t(0, t)$ is the partial derivative of F with respect to time. Thus, the short rate (r) generally follows the slope of the initial instantaneous forward rate curve, and when it deviates from that curve, it reverts back at its mean reversion rate (α). One disadvantage of the Hull-White model is that when interest rates are close to zero, there is a possibility that the negative rates may occur under the model. This is not a serious concern in the South African market as interest rates are relatively high compared to those in many developed markets which have approached the zero lower bound over the past decade.

4.4.2 Market volatility scenarios for the QPMM approach

IM requirements may be pro-cyclical, increasing as market volatility increases, for a full discussion refer to Chapter 2 (section 2.4). Contributions to the DF are based on the PFE's of the two biggest clearing members; thus, DF contributions are also pro-cyclical. Therefore, it is necessary to consider how IM and DF demands react to differing levels of market volatility.

The volatility is captured by fitting an appropriate GARCH model to the risk factor, in this case, the 3-month Jibar interest rate. Empirical results from Chapter 3 find that the GARCH(1,1) estimates of conditional variance are explosive for 3-month Jibar. According to Bollerslev (1986), when this occurs, the GARCH model is unstable, indicating that the covariance process is not covariance-stationary. As a result, the estimates of volatility are overstated. This has important implications in valuing interest-rate sensitive financial products. Lamoureux & Lastrapes (1990) find that the explosive conditional variance may be due to structural changes in the variance process. For instance, if the variance is high but constant for some time and low but constant for some time, a simple GARCH model will overstate the volatility because it holds conditional variance fixed throughout the sample period. Therefore, allowing the conditional variance to switch within regimes or states may result in better estimates of volatility.

Chapter 3 summarises the results of testing the ARCH, GARCH, E-GARCH, GJR-GARCH and T-GARCH models for up to four regimes and six conditional distributions, to determine the best in-sample fit for the 3-month Jibar rate. Empirical results indicate that the 4-State

Threshold GARCH with Student's t distribution provides the best fit for the Jibar 3 month data between week 36 in 2001 and week 28 in 2018.

The volatility rate and mean reversion rate can be inputted into a model for the interest term structure of the Swap Zero curve derived in section 4.4.1 above, resulting in variations of the market value of the portfolio attributed to changes in market volatility. The mean reversion rate is 0.5336

Four volatility scenarios are considered:

1. A period of tranquil market conditions (taken as the mean volatility during the low volatility market state 1).
2. A period of normal market conditions (taken as the average mean volatility of the two normal market conditions states 2 and 3).
3. A period of market stress (taken as the mean volatility during the market stress state 4).
4. A period of extreme market stress (taken as the maximum volatility during the market stress state 4).

Table 4.7: Market volatility scenarios

Sigma values for market volatility scenarios			
Tranquil market	Normal market	Market stress	Extreme market stress
0.0091	0.0412	0.1642	0.3230

Source: Author's calculation.

4.4.3 IM methodology for the QPMM approach

The resulting market value of the four portfolios calculated under tranquil, normal, stress and extreme market stress conditions can then be used to generate a distribution of portfolio gains and losses, for which the worst-case loss according to a pre-determined confidence level can be calculated. The loss of a portfolio over a period (margin period of loss) is the negative change in the mark-to-market value of the portfolio. The close out period or margin period of loss used by SwapClear is five days for clearing members and seven days for clients. This analysis assumes that ODPs are clearing members and thus a five-day margin period of loss is assumed. Using the market value of these derivative

portfolios, the gains-loss distributions for all outstanding positions are calculated to establish the worst-case loss for:

- the CCP for centrally cleared swaps according to a pre-fixed confidence level of 99.7% following SwapClear’s framework for collateral demand on centrally cleared derivatives.
- the counterparties for bilateral trades according to a pre-fixed confidence level of 99% following the BCBS-IOSCO framework for collateral demand on non-centrally cleared derivatives in South Africa.

SwapClear uses an exponentially weighted moving average (EWMA) volatility scaling to give a higher weight to more recent historical data. EWMA can be seen as a special case of the single regime GARCH(1,1) model in which variance is a linear combination of the squared percentage change in the data and the previous period’s variance.

$$\sigma_t^2 = \alpha_0 + \alpha_1 r_{t-1}^2 + \beta \sigma_{t-1}^2$$

Equation 4.6: GARCH (1,1)

where $\alpha_0 = 0$, $\alpha_1 = 1 - \lambda$ and $\beta = \lambda$. Thus, the equation for EWMA is as follows:

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

Equation 4.7: EWMA equation

A decay parameter (λ) controls how quickly recent information is incorporated into the model’s estimate of volatility. The decay factor allows more recent returns to have a greater weight on the variance because each squared return is weighted by λ , which acts as a multiplier of the prior day’s weight. See table 4.8 for an illustration of the impact of a change in λ on the weighting of past observations. Thus, today’s variance equals yesterday’s variance (weighted by λ) plus yesterday’s squared return (weighted by $(1 - \lambda)$). When $\lambda = 1$, the model is never updated, and for smaller values of λ , recent information is given more weight. It is therefore expected that the larger the decay factor, the less pro-cyclical margin demands are. The popular RiskMetrics model uses a decay factor of 94%, while SwapClear uses a decay parameter of 99.2% (Reserve Bank of Australia, 2016). Therefore, the two

different λ values of 0.94 and 0.992 are tested to observe the degree to which IM demands change as the model updates with new information.

Table 4.8: The impact of a change in the decay factor on the weighting of past observations.

	Weighting of each observation ($\lambda = 94\%$)	Weighting of each observation ($\lambda = 99.2\%$)
r_{t-1}^2	$(1 - 0.94)(0.94)^0 = 6\%$	$(1 - 0.992)(0.992)^0 = 0.793\%$
r_{t-2}^2	$(1 - 0.94)(0.94)^1 = 5.64\%$	$(1 - 0.992)(0.992)^1 = 0.794\%$
r_{t-3}^2	$(1 - 0.94)(0.94)^2 = 5.30\%$	$(1 - 0.992)(0.992)^2 = 0.787\%$
r_{t-4}^2	$(1 - 0.94)(0.94)^4 = 4.68\%$	$(1 - 0.992)(0.992)^3 = 0.781\%$

Source: Author's calculations.

SwapClear's model is proprietary and impossible to fully replicate. It makes use of various anti-procyclicality features which this study was unable to replicate and therefore acknowledges that estimates would be biased upwards in times of market stress.

SwapClear uses a VaR/ES type risk measure (see equations 4.8 and 4.9 below) to generate a gain-loss distribution for each outstanding cleared portfolio. The worst-case loss on this gain-loss distribution is then calculated at a one-tailed 99.7%. The exact weighting attributed to VaR and ES respectively is not publicly disclosed; therefore, both are estimated to serve as the lower and upper bounds for the estimates. However, these lower and upper bounds are illustrative as the study is unable to fully replicate SwapClear's model.

The BCBS-IOSCO rules require IM model calculations to be benchmarked against IM amounts used by CCPs. Thus, the QPMM model is used for the final estimates, with a 99% confidence level as per the BCBS-IOSCO framework. However, in practice the ISDA's standard initial margin model or "SIMM" is the most commonly used model to calculate margin on non-centrally cleared derivatives globally. The model applies a sensitivity-based calculation across four product groups; interest rates and foreign exchange, credit, equity and commodities. The underlying calibration only changes annually which means it is less pro-cyclical than the methodology used in this study and thus results may be overstated if South African Authorities license the SIMM model.

The probability of a portfolio loss exceeding the value at risk is equal to 1- the confidence level or quantile (q) of the distribution: $P(r_t < -VaR_{1-q}) = 1 - q$

If $q = 99.7\%$, then $(1 - q) = 0.003 = \alpha$

The square root of the σ_t^2 estimate resulting from the EWMA model is used in the VaR and ES risk measures.

$$VaR_t^\alpha = \sigma_t \Phi_\alpha^{-1}$$

Equation 4.8: VaR

$$ES_t^\alpha = \sigma_t \frac{\varphi(\Phi_\alpha^{-1})}{\alpha}$$

Equation 4.9: ES

where σ_t is the square root of the σ_t^2 estimate resulting from the EWMA model, Φ is the cumulative distribution function of the standard normal distribution, and φ is the density function of the standard normal distribution. The use of a gaussian or standard normal distribution is less desirable than a distribution which accounts for the fat tails in the data identified in Chapter 3 however not possible using the software programme.

Therefore, IM demands in ZAR will be calculated for each of the four portfolios, using the four market volatility scenarios and two decay factors using the ES and VaR methodology. IM demanded on non-centrally cleared derivatives may be re-hypothecated once, in other words, the velocity of collateral is limited to 2 by regulation. Re-hypothecation is not permitted for centrally cleared derivatives. See Chapter 2, section 2.3.2.1 for more information about the re-hypothecation of collateral.

4.4.4 DF methodology for centrally cleared derivatives using the QPMM approach

SwapClear's DF is calculated to cover the unmargined PFE if the two largest clearing members defaulted (cover 2 charge), plus a 10% buffer (BCBS-IOSCO, 2016). Unmargined exposures are the result of the worst-case loss minus IM contributions. According to Lin & Surti (2015), this amount is then mutualised across all its clearing members in a pro-rata

fashion. The volatility estimate is doubled for each of the four volatility scenarios to reflect the worst-case loss under each scenario. SwapClear’s methodology for DF contributions is proprietary as is SwapClear’s IM methodology, therefore the DF estimates will be calculated for the two cleared portfolios with information that is publicly available, i.e. according to a 99.7% confidence level and a decay factor of 99.2%. The VaR and ES risk measures will serve to loosely illustrate the lower and upper bounds for the DF. Once again, the anti-procyclical measures employed by SwapClear’s model could not be replicated and therefore the illustrative estimates are assumed to be more procyclical than reality. It is possible that South African ODPs who become SwapClear clearing members’ contribution would not exceed the minimum DF contribution of 10 million GBP.

4.4.5 IM methodology for the SMS approach

The BCBS-IOSCO specifies the SMS approach; it is computationally simple and is only sensitive to changes in the net-to-gross ratio. The first step is to calculate the gross IM by multiplying the gross notional exposure of each derivative by the IM rates specified in table 4.9.

Table 4.9: Standardised IM schedule

Asset class	Duration	IM requirement (as a % of gross notional exposure)
Credit	0-2 years	2%
	2-5 years	5%
	5 years +	10%
Commodity	All	15%
Equity	All	15%
Foreign exchange	All	6%
Interest rate	0-2 years	1%
	2-5 years	2%
	5 years +	4%
Other	All	15%

Source: BCBS-IOSCO (2015b).

A percentage of the gross IM is then adjusted by a ratio of the net current replacement cost to gross current replacement cost (NGR) according to equation 4.10 below:

$$\text{Net standardised IM} = 0.4 \times \text{Gross IM} + 0.6 \times \text{NGR} \times \text{Gross IM}$$

Equation 4.10: Net standardised IM

NGR is the ratio of the net current replacement cost to gross current replacement cost for transactions subject to the relevant legally enforceable netting agreement, where the net replacement cost is the maximum of zero and the sum of current market values of all OTC derivative transactions in the netting set. Equation 4.10 and the relative percentages may be adjusted by the PA from time to time.

The total IM required, according to the standardised margin schedule is the net standardised IM amount. Setting the NGR to 0 provides the lower bound for estimates, while the upper bound is given when NGR is set equal to 1.

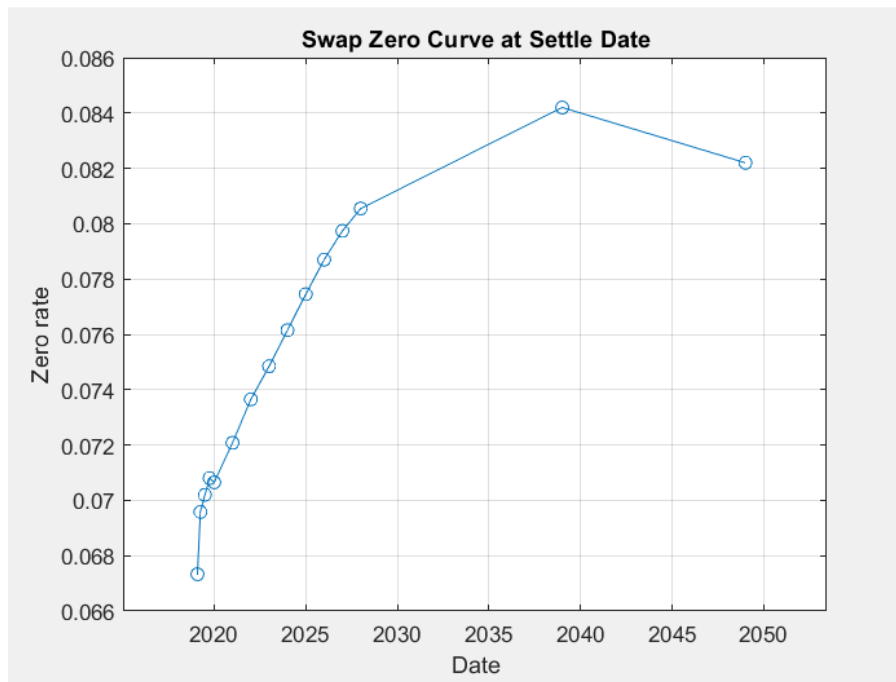
4.5 Results

The analysis for market structure scenarios 1 and 2 assumes all existing contracts as of December 2018, which are clearing eligible are cleared through a CCP and the balance is subject to IM requirements on non-centrally cleared derivatives at a threshold of 100 billion ZAR for covered entities. The analysis for market structure scenario 3 assumes all existing contracts remain uncleared and that they are subject to the BCBS-IOSCO's margining requirements using the SMS approach.

4.5.1 IM requirements for cleared and non-centrally cleared derivatives in potential market structure scenario 1 using the QPMM approach.

The Swap Zero Curve (figure 4.2) is constructed using South African market interest rates up to thirty years, covering the remaining time to maturity of the portfolios.

Figure 4.2: Swap Zero Curve



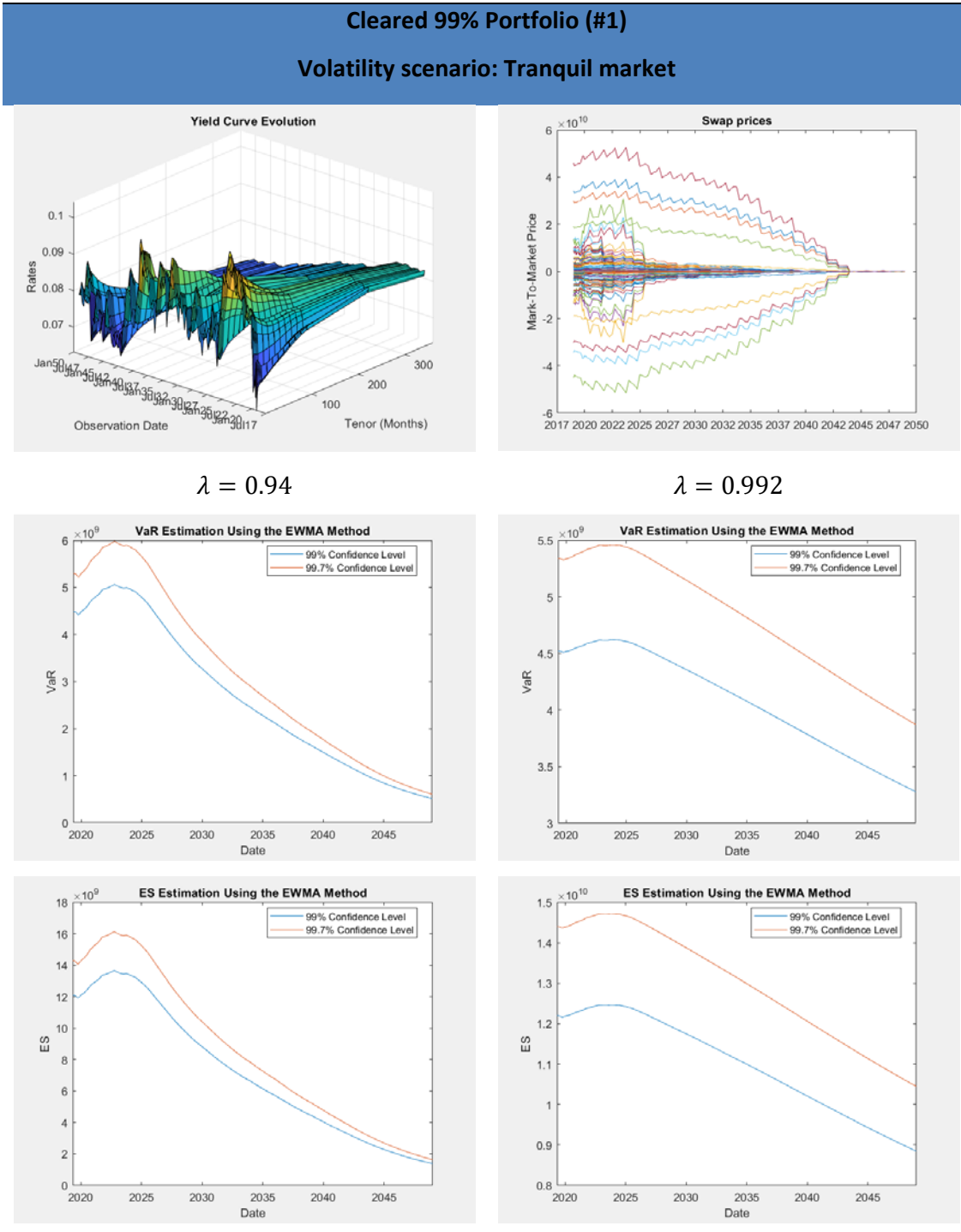
Source: Created by Author using data from Bloomberg.

The IM for the four portfolios is estimated using the two risk measures (VaR and ES) at two pre-fixed confidence levels (99% and 99.7%), varying the volatility (tranquil, normal, stress and extreme market stress scenarios), and decay factors (94% and 99.2%). The results for each combination of inputs are found in appendix B. For convenience, table 4.10 is shown below as an example.

The evolution of the Swap Zero Curve depends on the mean reversion (α) and volatility (σ) inputs for the Hull-White single-factor model. α is held constant while σ is varied to represent tranquil, normal, stress and extreme market stress scenarios. The Swap Zero Curve Evolution is presented in the top left quadrant of table 4.10. The mark-to-market swap prices are presented in the top right quadrant. The mark-to-market values fluctuate greatly at the beginning of the period and then taper off. This is because the potential changes in market value are calculated for the outstanding contracts up to their maturity. As IRS gets closer to maturity, its values will begin to approach zero and have a zero value after maturity. 46.8% of notional amounts outstanding in each of the portfolios have a remaining time to maturity of fewer than two years (See table 4.10), explaining the steep decline in VaR and ES after around two years. This is because the study assumes a static portfolio as of

31 December 2018 after which no new contracts are created, and all existing contracts approach maturity.

Table 4.10: Results for Cleared 99% Portfolio (#1) under tranquil market conditions



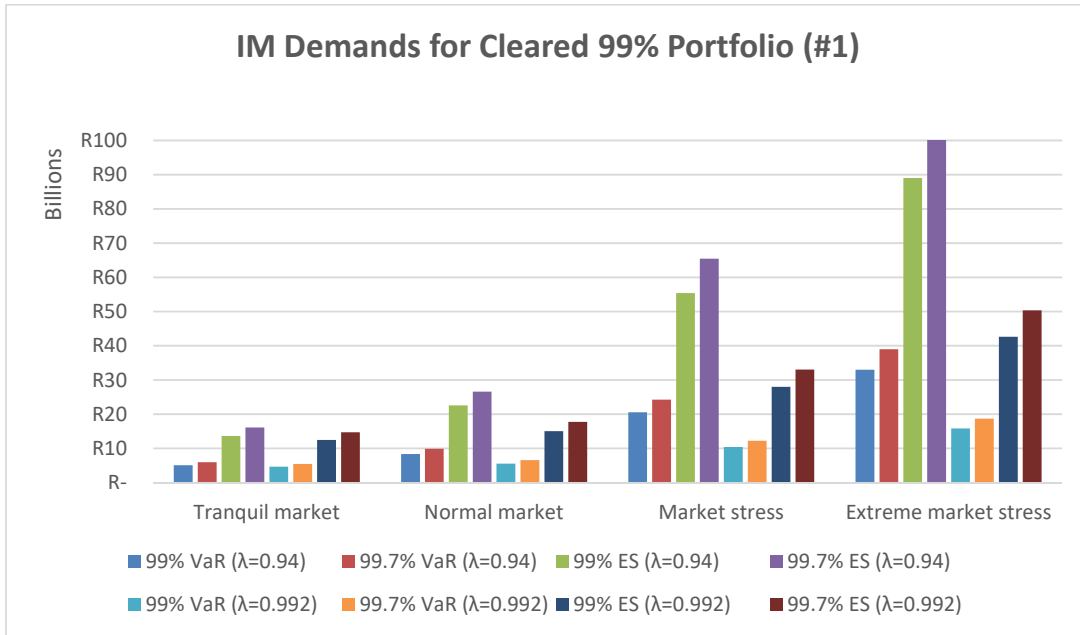
Source: Author's calculation.

Figures 4.3 to 4.6 illustrate the IM sensitivity of the four portfolios to the risk measure used, the confidence level, decay factor and volatility scenario. As anticipated, the use of the ES risk measure over the VaR measure results in significantly higher IM demands. On average, moving to an ES risk measure increases IM demands by 2.7 times the VaR amount. Increasing the confidence level from 99% as prescribed for non-centrally cleared derivatives to 99.7% as used by SwapClear results in more conservative IM demands, increasing IM demands by 18%.

The higher decay factor used by SwapClear (99.2%) results in a lower peak IM and a slower reaction to recent information than the RiskMetrics (94%) model in all cases. The relative impact varies greatly according to the market volatility scenario. In tranquil market conditions for portfolios with a 99% degree of direct hedging, holding the other input variables constant, the lower decay factor increases IM demands by 10%. This difference increases to 50% under normal market conditions, 98% under market stress and 109% in the extreme market volatility scenario. The two portfolios with a 90% degree of direct hedging were subject to a 10%, 54%, 100% and 109% increase under the various volatility scenarios when varying the decay factor from 99.2% to 94%. Thus, using a higher decay factor results in margin demands that are less sensitive to changes in volatility.

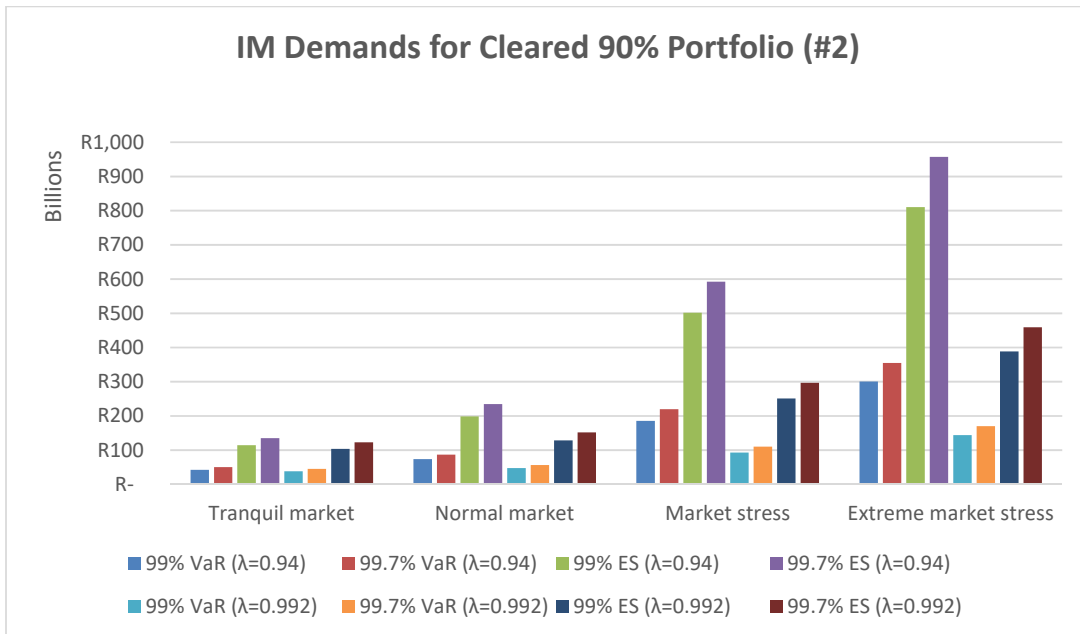
The comparison of figure 4.3 with figure 4.4 and figure 4.5 with figure 4.6 illustrates that lowering the degree of direct hedging greatly increases estimates for both the cleared and uncleared portfolios under all conditions. Decreasing the degree of direct hedging assumed from 99% to 90% increases IM demands by between 733% and 812%. As mentioned in table 4.1; Lin & Surti (2015) found that the IM and DF amounts held by SwapClear in their end year 2011 report correspond with a degree of direct hedging between 99% and 99.5%. Therefore, the 99% portfolio may represent the more realistic collateral demands.

Figure 4.3: IM Demands for Cleared 99% Portfolio (#1)



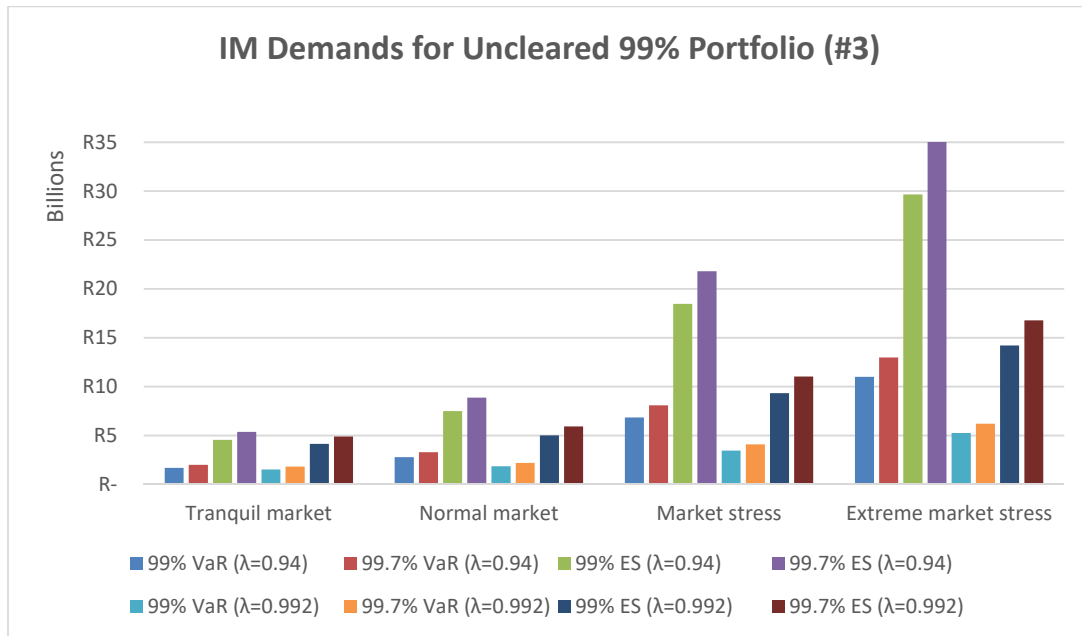
Source: Author's calculation.

Figure 4.4: IM Demands for Cleared 90% Portfolio (#2)



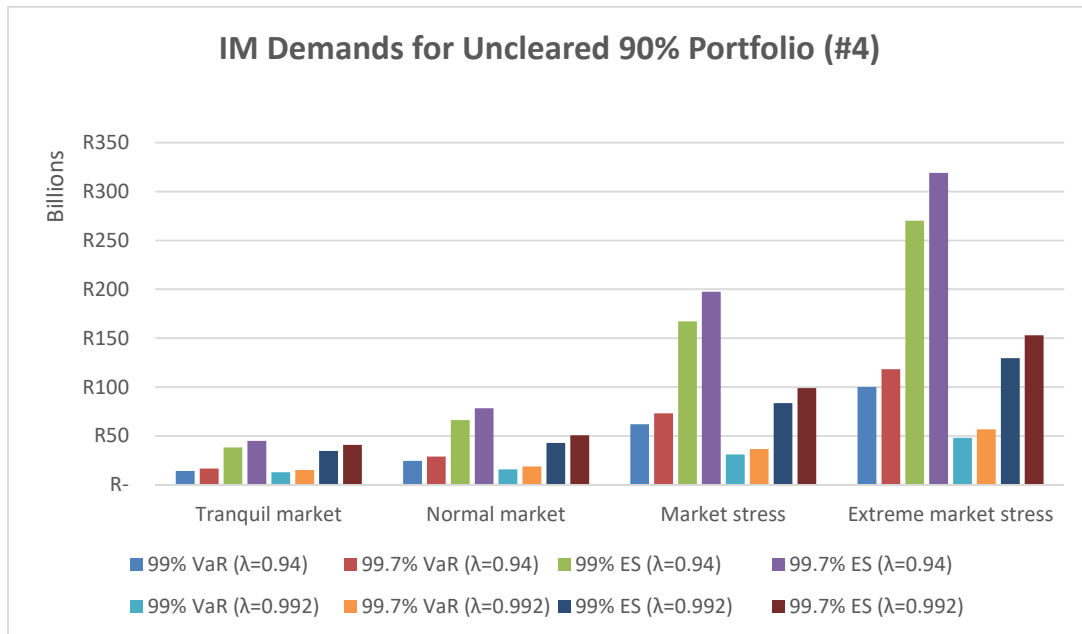
Source: Author's calculation.

Figure 4.5: IM Demands for Uncleared 99% Portfolio (#3)



Source: Author's calculation.

Figure 4.6: IM Demands for Uncleared 90% Portfolio (#4)



Source: Author's calculation.

IM demands are shown to be sensitive to changes in all of the model inputs tested. Demands fluctuate greatly depending on the volatility scenario, risk measure, decay factor and to a lesser extent, the confidence level. However, the greatest impact observed in this study is the degree of direct hedging assumed. This indicates that individual ODP has a substantial degree of direct control over the degree of their exposure to IM demands and that it is the degree of direct hedging rather than the aggregate portfolio size in nominal terms that determines the degree of exposure to IM, although in practice the 99% degree of direct hedging may be more realistic. In practice, the decay factor, weighting ascribed to each risk measure and the confidence level will remain relatively static, following the methodology set out by the BCBS-IOSCO for uncleared derivatives and the methodology of the chosen CCP. Market volatility is a source of pro-cyclicality in margin demands because as market volatility increases, so does CCR, and therefore by necessity, IM demands increase to protect against rising CCR. However, maintaining near balanced portfolios will significantly reduce ODP's exposure to changes in market volatility.

For the final estimates of IM, the inputs for the cleared portfolios are a 99.7% confidence level, and a decay factor of 99.2%. A 99% confidence level and a decay factor of 99.2% are assumed for the uncleared portfolios. The ES and VaR measures serve as the upper and lower bounds, respectively, for each volatility scenario. Finally, the impact of different regulations regarding re-hypothecation imposed on cleared and uncleared portfolios are captured. The velocity of collateral is 1 for the cleared portfolios and 2 for the uncleared portfolios.

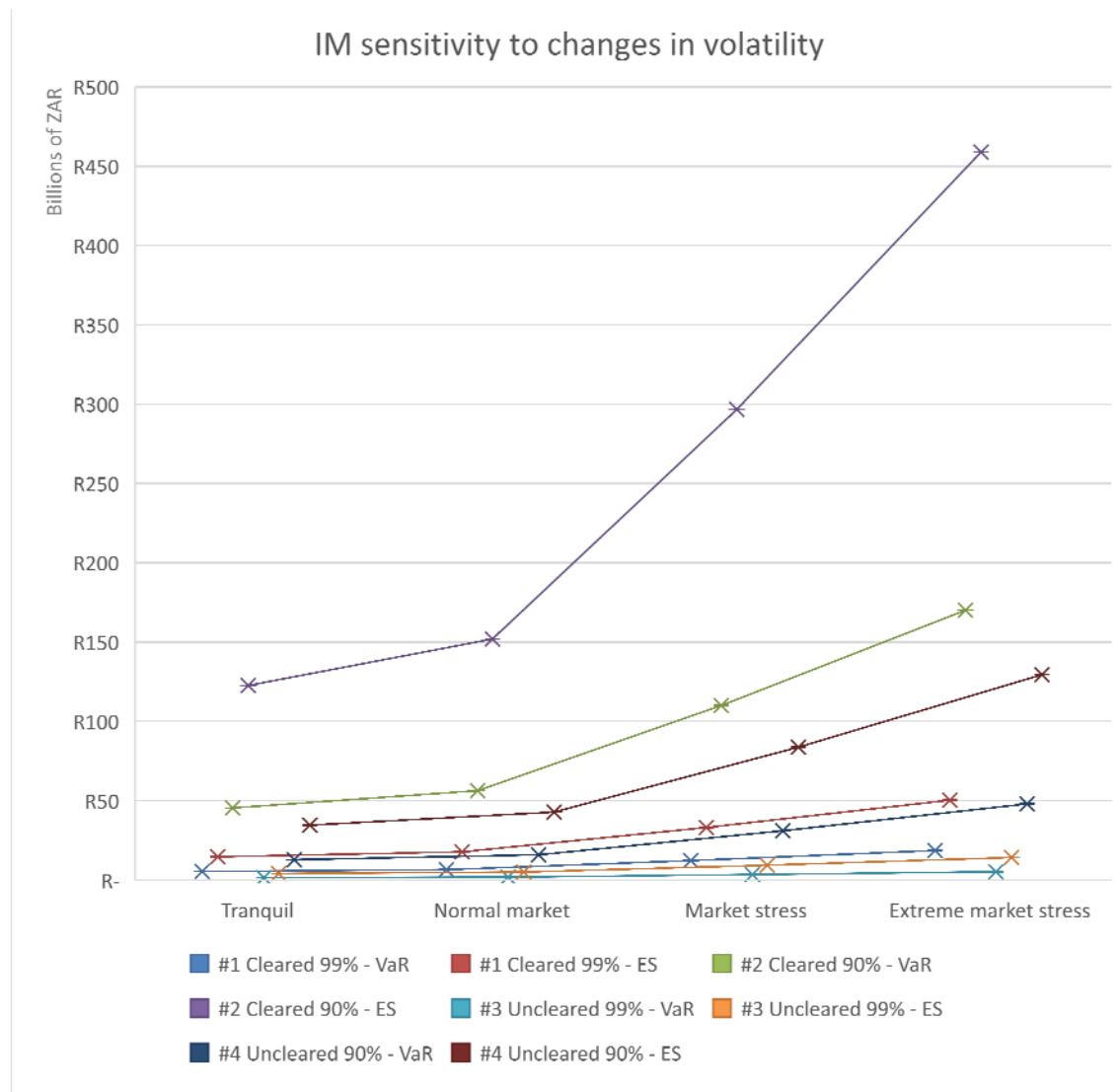
Table 4.11: IM estimates for cleared and uncleared portfolios in billions of ZAR - Market Structure Scenario 1

FINAL IM - no re-hypothecation									
VaR	Tranquil	Normal market stress	Market stress	Extreme market stress	ES	Tranquil market stress	Normal market stress	Market stress	Extreme market stress
#1 Cleared 99%	5.5	6.6	12.3	18.7	#1 Cleared 99%	14.7	17.8	33.1	50.3
#2 Cleared 90%	45.5	56.3	109.9	170.1	#2 Cleared 90%	122.7	151.9	296.6	458.9
#3 Uncleared 99%	1.5	1.9	3.5	5.3	#3 Uncleared 99%	4.2	5	9.3	14.2
#4 Uncleared 90%	12.8	15.9	31	48	#4 Uncleared 90%	34.6	42.9	83.7	129.5
FINAL IM - WITH re-hypothecation									
VaR	Tranquil market stress	Normal market stress	Market stress	Extreme market stress	ES	Tranquil market stress	Normal market stress	Market stress	Extreme market stress
#1 Cleared 99%	5.5	6.6	12.3	18.7	#1 Cleared 99%	14.7	17.8	33.1	50.3
#2 Cleared 90%	45.5	56.3	109.9	170.1	#2 Cleared 90%	122.7	151.9	296.6	458.9
#3 Uncleared 99%	0.75	0.95	1.75	2.65	#3 Uncleared 99%	2.1	2.5	4.65	7.1
#4 Uncleared 90%	6.4	7.95	15.5	24	#4 Uncleared 90%	17.3	21.45	41.85	64.75
Final upper and lower bound IM demands for the South African market depending on the direct hedging assumption across volatility scenarios - including the effect of re-hypothecation									
	Tranquil market	Normal market	Market stress	Extreme market stress		Tranquil market stress	Normal market stress	Market stress	Extreme market stress
99% Direct hedging	6.3 – 16.8	7.6 – 20.3	14.1 – 37.8	21.4 – 57.4		14.7 – 33.1	17.8 – 33.1	33.1 – 50.3	50.3 – 129.5
90% Direct hedging	51.9 – 140	64.3 – 173.4	125.4 – 338.5	194.1 – 523.7		122.7 – 296.6	151.9 – 296.6	296.6 – 458.9	458.9 – 1295.0

Source: Author's calculation. The models were estimated using Matlab, all code and output results are available on request.

IM demands are highly sensitive to changes in market volatility, with increasing volatility resulting in large increases in IM demands for all four portfolios³. See figure 4.7; the impact is the largest with portfolio #2 (cleared 90%) using ES. IM demands increase from 122.7 billion ZAR to 458.9 billion ZAR when transforming from tranquil market conditions to extreme market stress. Compared to 45.5 billion ZAR and 170.1 billion ZAR when using the VaR risk measure for the same portfolio.

Figure 4.7: IM sensitivity to changes in volatility



Source: Author's calculation.

³ In practice firms would be expected to change their portfolios as they adapt to a different volatility regime and thus margin would change accordingly.

4.5.2 DF requirements for centrally cleared derivatives in potential market structure scenarios 1 and 2.

Table 4.12 below presents the DF charge for the two cleared portfolios according to the direct hedging assumption. As expected the DF amounts are also highly sensitive to changes in market volatility, because the methodology is based upon the IM methodology for the cleared portfolios under a greater degree of market stress.

Once again, the degree of direct hedging has the largest impact on collateral demands. Under a direct hedging assumption of 99% in a period of extreme market stress, the DF demand is between 5.8 billion ZAR and 16.7 billion ZAR while under the 90% assumption the DF demand rises to between 55.2 billion ZAR and 148.8 billion ZAR.

SwapClear has a flat minimum DF contribution of £10 million per clearing member which serves as the floor for DF contributions. At an exchange rate of GBP/ZAR 20 then the total minimum contribution for all 6 ODPs used in the analysis would be 1.2 billion ZAR. This minimum amount is only higher than the tranquil market estimates for the 99% cleared portfolio using VaR and ES and it is the same as the normal market estimate for the 99% cleared portfolio using VaR.

Table 4.12: DF estimates for cleared portfolios in billions of ZAR

#1 Cleared 99%									
VaR	Tranquil market	Normal market	Market stress	Extreme market stress	ES	Tranquil market	Normal market	Market stress	Extreme market stress
Stressed IM for CM 1	2	2.9	6.6	9.6	Stressed IM for CM 1	5.4	7.9	17.8	25.8
IM contribution for CM 1	1.9	2.3	4.3	6.54	IM contribution for CM 1	5.1	6.2	11.6	17.6
	0.1	0.6	2.3	3.06		0.3	1.7	6.2	8.2
Total for CM 1 (Plus 10%)	0.11	0.66	2.53	3.37	Total for CM 1 (Plus 10%)	0.33	1.87	6.82	9.02
Stressed IM for CM 2	1.5	2.2	4.9	7.1	Stressed IM for CM 2	4	5.9	13.2	19.2
IM contribution for CM 2	1.4	1.7	3.2	4.9	IM contribution for CM 2	3.8	4.6	8.6	13.1
	0.1	0.5	1.7	2.2		0.2	1.3	4.6	6.1
Total for CM 2 (Plus 10%)	0.11	0.55	1.87	2.42	Total for CM 2 (Plus 10%)	0.22	1.43	5.06	6.71
Total for cover 2 DF charge	0.22	1.21	4.4	5.79	Total for cover 2 DF charge	0.55	3.3	11.88	15.73
#2 Cleared 90%									
VaR	Tranquil market	Normal market	Market stress	Extreme market stress	ES	Tranquil market	Normal market	Market stress	Extreme market stress
Stressed IM for CM 1	16.8	25.8	60.2	88.3	Stressed IM for CM 1	45.4	69.7	162.3	238.2
IM contribution for CM 1	15.9	19.7	38.5	59.5	IM contribution for CM 1	42.9	53.2	103.8	160.6
	0.9	6.1	21.7	28.8		2.5	16.5	58.5	77.6
Total for CM 1 (Plus 10%)	0.99	6.71	23.87	31.68	Total for CM 1 (Plus 10%)	2.75	18.15	64.35	85.36
Stressed IM for CM 2	12.5	19.2	44.7	65.6	Stressed IM for CM 2	33.2	51.8	120.5	177
IM contribution for CM 2	11.8	14.6	28.6	44.2	IM contribution for CM 2	31.9	39.5	77.1	119.3
	0.7	4.6	16.1	21.4		1.3	12.3	43.4	57.7
Total for CM 2 (Plus 10%)	0.77	5.06	17.71	23.54	Total for CM 2 (Plus 10%)	1.43	13.53	47.74	63.47
Total for cover 2 DF charge	1.76	11.77	41.58	55.22	Total for cover 2 DF charge	4.18	31.68	112.09	148.83
Final upper and lower bound DF demand for the South African market depending on the direct hedging assumption across volatility scenarios									
	Tranquil market	Normal market	Market stress	Extreme market stress		Tranquil market	Normal market	Market stress	Extreme market stress
99% Direct hedging	0.2 – 0.6	1.2 – 3.3	4.4 – 11.9	5.8 – 16.7		5.8 – 16.7			
90% Direct hedging	1.8 – 4.2	11.8 – 31.7	41.6 – 112.1	55.2 – 148.8		55.2 – 148.8			

Source: Author's calculation. The models were estimated using Matlab, all code and output results are available on request.

4.5.3 IM requirements for non-centrally cleared derivatives in potential market structure scenario 2.

The results for the cleared portfolios are the same as those in section 4.5.1; however, the IM for the uncleared portfolio is now calculated using the SMS approach rather than the QPMM approach.

The SMS approach is only sensitive to changes in the NGR. Setting the NGR equal to 0 (1) provides the lower (upper) bound for estimates. If IM requirements for only 25% of derivatives are calculated using the SMS, the estimate varies between 56 - 140 billion ZAR. Allowing collateral to be re-hypothecated only once brings the total demand to 28 – 70 billion ZAR.

The highest estimate after re-hypothecation for the 90% uncleared portfolio calculated using ES and under extreme market conditions was 64.75 billion ZAR. Thus, assuming an NGR of 1 results in a higher IM requirement using the SMS approach than the most conservative requirement using the QPMM approach. The lower bound IM requirement using the SMS approach is approximately equivalent to the extreme market stress amount using VaR and higher than the normal market stress amount using ES for the 90% uncleared portfolio. Therefore, the use of the SMS approach results in much higher IM requirements during tranquil and normal market conditions than the QPMM.

4.5.4 IM requirements for non-centrally cleared derivatives in potential market structure scenario 3 using the SMS approach.

If IM requirements for 100% of the market are calculated using the SMS approach, the estimate varies between 224 and 560 billion ZAR. Allowing for re-hypothecation, the requirement declines to between 112 and 280 billion ZAR. Before re-hypothecation, the upper bound IM estimate is higher than the upper bound under extreme market stress for the market under a 90% hedging assumption. After re-hypothecation, the lower and upper bound estimates are lower than the lower and upper bound estimates respectively under market stress assuming 90% direct hedging. Therefore, using the SMS approach for the whole market, IM requirements are more conservative than the QPMM results under tranquil and normal market stress; however, they do not spike under market stress and

extreme market stress. In addition, when central clearing isn't mandated, there are no DF requirements.

4.6 Conclusion

In this Chapter, collateral demands that could result from the enforcement of margining requirements on South African ODP's are estimated under three potential market structure scenarios. In the market structure scenario 1 considered, data combined from ODP's financial statements as well from the SARB are used to calibrate the simulated long and short portfolio positions. IM requirements for assumed centrally cleared and non-centrally cleared portfolios were calculated using the QPMM approach with two assumptions of the degree of direct hedging (90% and 99%) and based on four volatility regimes (tranquil, normal, stress and extreme market stress). In addition, DF requirements were calculated using the two assumptions of the degree of direct hedging and based on the four market volatility regimes for the cleared portfolios. The volatility regimes were extracted from historical data for the benchmark interest rate for South African IRS using a Markov-Switching GARCH, see Chapter 3 for more information. The sensitivity to model inputs such as the decay factor and the confidence level was also examined. The risk measures VaR and ES were used to construct the lower and upper bounds for estimates, respectively.

Changes in the model decay factor have a significant impact on the pro-cyclicality of QPMM IM demands. Giving a higher weight to more recent data (i.e. a lower decay factor) is more pro-cyclical due to the rapid decline in the weight given to previous observations. Given the IM sensitivity to the decay factor, a prescriptive rule for the decay factor set by authorities and global standard-setting bodies is justified to ensure consistency across QPMM models and to limit pro-cyclicality. The results suggest that to the extent that past market volatility is an indication of the possible future distribution of market volatility, IM and DF requirements could fluctuate greatly. IM calls are made daily and even intra-daily, which means a sharp increase in market volatility can cause a jump in IM demands. A quick transition from tranquil to extreme market stress could increase IM demands by as much as 3.7 times the amount. For example, from 122.7 billion ZAR to 458.9 billion ZAR, assuming 90% direct hedging in the centrally cleared portfolio. Increasing margin demands could have a second-round detrimental effect on market volatility via a liquidity spiral. Ultimately, the

degree of sensitivity to changes in market volatility is determined by the degree of direct hedging in the portfolio, although in practice the 99% degree of direct hedging may be more realistic. Thus, ODPs can limit their exposure to IM and DF requirements by balancing their books instead of using internal delta hedging techniques.

The IM requirements for non-centrally cleared derivatives are more conservative when using the SMS approach compared to the QPMM approach. In the market structure scenario 2, the IM requirements on non-centrally cleared derivatives are much higher during tranquil and normal market conditions under both hedging assumptions than market structure scenario 1. However, a key finding of the study is that if central clearing is not mandated (market structure scenario 3), total collateral costs using the SMS approach are restricted to between 112 and 280 billion ZAR, depending on bilateral netting benefits. This is less than under market stress conditions assuming a 90% direct hedging assumption in market structure scenarios 1 and 2. This is because, under the BCBS-IOSCO's rules for both the QPMM and SMS approach to calculating IM requirements, collateral is allowed to be re-hypothecated once. In addition, non-centrally cleared derivatives do not require contributions to a CCP's DF. However, even after including contributions to a CCP's DF, the collateral costs under market structure scenario 3 are higher than under tranquil or normal market stress conditions in market structure scenarios 1 and 2. For this reason, ODPs using the SMS approach are incentivised to clear those contracts that are initiated during tranquil and normal market conditions under a 90% direct hedging assumption and they are always incentivised to centrally clear under a 99% direct hedging assumption. The SMS approach avoids pro-cyclicality; however, CCR may be overcovered during tranquil or normal market stress conditions which increases market costs. Conversely, CCR would be under covered during times of market stress and extreme market stress.

Mandatory central clearing and IM requirements for bilateral contracts are intended to reduce CCR in the global derivatives market; however, the extreme sensitivity to QPMM model parameter calibrations could increase systemic risk if collateral demands are not met. Thus, Authorities may consider IM floors and ceilings which would reduce the pro-cyclical nature of IM demands while still allowing them to fluctuate with market volatility as they should do to more accurately reduce CCR. This would make ODPs and their end-user clients more resilient to unexpected shocks and extreme tail losses and lessen the pressure on

HQLA demand from the OTC derivatives market during times of market stress. In contrast, the conservative IM requirements resulting from the SMS approach are not pro-cyclical; however, they are definitely more costly during tranquil and normal market conditions. The two approaches effectively represent a trade-off between accurate market risk protection and pro-cyclicality. A benefit of the SMS approach is that it is a transparent and straightforward methodology which may be more appealing to smaller market participants who are not able to develop and maintain a risk-sensitive QPMM model. However, the ISDA's SIMM has developed to be the preeminent methodology used to calculate IM requirements on non-centrally cleared derivatives which means there would be pressure on ODPs to use the SIMM when dealing with foreign counterparties. This would then translate to pressure on Authorities to license SIMM. The study only estimates IM requirements for South African ODPs; the IM requirements for their clients are not considered. Thus, estimates do not cover the entire market and are therefore understated. However, dealers are at the core of the market, with two-thirds of total notional amounts outstanding being inter-dealer transactions. In addition, "uncovered entities" such as non-financial end-users that are not systemically important, and some sovereigns are exempt from posting IM; however, these make up only 2% of the total South African market according to the IMF. These exemptions reduce the incentives for central clearing for these end-users. As noted by the DAT, only if the dealer spread on non-centrally cleared derivatives is high enough to offset the clearing fees and mandatory IM on all cleared trades, are these end-users incentivised to centrally clear.

In practice IM requirements on cleared and uncleared derivatives will be subject to a grandfathering exemption; in other words, only new contracts entered into after the implementation of the requirements will be subject to the requirements. The South African derivatives market has seen a general upward trend in gross notional amounts outstanding for over a decade (see figure 1.1). The IM and DF requirements estimated above are based on the market size as of December 2018; thus, the effect of IM requirements on future market size and therefore, future IM requirements is unknown. IM requirements on non-centrally cleared derivatives are not yet in force in South Africa, and no CCP has been licenced to date. None of the South African ODPs are expected to exceed the first, second or third implementation thresholds for IM requirements on non-centrally cleared derivatives.

CHAPTER 5

FOREIGN EXCHANGE RATE EXPOSURE

5.1 Introduction

The final research objective, which is to quantify and examine the foreign exchange rate risk that ODPs would be exposed to should an international CCP be licenced by Authorities, is addressed in this Chapter. The IM and DF contributions on centrally cleared derivatives under the three potential market structure scenarios calculated in Chapter 4 are used to quantify and examine the foreign exchange rate risk that ODPs would be exposed to through an international CCP.

SwA depreciation of the local currency increases the relative cost of unhedged foreign currency denominated liabilities for individual South African firms. Thus, membership or even client clearing through an international CCP could expose derivative market participants to foreign exchange rate risk. Licencing an international CCP may expose South African ODPs to foreign exchange rate risk as currently, the biggest international CCP clearing IRS, SwapClear, does not accept IM in ZAR and DF contributions are exclusively accepted in GBP. This exposure could increase rapidly as CCPs are able to demand IM as frequently as intra-day. The exposure may be managed with natural or synthetic hedging strategies as discussed in section 5.2.1 below; however, IM and DF⁴ requirements would fluctuate with exchange rate volatility. As at February 14 2019, the South African rand had reclaimed its position as the most volatile currency in the world from the Turkish lira, primarily due to concerns that turmoil at the state-owned electricity company (Eskom) could lead to a sovereign credit rating downgrade (Goko, 2019) which did materialise in early 2020. The rand then reached an all-time low during the Covid-19 crisis of Q1 2020. In addition to high volatility, a sustained period of depreciation may make hedging more costly.

⁴ DF contributions would not fluctuate if South African ODPs cleared as clients.

It is consequential to estimate the potential foreign exchange rate exposure of South African ODPs from clearing through an international CCP for macroprudential and microprudential stability. According to Heath, Kelly & Manning (2012), an excess demand for HQLA in a foreign denominated currency could lead to a financial crisis because the local central bank is not the ultimate source of the needed liquidity. This is particularly true for institutions in the periphery of a central clearing network, for instance, small dealers like SA ODPs and domestic end-users. The two currencies (against the ZAR) considered in this analysis are the GBP as it is the preferred currency accepted by SwapClear as well as the USD because it is still the world's top reserve currency (IMF, 2019). An estimation of risk is crucial to limiting the misallocation of capital, for this reason, the presence of regime-switching, asymmetry, and different conditional distributions are tested for. As per the methodology used in Chapter 3, this study will investigate the in-sample accuracy of the ARCH, GARCH, E-GARCH, GJR-GARCH and T-GARCH models for up to four regimes and six conditional distributions for both currencies. The top-performing model is then used to estimate the VaR and ES for both exchange rates at a 99% confidence level to evaluate the exchange rate risk exposure to local ODPs through their cleared derivative portfolios.

5.2 Literature review

Most countries abandoned fixed exchange regimes in favour of floating regimes after the fall of the Bretton Woods system in 1973. The ZAR has been allowed to freely float since South African financial market liberalisation in 1995. However, the SARB does reserve the right to intervene to avoid excessive fluctuations of the ZAR (Hsing, 2016). The international movement towards floating exchange rate regimes has resulted in an increase in the daily volatility of exchange rates as well as the creation of techniques and financial products to mitigate exchange rate risk, these are discussed in section 5.2.2. According to Mpofu (2016), the movement to a floating regime has resulted in increased nominal and real ZAR volatility. Attempts to explain and forecast exchange rate movements have dominated international economics since exchange rates have been allowed to float. Section 5.2.1 discusses structural models of exchange rate determination, the random walk hypothesis and the potential presence of regime-switching.

5.2.1 Models of exchange rate determination

In the decades following the movement to floating exchange rates, the monetary structural models of exchange rate determination came to dominate the literature. Meese & Rogoff (1983a & 1983b) tested the out-of-sample performance of the Frenkel-Bilson, Dornbusch-Frankel and Hooper-Morton monetary structural models. The Frenkel-Bilson model assumes that prices are perfectly flexible, money markets are always in equilibrium and purchasing power parity (PPP) holds. PPP postulates that arbitrage will ensure that the exchange rate equates the cost of goods in the domestic currency with that of the foreign currency. The Dornbusch-Frankel model, on the other hand, allows deviations from PPP in the short-run due to sticky prices which gradually adjust and are flexible in the long-run. The Hooper-Morton model extends the Dornbusch-Frankel model by incorporating the trade balance which allows for long-run deviations from PPP. Meese & Rogoff (1983a & 1983b) found that none of these models were able to outperform a simple random walk in the short-term (less than a year).

Cheung, Chinn & Pascual (2003) tested the in-sample and out-of-sample performance of the more modern structural models; uncovered interest rate parity (UIP), productivity model and a behavioural equilibrium exchange rate (BEER) model. UIP states that the interest rate differential between countries will equal the expected change in the exchange rate between those countries. Productivity models assume that PPP does not hold and movements in the real and nominal exchange rate are due to productivity differentials between countries caused by different rates of technological progress. The BEER model is an extension of PPP which seeks to explain long-run changes in purchasing power. Cheung, Chinn & Pascual (2003) found that none of these modern models were able to outperform a random walk in the short-term, however, they found outperformance in the long-term is likely. Despite their limitations, structural theories may be able to explain the long-term exchange rate movements; however, they have had difficulty in explaining empirically observed short-term exchange rate volatility (Salvatore, 2011).

The short-term explanatory success of a random walk over various structural models may be due to the highly competitive nature of global foreign exchange markets with quick price discovery and a large number of competing buyers and sellers. However, the degree of

market efficiency, or whether the Efficient Market Hypothesis (EMH) always holds, is debated. Behavioural economics highlights the cognitive biases and predictable errors in human behaviour which could lead to a violation of even weak-form efficiency. Yamani (2017) tests market efficiency for a group of developed and developing countries and finds that during periods of low volatility, the random walk hypothesis is accepted for both developed and developing foreign exchange markets. However, during a period of extreme market volatility, developing markets' efficiency deteriorated rejecting the random walk hypothesis. This is possibly due to the "flight-to-quality" phenomenon whereby investment shifts away from assets that are perceived as risky, resulting in a reduction of liquidity in developing markets. The CGFS (2013) also found that global liquidity shocks typically involve shortfalls in foreign exchange liquidity.

Engel & Hamilton's (1990) pioneering work finds that there are long swings in the quarterly USD exchange rate against major currencies between 1973 and 1988, which persist over time, rejecting the random walk hypothesis. They do so by testing the null hypothesis that the change in the exchange rate during the current period is independent of the state in the previous period, i.e. $H_0: p_{11} = 1 - p_{22}$. In other words, the null hypothesis is that exchange rates follow a martingale (where the expected value of the next random variable in a sequence, given all prior values, is its current value) and the alternative is the presence of segmented trends. If the null holds, the probability of currently being in a state does not depend on the state of the previous period; thus, the process follows a random walk. They reject the null and find that long swings are captured by a Markov-switching process which is a feature of changing underlying economic conditions. Engel & Hamilton find that a two regime Markov-switching process outperforms a random walk both in-sample and out-of-sample in the short-term. Kirikos (2000) uses Engel & Hamilton's methodology and expands the quarterly data set to 1973-1997, finding that the Markov-switching model outperforms a random walk in out-of-sample in the short-term; however, the random walk performs better within in-sample forecasts. Kirikos concludes that despite the relatively better performance in-sample forecasting, the exchange rate does not follow a random walk. Cheung & Erlandsson (2005) offer evidence of the presence of Markov switching dynamics in monthly USD based exchange rates, concluding that high data frequency and large sample size are crucial for determining the number of regimes. Goutte & Zou (2011) find that

allowing regime switching in foreign exchange rate data results in superior explanatory power in-sample. Akinboade & Makina (2006) find that structural breaks in the ZAR exchange rate against its major trading partners must be accounted for when forecasting, otherwise results may be spurious. Yuan (2011), using quarterly data from 1973-2007 for major exchanges (AUD, GBP, CAD and JPY against USD), found that a Markov-switching GARCH model outperforms a random walk in the short-term, and is robust over different sample periods. He emphasises that exchange rates follow persistent trends, and correctly identifying these trends through a Markov-switching model is the key to beating a random walk. Khemiri (2012) finds the presence of regime-switching as well as asymmetry in the conditional variance within the regime in high-frequency Deutsche Mark/USD exchange rate data during one trading week in August of 1992. Panopoulou & Pantelidis (2015) find that regime-switching models outperform a random walk in forecasting for the GBPUSD between 1973 and 2011.

A variety of underlying economic conditions may cause regime-switching in exchange rates; for instance, changing monetary and fiscal policies (through a delay), and business cycle fluctuations. Lee & Chen (2006) identify central bank intervention in foreign exchange markets as a justification for the use of Markov-switching models. According to De Grauwe & Kaltwasser (2007), divergent beliefs about the fundamental value of a currency can lead to optimistic and pessimistic regimes. Linked to this is the impact of speculation on the value of a currency. According to Salvatore (2011), speculation in the foreign exchange market may be stabilising or destabilising. Stabilising speculation refers to the purchase (sale) of foreign currency when the domestic currency depreciates (appreciates), in the expectation it will soon appreciate (depreciate), in order to make a profit. Destabilising speculation, on the other hand, is when the foreign currency is sold (purchased) when it depreciates (appreciates) in the expectation that it will continue to depreciate (appreciate). Therefore, stabilising speculation moderates or counteracts fluctuations in the value of a currency whilst destabilising speculation exacerbates these fluctuations and may increase exchange rate volatility.

5.2.2 Foreign exchange rate exposure measurement and mitigation techniques

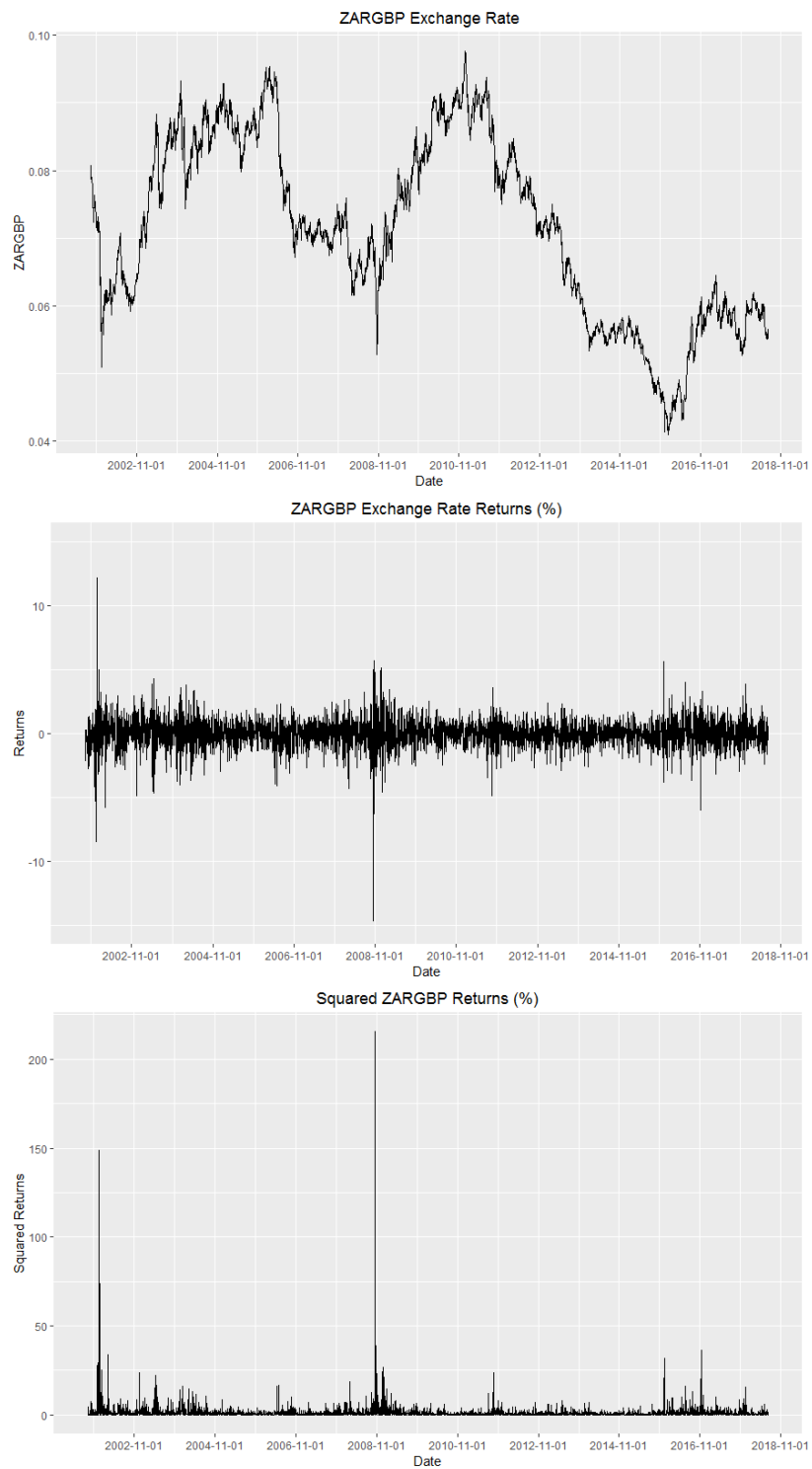
Foreign exchange rate risk takes three forms; transaction, translation and economic (Papaioannou, 2006). Transaction risk stems from specifically identifiable cash flows, either payable or receivable, in foreign currency. Translation risk affects multinational corporations and originates from the consolidation of the financial statements of a foreign subsidiary with that of a parent company. Finally, economic risk arises when the currency denomination of assets differs from the currency denomination of liabilities. Translation exposure is an accounting risk, whereas transaction and economic exposure are liquidity risks. The difference being that transaction exposure is a stock (representing a specific quantity at a specific point in time) whereas economic exposure is a flow (changing through time). Transaction exposure can be effectively hedged either naturally or through structured products because the exact amount is known, and the payment/receipt date is known. Natural hedging involves the matching of for example interest on foreign denominated assets with future payment obligations. Structured products available for currency risk management include currency options, futures, forwards, cross-currency swaps. Economic exposure, on the other hand, is more costly to hedge against because a long period of sustained depreciation will continuously increase the cost of servicing liabilities. Conversely, a prolonged period of appreciation will erode the value of foreign-denominated assets. For this reason, natural hedging is more appropriate than structured products. The exact amount of IM and DF demanded by an international CCP in foreign-denominated currency is unknown because it is affected by market value and market volatility. Options with a maturity of more than a year can limit economic risk; however, a sustained depreciation over the long-term increases the cost of meeting the capital requirements.

5.3 Discussion of the data

The data analysed consists of 4310 daily observations of the nominal bilateral exchange rates for ZARGBP and ZARUSD spanning from 09/09/2001 to 11/07/2018. The continuously compounded returns series consists of 4309 daily observations and is expressed as a percentage. The data was sourced from Bloomberg. The exchange rates are quoted using the direct method, meaning the units of foreign currency per ZAR are displayed. Thus, an

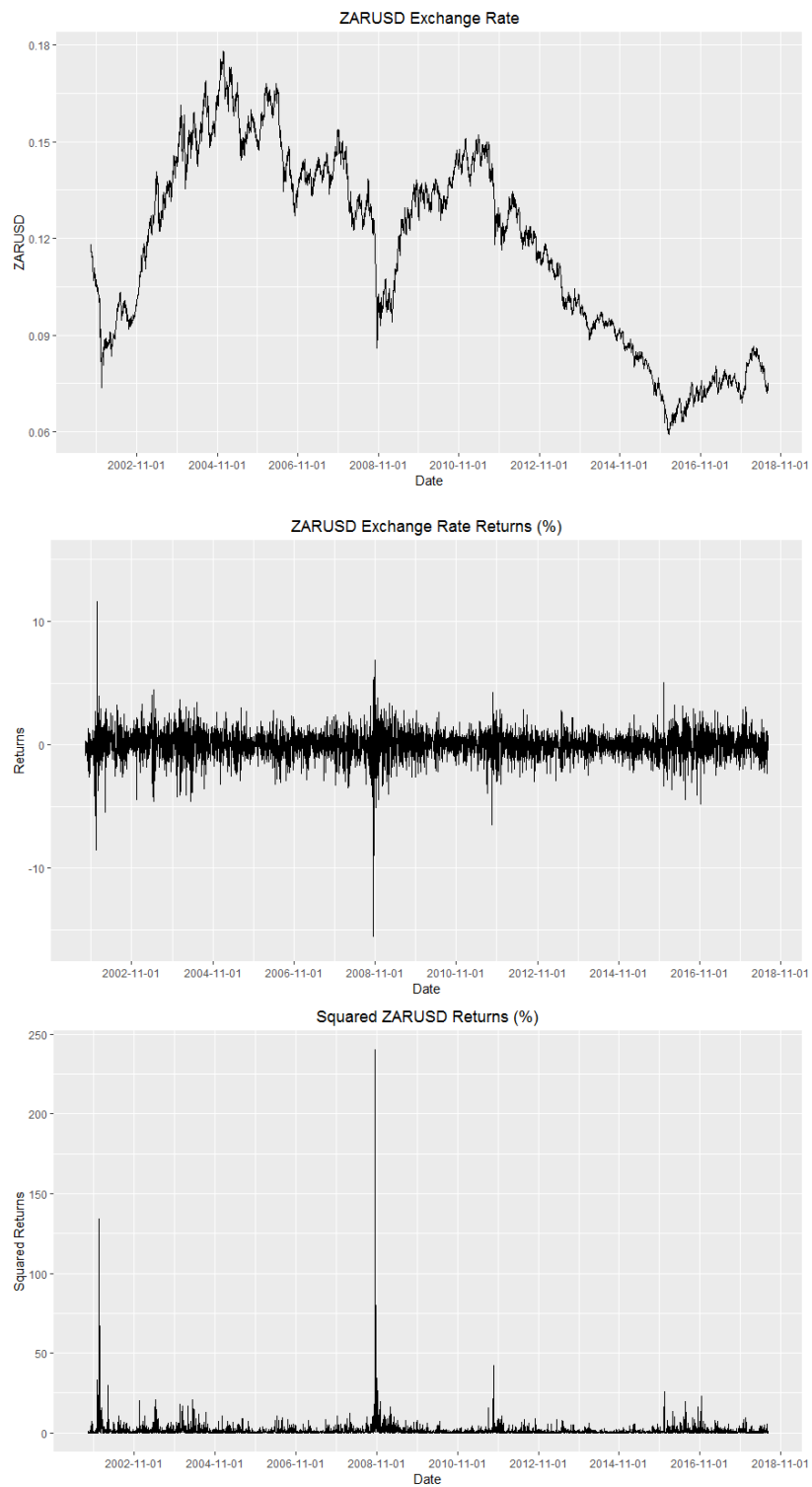
increase in value is equivalent to an appreciation of the ZAR and a decrease to a depreciation. The levels, returns, as well as squared returns for both exchange rates, are presented in figures 5.1 and 5.2. The squared returns provide a useful indication of volatility in the returns data. Unconditional variance can be calculated as the average of the sum of squared returns; however, unconditional variance is assumed to remain constant over time. Therefore, heteroskedasticity and persistence in volatility require more advanced modelling, for instance, through GARCH type (conditional variance) models.

Figure 5.1: The ZARGBP Nominal Exchange Rate, illustrated in Levels, Returns and Squared Returns



Source: Created by Author using data from Bloomberg.

Figure 5.2: The ZARUSD Nominal Exchange Rate, illustrated in Levels, Returns and Squared Returns



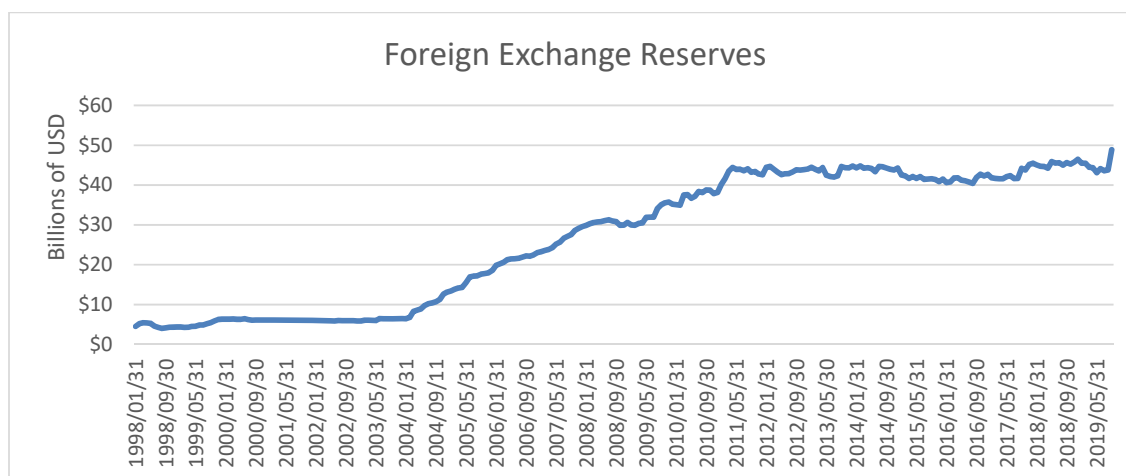
Source: Created by Author using data from Bloomberg.

South Africa is a small open economy with a high level of integration with global financial markets, therefore shocks to the value of the currency may originate externally or domestically. An exchange rate may be influenced by domestic and foreign interest rates, real GDP, domestic and foreign inflation rates, commodity prices, preference for local and foreign investment products, sentiments and stock prices, amongst others. Hassan (2014) found that an increase in the VIX led to an increase in short-term ZAR volatility. Maveé, Perrelli & Schimmelpfenning (2016) found the same relationship between global volatility and short-term ZAR volatility, in addition, they conclude that an increase in the VIX led to higher volatility when the ZAR was depreciating compared to if it was appreciating. Interestingly they find that domestic economic shocks and economic shocks from other emerging markets are not statistically relevant in ZARUSD data, only those originating in the USA. Lastly, Maveé et al. find that domestic political shocks increase ZAR volatility. Mporo & Peters (2016) find that domestic political shocks, as well as monetary policy announcements, had large and significant effects on ZAR returns. Arezki et al. (2014) find that global volatility, as well as commodity price shocks (particularly gold prices), increase ZAR volatility. Laakkonen & Lanne (2009) find asymmetry in response to past negative news on the EURUSD volatility while Hassan (2012) finds asymmetry in the volatility of the EURUSD and GBPUSD exchange rates. The source of several large sudden shocks to the ZAR against the two currencies under study and during the period under observation are discussed in the following section.

The period under observation begins with the depreciation of 2001. Between 1 September and 31 December 2001, the nominal ZARUSD fell by 42%. In addition to the large depreciation, the volatility of the ZAR against both currencies spiked (see the squared returns figure for both exchange rates). The depreciation was so rapid that the incumbent South African President appointed a Commission to investigate possible causes (Myburgh, 2002). The Commission investigated whether the October 14th announcement that the SARB would tighten the enforcement of exchange controls led to the depreciation. South African exchange controls prevent authorised foreign exchange dealers from providing foreign currency to customers unless proof of a real transaction in goods or services are provided. This is intended to prevent harmful (destabilising) speculation in the market, which could increase market volatility. However, domestic evasion of these controls is possible and

purely offshore transactions are not subject to the same restriction, allowing them to be used to speculate freely. The Commission found that although turnover in the foreign exchange market declined after the announcement, the main depreciation occurred in December, ruling out the announcement as the primary cause (Bhundia & Ricci, 2005). Contributing factors identified were the land reform policies in neighbouring Zimbabwe, the delay to privatise the national telecommunications provider and the September 11 terrorist attacks (SARB, 2001). Another contributing factor was the foreign exchange reserve management by the SARB. The SARB intervened heavily in the foreign exchange market during 1996 and 1998. The SARB then began to gradually draw down on the net open forward position to recoup foreign exchange reserves which were at a low after the interventions of 1996 and 1998. This led to excess demand for foreign currency and may have made the ZAR vulnerable to speculative attack. The SARB controls South Africa's foreign exchange reserves which are available *"for direct financing of payment imbalances, for indirectly regulating the magnitudes of such imbalances through intervention in exchange markets and for meeting a defined range of other objectives for a country"* (SARB, 2019a). The SARB can use the country's foreign exchange reserves to buy or sell ZAR for foreign currency, exerting demand or supply pressure respectively on the exchange rate. The degree of direct intervention by the SARB is not formally disclosed, as such announcements may invite a speculative attack, as happened during the 2001 depreciation. An indication of the degree of intervention is the net foreign exchange reserves held. Foreign reserves were depleted after the interventions in the late '90s, reaching a low of 4 billion USD in August 1998. Since then the SARB has been reluctant to intervene in the foreign exchange market. As a result, foreign reserves have been steadily increasing over the past two decades (see figure 5.3), reaching a high of 48.9 billion USD in September 2019 (SARB, 2019b).

Figure 5.3: South African Foreign Exchange Reserves held by the SARB expressed in USD: 1998 - 2019



Source: Created by Author using data from the SARB.

The ZAR slowly recovered its 2001 losses between early 2002 and mid-2006. However, the exchange rate began a depreciating cycle again in May 2006 due to global risk aversion to emerging markets as well as a reduction in some commodity prices (SARB, 2006). The depreciating cycle ended in November 2006 with the currency largely holding its value until the outbreak of the Great Financial Crisis. Lehman Brothers filed for bankruptcy on 15 September 2008, resulting in the highest volatility spike for the ZAR against both currencies during the period under observation. Although South Africa was not directly affected by the Great Financial Crisis, secondary effects such as unprecedented capital outflows, plunging stock prices and the reduction in the price and demand for export commodities led to a sudden and large depreciation of the rand against the pound and dollar. The post-crisis stock market rebound left these two exchange rates at close to pre-crisis levels. QE used by the Fed helped the ZAR to further appreciate in 2010 and 2011 due to the search for yield, increasing domestic capital inflows (Kganyago, 2016). The ZAR began a long depreciating cycle from early 2011 until early 2016. Slowing growth in China negatively impacted commodity prices; a striking example is a fall in the price of iron ore “from almost US\$180 per tonne in 2011 to under US\$50 in the first half of 2016” (Kganyago, 2016). Meanwhile, on the commodity supply side, labour tensions in the mining industry cumulated in the Marikana massacre of August of 2012. The FED’s tapering off of QE in 2013 led to large domestic capital outflows. Another factor was the European sovereign debt crisis, which reached its height between 2010 and 2012.

On 9 December 2015, The South African Finance Minister was dismissed in favour of a little-known backbencher from the ruling political party. The ZAR saw a major depreciation over the following days due to large capital outflows. Public and political pressure prompted the appointment of a former Finance Minister on 13 December. After the appointment, the ZAR followed an appreciating trend which lasted until early 2017. In the wake of the 23 June 2016 Brexit vote, the Bank of England entered a phase of monetary easing, and the Fed halted tightening, the search for yield once again led investors to South Africa and other emerging economies. Rising commodity prices further boosted the rand's strength in the second half of 2016. The US Presidential election on November 8, 2016, resulted in a brief volatility spike against both currencies, without a large impact on the value of the rand. A leadership struggle in South Africa's ruling political party between December 2017 and 14 February 2018 culminated in the resignation of incumbent President Jacob Zuma and the assumption of office by Cyril Ramaphosa. A strong appreciation of the ZAR followed Ramaphosa's assumption of the office until midway through 2018. From mid-2018 until the end of the period under observation, the ZAR followed a depreciating trend. Primarily due to growing risk aversion toward emerging markets, weak domestic growth, rising US interest rates as well as the fall out of a trade war between the US and China according to the SARB (2018). Interestingly periods of large depreciations are associated with large spikes in the squared returns for both exchange rates. This indicates that depreciations are coupled with spikes in volatility, providing intuitive insights into potential shifts in volatility regimes.

5.4 Statistical analysis of the data

The Augmented Dickey-Fuller and Phillips Perron unit root tests both indicate that the returns for the two exchange rate series are stationary.

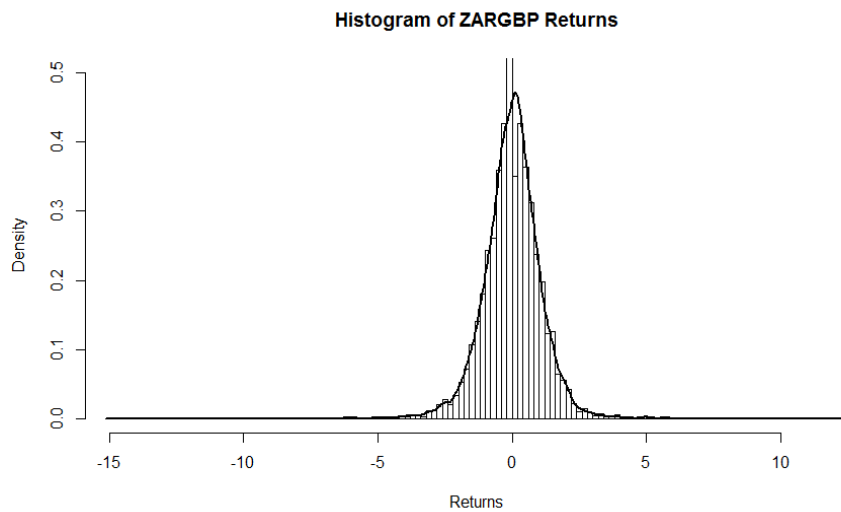
Table 5.1: Statistics for the first four moments of the ZARGBP and ZARUSD

Descriptive statistics	ZARGBP	ZARUSD
Min	-14.68	-15.49
Max	12.19	11.57
Median	0	0.02
Standard deviation	1.11	1.17
Skewness co-efficient	-0.53	-0.72
Kurtosis co-efficient	13.66	12.37

Source: Author's calculations.

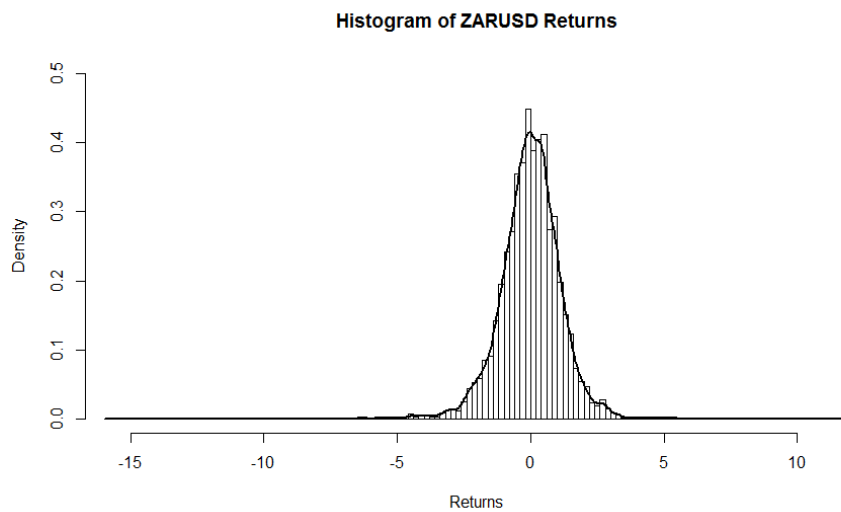
The skewness and kurtosis coefficients indicate that the conditional distribution is not normally distributed; in addition, the null of normality is rejected by the Jarque-Bera test for both series. The histograms in figures 5.4 and 5.5 illustrate the highly leptokurtic nature of the data, with long left tails.

Figure 5.4: Histogram for ZARGBP Returns



Source: Created by Author using data from Bloomberg.

Figure 5.5: Histogram for ZARUSD Returns



Source: Created by Author using data from Bloomberg.

The Ljung-Box test returns p-values of 0.124 and 0.105 for AR(1) ZARGBP and AR(1) ZARUSD respectively, which are both non-significant at the 95% level, rejecting the null of serial correlation. The LM test is performed to test for the presence of ARCH effects, returning p-values of 2.2e-16 for both exchange rates. The null hypothesis of no ARCH effects is thus strongly rejected for both exchange rate series. Therefore, it is possible to model these ARCH effects using GARCH type models.

5.5 Methodology

This study employs a univariate approach to modelling foreign exchange rate volatility as well as measuring exchange rate risk because it is desirable to measure the exchange rate exposure for each of the two selected exchange rates individually. Papaioannou (2006) identifies VaR as the most appropriate approach for measuring foreign exchange rate risk. Given the recent regulatory focus on ES over VaR, both will be calculated. Papaioannou (2006) finds that when measuring exchange rate risk, the typical holding period is one day, and the confidence levels are typically 99% and 95%. For the sake of prudence, this study measures exchange rate risk at the 99% confidence level for VaR and ES.

Pérignon, Deng & Wang (2008) find that a GARCH type model is superior for calculating VaR because it accounts for volatility clustering. The possible existence of regime-switching is supported in the literature review as well as in the discussion of the data (section 5.3). Therefore, the alternative hypothesis of the presence of regime-switching is tested against the null hypothesis of a random walk, following Engel & Hamilton (1990). As in Chapter Three, the two exchange rates will be fitted to a total of 120 GARCH-type models to identify the best performing in sample-fit for each series. The ARCH, GARCH, E-GARCH, GJR-GARCH and T-GARCH (see equations 3.4 To 3.8 respectively), with six conditional distributions (equations 3.9 – 3.11) and up to a maximum of four regimes will be tested. The best performing GARCH type model for each exchange rate will then be used to forecast the 99% VaR and ES for one period ahead. The percentage daily loss for each exchange rate under the appropriate number of regimes will provide a band for the potential economic exposure to an international CCP from IM and DF demands denominated in GBP or USD. The IM and DF demand in ZAR for the cleared portfolio under the two direct hedging assumptions of 90% and 99% were calculated in Chapter 4.

5.6 Empirical analysis

As in Chapter 3, the AIC and BIC goodness-of-fit tests are used to select the preferred in-sample model for both exchange rates. The lowest AIC and BIC indicate the model which provides the best fit for the data. The model with the lowest AIC is the one that maximises the likelihood function. The BIC imposes a greater penalty on the number of parameters than the AIC; therefore, it favours parsimony (see equations 3.12 and 3.13). The results of the 120 models tested for each of the two exchange rates are presented in Appendix C. The AIC and BIC both select the 3-State T-GARCH with a GED distribution for the ZARGBP data. Thus, the ZARGBP data exhibits regime-switching, asymmetry in response to past negative observations as well as a non-normal distribution. However, the AIC and BIC select different models for the ZARUSD data. The AIC prefers the 3-State GJR-GARCH with Skewed Student's t distribution while the BIC prefers the 1-State GJR-GARCH with Skewed Student's t distribution. Thus, the ZARUSD data exhibits asymmetry in response to past negative observations and a skewed non-normal distribution; however, the presence of regime-switching is uncertain. Both exchange rates are characterised by non-gaussian distributions, as indicated by the histograms (figures 5.4 and 5.5). The ZARUSD data exhibited a higher degree of left skewness than the ZARGBP (see table 5.1). The two top-performing models for the ZARUSD exhibit skewness while the unilaterally selected model for the ZARGBP does not. A summary of the top three models selected are presented in table 5.2 below.

Table 5.2: Details of the 3-State T-GARCH, 3-State GJR-GARCH and 1-State GJR-GARCH

Coefficients	ZARGBP		ZARUSD		ZARUSD	
	3-State T-GARCH GED		3-State GJR-GARCH SSTD		1-State GJR-GARCH SSTD	
$\alpha_{0,1}$	0.0000001	(0.00E+00)	0.0000325	(2.99E-26)	0.02487457	(6.12E-3)
$\alpha_{1,1}$	0.0000010	(2.00E-14)	0.0206636	(4.13E14-)	0.03835724	(1.35E-2)
$\alpha_{2,1}$	0.9998910	(8.84E-29)	0.0001000	(2.00E-12)	0.04040547	(1.40E-2)
β_1	0.4578817	(9.12E-33)	0.9791053	(3.51E-26)	0.91899899	(5.84E-3)
ν_1	0.7000001	(5.36E-33)	7.7183220	(7.38E-20)	9.26425360	(1.15E-0)
ξ	n/a		0.5994591	(7.17E-21)	0.88249675	(1.95E-2)
$\alpha_{0,2}$	0.0171905	(6.15E-22)	0.0736896	(8.59E-21)	n/a	
$\alpha_{1,2}$	0.0411394	(9.70E-22)	0.0003589	(3.36E-23)	n/a	
$\alpha_{2,2}$	0.0473002	(1.37E-22)	0.1820260	(6.09E21-)	n/a	
β_2	0.9442416	(2.14E-36)	0.7126342	(1.95E-20)	n/a	
ν_2	2.1017450	(9.57E-22)	36.336790	(4.45E-20)	n/a	
ξ	n/a		1.1431126	(1.18E-19)	n/a	
$\alpha_{0,3}$	0.0313603	(4.78E-22)	0.0629000	(4.39E-21)	n/a	

$\alpha_{1,3}$	0.0014660	(1.62E-24)	0.0528538	(2.64E-21)	n/a
$\alpha_{2,3}$	0.1243920	(2.15E-21)	0.1003761	(3.98E-21)	n/a
β_3	0.9488326	(7.54E-33)	0.8757591	(6.83E-22)	n/a
ν_3	1.3926720	(1.00E-20)	92.846010	(1.24E-21)	n/a
ξ	n/a		0.9953466	(9.29E-20)	n/a
σ_1 Mean	0.7308		1.0959		1.0881
σ_1 Maximum	14.8301		3.2068		4.8496
σ_2 Mean	0.9306		0.7871		n/a
σ_2 Maximum	2.3790		6.7019		n/a
σ_3 Mean	1.6215		1.2292		n/a
σ_3 Maximum	9.0392		6.4041		n/a
Log-likelihood	-5924.46		-6221.15		-6250.76
AIC	11890.93		12490.29		12513.52
BIC	12024.67		12643.13		12551.73

Source: Author's calculations. Standard errors are in brackets. All of the coefficients are significant at the 1% level.

The ARCH and GARCH parameters are positive and statistically significant for all three models. All three models are covariance-stationary in each state. Recall from Chapter 3 (see the discussion after equation 3.7) that covariance-stationarity in each state for the GJR model requires $\alpha_{1,k} + \alpha_{2,k}E[|\eta_{k,t}^2 \mathbb{I}\{\eta_{k,t} < 0\}|] + \beta_k < 1$. Covariance-stationarity requires $\alpha_{1,k}^2 + \beta_k^2 - 2\beta_k(\alpha_{1,k} + \alpha_{2,k})E[\eta_{t,k} \mathbb{I}\{\eta_{t,k} < 0\}] - (\alpha_{1,k}^2 - \alpha_{2,k}^2)E[\eta_{t,k}^2 \mathbb{I}\{\eta_{t,k} < 0\}] + \beta_k < 1$ for a T-GARCH (see the discussion after equation 3.8). The volatility persistence for each state of a T-GARCH is calculated as follows:

$$\alpha_{1,k}^2 + \beta_k^2 - 2\beta_k(\alpha_{1,k} + \alpha_{2,k})E[\eta_{t,k} \mathbb{I}\{\eta_{t,k} < 0\}] - (\alpha_{1,k}^2 - \alpha_{2,k}^2)E[\eta_{t,k}^2 \mathbb{I}\{\eta_{t,k} < 0\}] + \beta_k$$

The volatility persistence for the GJR-GARCH is calculated by $\alpha_{1,k} + \alpha_{2,k}E[|\eta_{k,t}^2 \mathbb{I}\{\eta_{k,t} < 0\}|] + \beta_k$. In both equations, $E[|\eta_{k,t}^2 \mathbb{I}\{\eta_{k,t} < 0\}|] = \frac{1}{2}$ for an unskewed distribution and is dependent on the degree of asymmetry as per Trottier & Ardia (2016) for a skewed distribution. The volatility persistence for each model per state is presented in tables 5.3 – 5.5.

Table 5.3: The persistence in volatility per state of the 3-State T-GARCH GED for the ZARGBP data

Volatility persistence of each state of the 3-State T-GARCH GED	
State 1	0.0017689
State 2	0.8099124
State 3	0.7847350

Source: Author's calculations.

Table 5.4: The persistence in volatility of the 1-State GJR-GARCH SSTD for the ZARUSD data

Volatility persistence of each state of the 1-State GJR-GARCH SSTD	
State 1	0.9807914

Source: Author's calculations.

Table 5.5: The persistence in volatility per state of the 3-State GJR-GARCH SSTD for the ZARUSD data

Volatility persistence of each state of the 3-State GJR-GARCH SSTD	
State 1	0.9998589
State 2	0.7949048
State 3	0.9808084

Source: Author's calculations.

The volatility persistence for the single state GJR-GARCH is almost indistinguishable from that of the 3rd state of the 3-State GJR-GARCH. However, it does not represent the persistence of other two states, either under or overstating the persistence, indicating that the single state model is unable to capture the full extent of the volatility dynamics in the ZARUSD data. The transition probability matrices for the two multi-state models are presented in tables 5.6 and 5.7. The transition probabilities for both multi-state models are not $p_{11} = 1 - p_{22}$, therefore rejecting the null hypothesis used by Engel & Hamilton (1990). Thus, confirming that the multi-state models do not follow a random walk and the data exhibits regime-switching behaviour. This result indicates that the 3-State model is preferred over the 1-State model for the ZARUSD data.

Table 5.6: The transition probability matrix of the 3-State T-GARCH GED for the ZARGBP data

	t+1 k=1	t+1 k=2	t+1 k=3
t k=1	0.06337951	0.5273493	0.4092712
t k=2	0.10140738	0.8798137	0.0187789
t k=3	0.02379537	0.3639686	0.6122360

Source: Author's calculations.

Table 5.7: The transition probability matrix of the 3-State GJR-GARCH SSTD for the ZARUSD data

	t+1 k=1	t+1 k=2	t+1 k=3
t k=1	0.001395446	0.99673049	0.001874068
t k=2	0.142617649	0.27717880	0.580203556
t k=3	0.656423584	0.00118952	0.342386895

Source: Author's calculations.

The mean and maximum volatility per state are presented in percentage terms in table 5.2 (they are presented in percentages because the returns data were expressed in percentages for the ZARUSD and ZARGBP). For the ZARGBP data, State 1 represents a period of the lowest mean volatility combined with the highest maximum volatility, indicating that volatility shocks in this state are particularly large and rare. The volatility persistence of State 1 is extremely low at 0.1769% and reports only a 6.3% chance of remaining in State 1 in $t+1$ if initially in State 1. State 2 represents the more moderate state with the lowest maximum volatility and the lowest differential between the mean and maximum volatility. State 2 is the most persistent state, the probability of remaining in State 2 in $t+1$ if initially in State 2 is 88%, and it has the highest volatility persistence of 80.99%. State 3 characterises the highest mean volatility and a high maximum volatility. The probability of remaining in State 3 in $t+1$ if initially in State 3 is 61% and its volatility persistence is 78.47%.

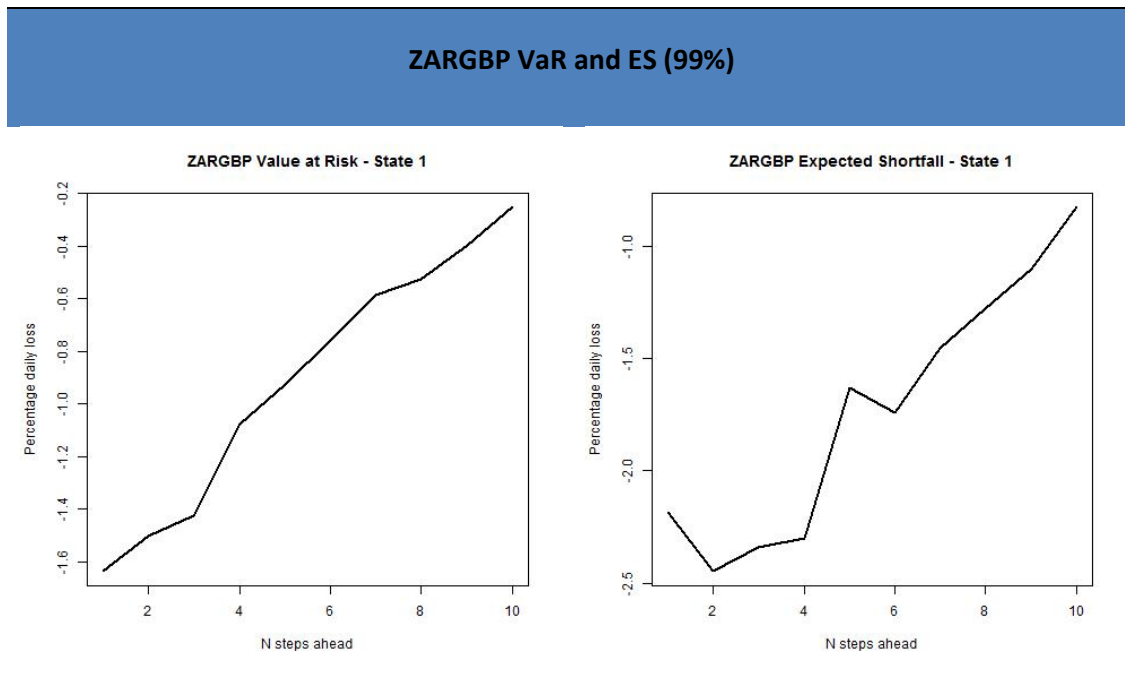
The single state ZARUSD reports a mean and maximum volatility that represents an approximate average of the volatilities in three states of the multi-state model. It neither captures the lowest nor highest volatilities of the three-state model. The single state model also reports a high volatility persistence of 98.08%. State 1 of the 3-State GJR-GARCH exhibits the smallest differential between the mean and maximum volatility as well as the lowest maximum volatility amongst the three states. It has a high volatility persistence of 99.99% and a 0.14% probability of remaining in State 1 in $t+1$ if initially in State 1. State 2 reports the lowest mean volatility combined with the highest maximum volatility. There is a 28% probability of remaining in State 2 in $t+1$ if initially in State 2, and the volatility persistence is the lowest for this state at 79.49%. State 3 reports the highest mean volatility and a maximum volatility slightly smaller than that of State 2. The volatility persistence is slightly lower than that of State 1 at 98.08% and the probability of remaining in State 3 in $t+1$ if initially in State 3 is 34%.

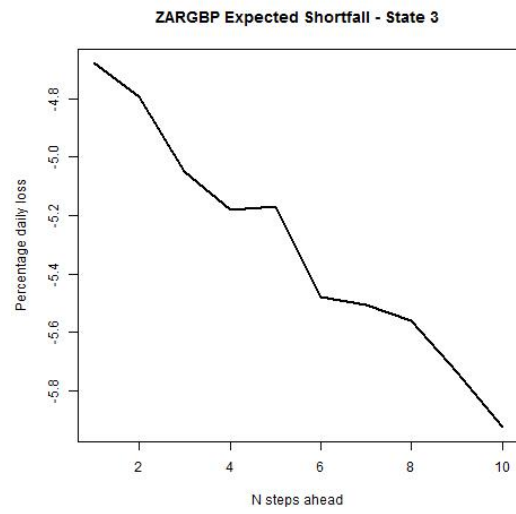
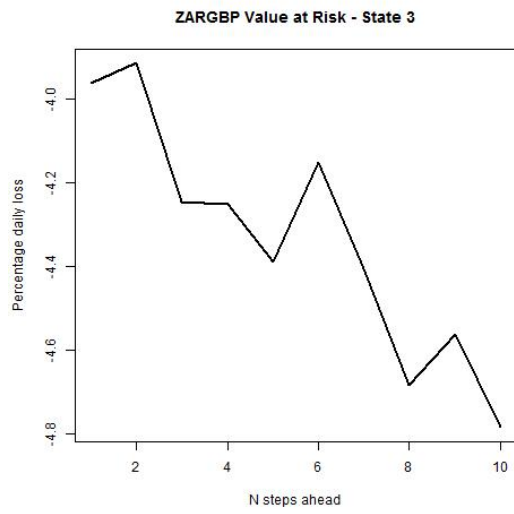
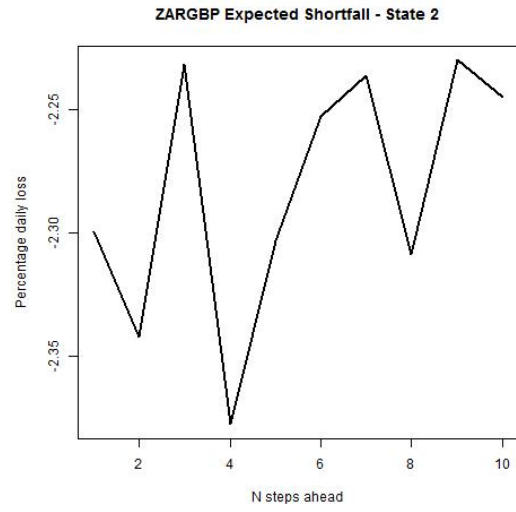
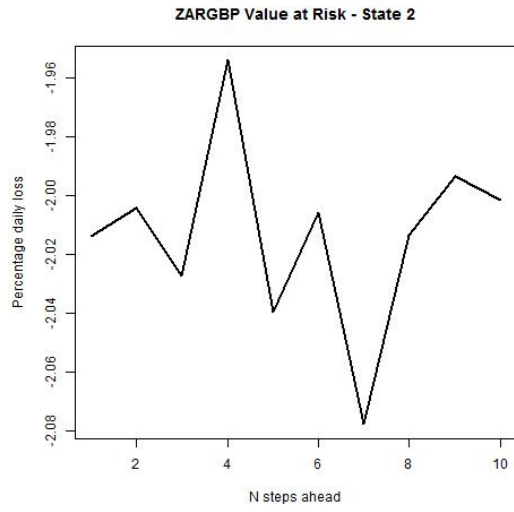
5.7 Exchange rate exposure

The 10-day ahead VaR and ES for all three models per state are illustrated below in tables 5.8 – 5.10. The influence of the volatility dynamics in each state can be seen through the percentage daily loss as well as the fluctuation of VaR and ES over the 10-day ahead period. The states with the smaller differential between the mean and maximum volatility and

higher volatility persistence tend to fluctuate around the mean percentage daily loss. See the VaR and ES diagrams of State 2 for the ZARGBP model as well as the single state model for ZARUSD and State 1 of the 3-State ZARUSD model. These diagrams exhibit a zig-zag type pattern, displaying a high reversion to the mean percentage daily loss as well as a high volatility persistence. The states with a high differential between mean and maximum volatility and lower volatility persistence, on the other hand, tend to exhibit more of an explosive process, either increasing or decreasing the loss as the number of steps ahead increases. For example, see the VaR and ES diagrams of States 1 and 3 for the ZARGBP model as well as States 2 and 3 for the 3-State ZARUSD model for illustrations of a diversion from the mean percentage daily loss through time. The percentage daily loss is influenced more by the mean volatility than by the maximum volatility in each state, indicating that extreme tail losses are large and rare.

Table 5.8: 3-State T-GARCH GED 10 steps ahead percentage daily loss for VaR and ES at 99% for ZARGBP

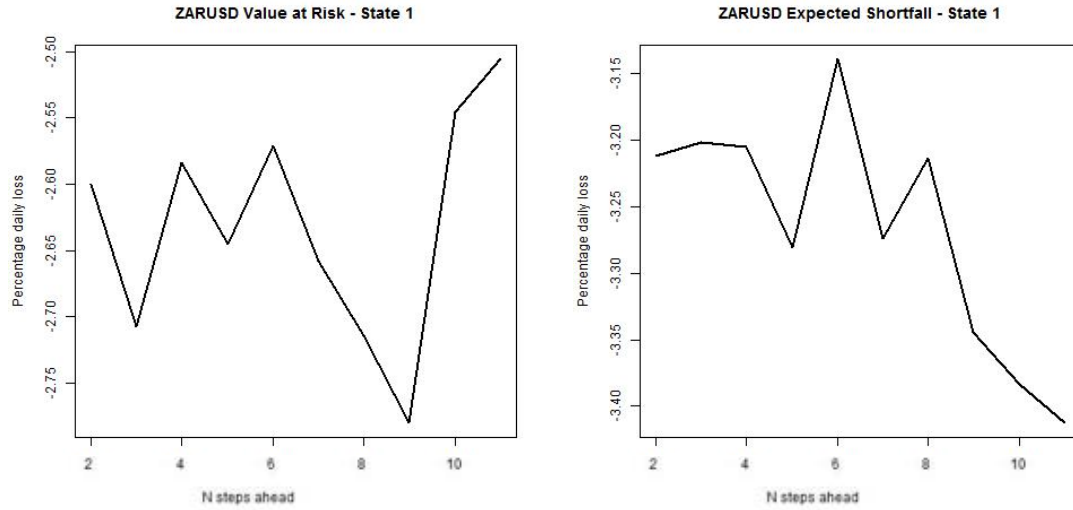




Source: Created by Author using data from Bloomberg.

Table 5.9: 1-State GJR-GARCH SSTD 10 steps ahead percentage daily loss for VaR and ES at 99% for ZARUSD

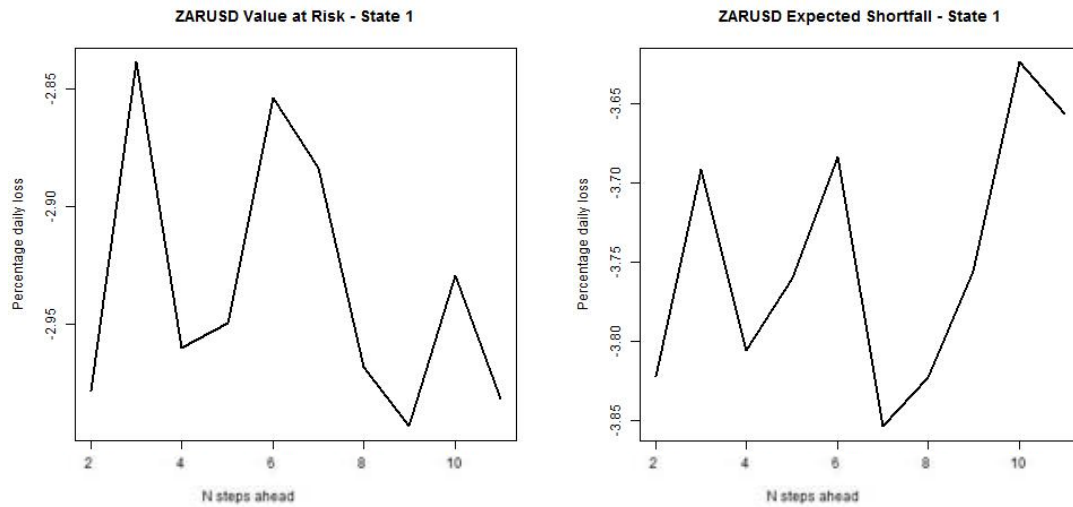
ZARUSD VaR and ES (99%)

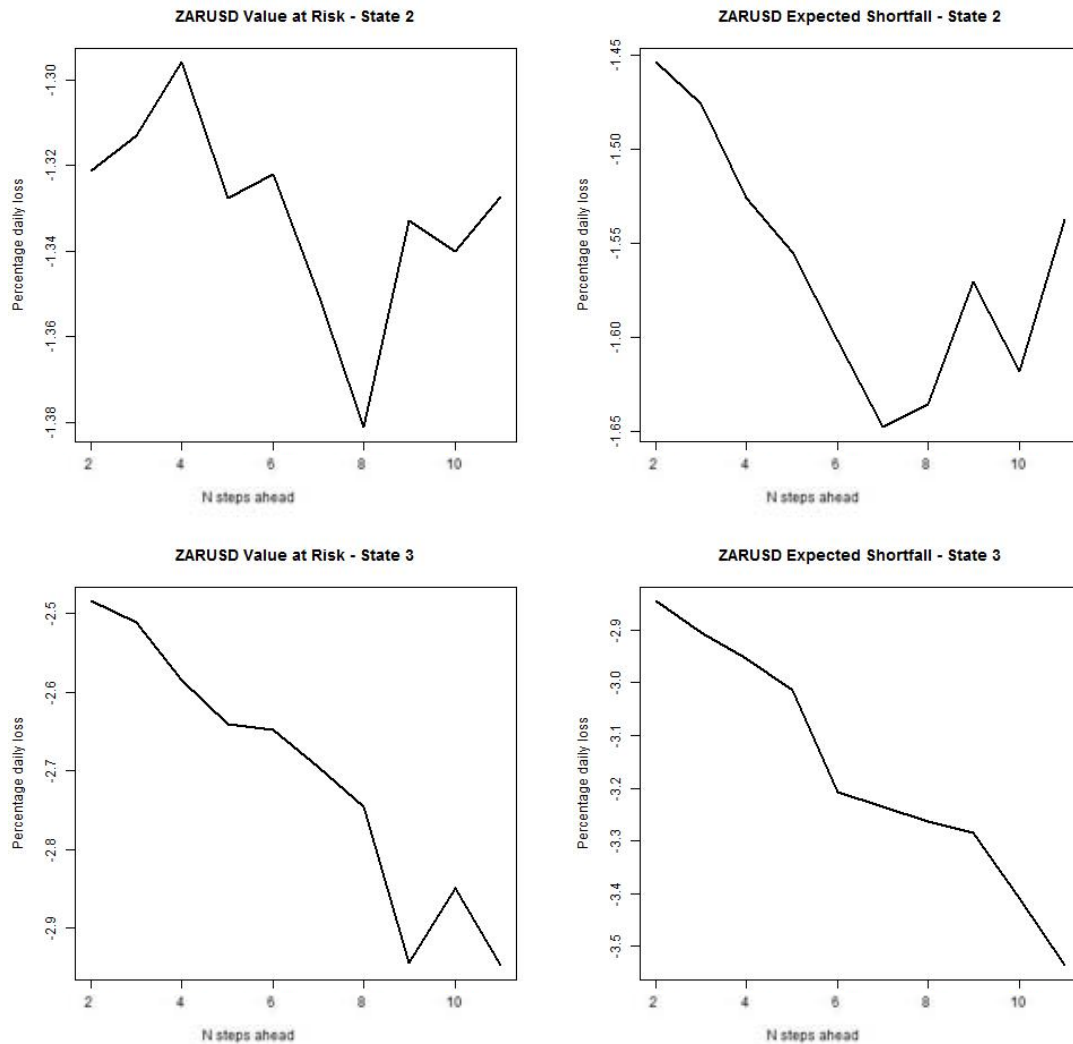


Source: Created by Author using data from Bloomberg.

Table 5.10: 3-State GJR-GARCH SSTD 10 steps ahead percentage daily loss for VaR and ES at 99% for ZARUSD

ZARUSD VaR and ES (99%)



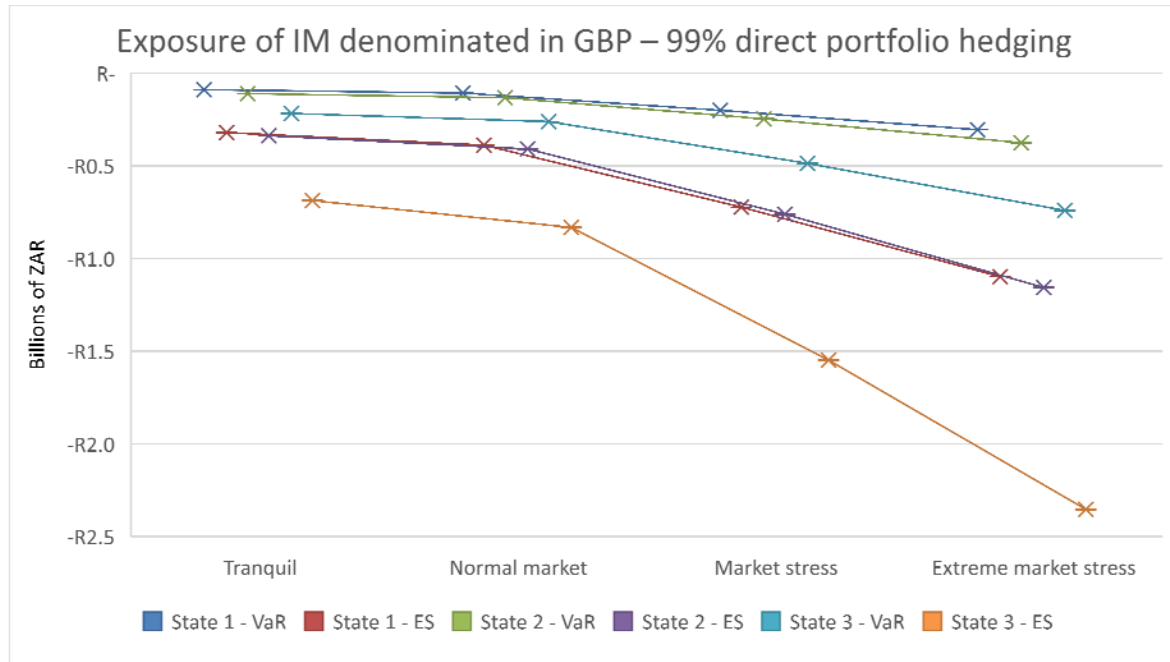


Source: Created by Author using data from Bloomberg.

As per the methodology discussed in section 5.5 above, the 1 step ahead VaR and ES are used to estimate the foreign exchange rate exposure due to IM and DF requirements per market volatility scenario and state for both currencies. The IM requirements denominated in billions of ZAR for the centrally cleared portfolios of the South African ODPs assuming 99% and 90% direct portfolio hedging are extracted from table 4.11 in Chapter 4. The DF requirements denominated in billions of ZAR for the centrally cleared portfolios of the South African ODPs assuming 99% and 90% direct portfolio hedging are extracted from table 4.12.

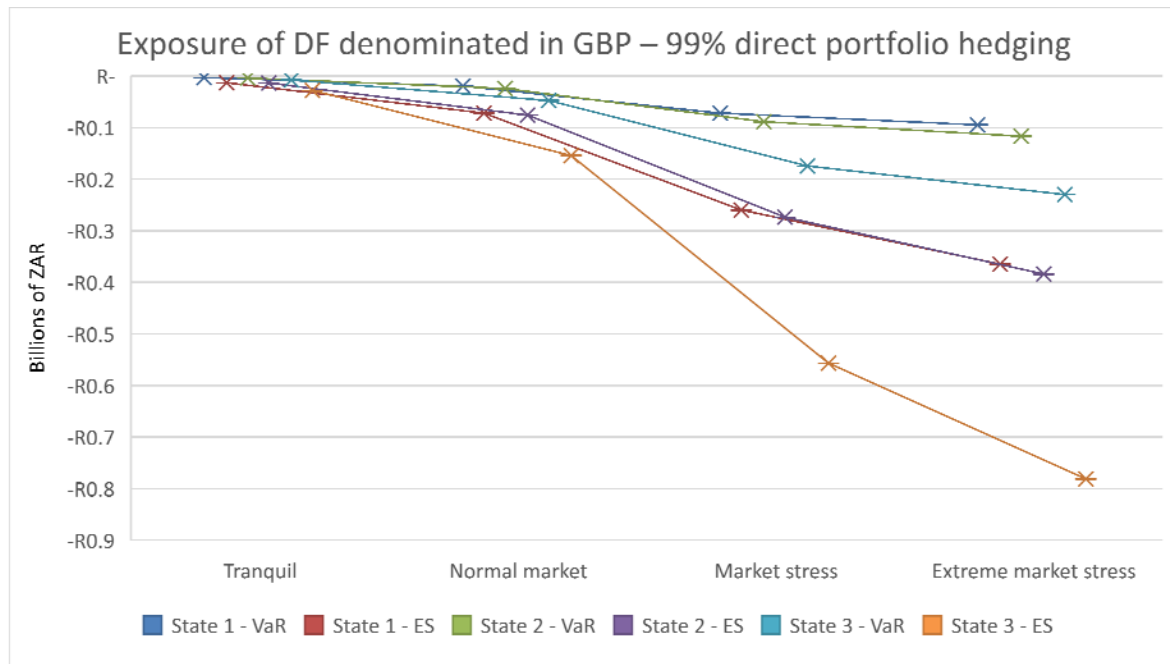
5.7.1 Foreign exchange rate exposure denominated in GBP

Figure 5.6: Foreign exchange rate exposure of IM denominated in GBP – 99% direct portfolio hedging



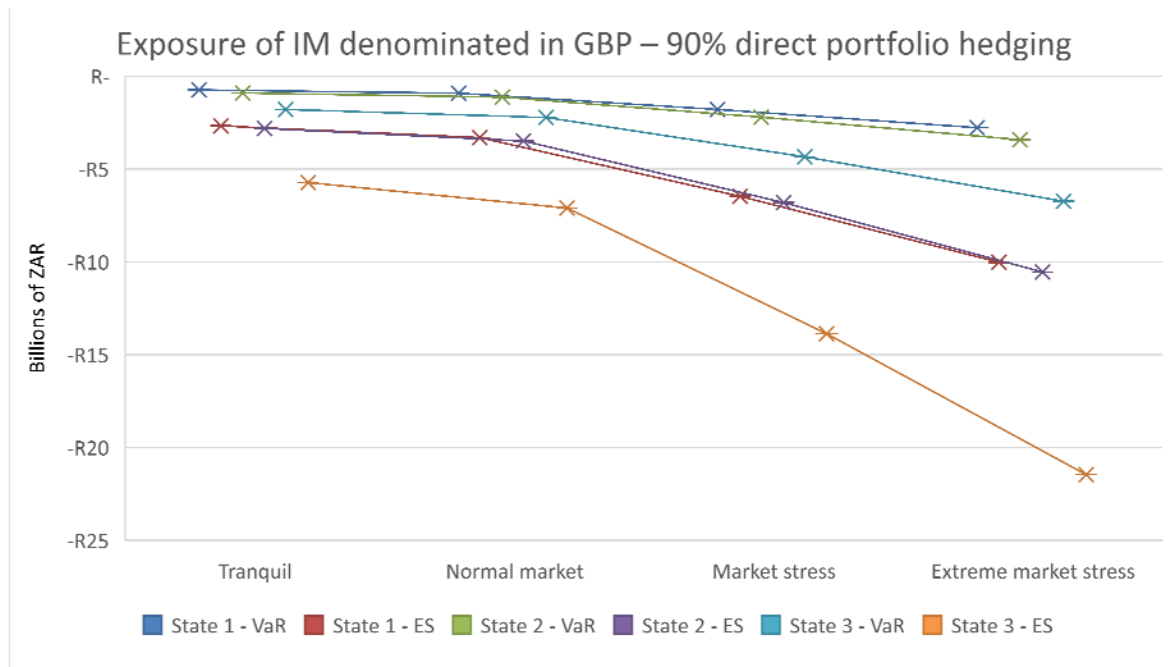
Source: Author's calculations.

Figure 5.7: Foreign exchange rate exposure of DF denominated in GBP – 99% direct portfolio hedging



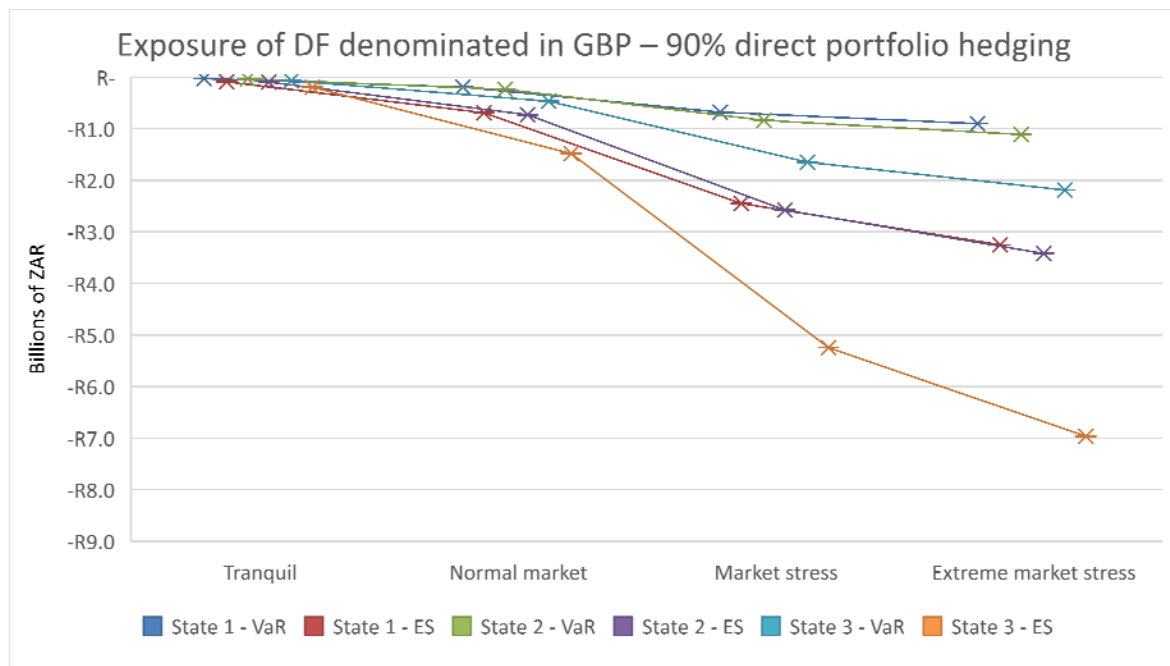
Source: Author's calculations.

Figure 5.8: Foreign exchange rate exposure of IM denominated in GBP – 90% direct portfolio hedging



Source: Author's calculations.

Figure 5.9: Foreign exchange rate exposure of DF denominated in GBP – 90% direct portfolio hedging



Source: Author's calculations.

See figure 5.6, which illustrates the 1-day ahead foreign exchange rate exposure of IM requirements denominated in GBP under a 99% direct portfolio hedging assumption across volatility scenarios and per state of the 3-State T-GARCH GED. The exposure increases as the market volatility increases and ES is more sensitive to changing market conditions than VaR, as is to be expected.

States 1 and 2 report similar foreign exchange rate exposure. State 1 has the lowest VaR and ES 1 step ahead and a sharply declining exposure as the number of steps ahead increase. It has an incredibly small volatility persistence, meaning that shocks quickly dissipate. Despite being characterised by the highest maximum volatility, State 1 also exhibits the lowest mean volatility. This indicates that in this state, shocks are very large; however, they are rare and quickly dissipate.

State 2 is characterised by the lowest maximum volatility, the smallest differential between mean and maximum volatility and the highest volatility persistence, the VaR and ES follows a mean-reverting process, as illustrated in table 5.8. The 1-day foreign exchange rate VaR of IM demands denominated in GBP is 0.09 and 0.11 billion ZAR in the tranquil market conditions, rising to 0.31 and 0.38 billion ZAR for States 1 and 2 respectively. The ES of IM demands is 0.32 and 0.34 billion ZAR in tranquil market conditions, rising to 1.1 and 1.16 billion ZAR for States 1 and 2 respectively under extreme market stress.

State 3, in contrast, represents a high-risk state, with the highest mean volatility and a high maximum volatility. The volatility persistence is slightly lower than that of State 2, and the exposure increases as the number of steps ahead increase, displaying a more explosive exchange rate risk. The IM VaR in State 3 increases from 0.22 billion ZAR under tranquil market conditions to 0.74 billion ZAR under extreme market stress, while the ES rises from 0.69 to 2.35 billion ZAR.

Figure 5.7 illustrates the foreign exchange rate exposure of DF requirements denominated in GBP under a 99% direct portfolio hedging assumption. If South African ODPs' DF contributions did not exceed the minimum contribution required by SwapClear then the foreign exchange rate exposure would be represented by the VaR under normal market conditions. The DF VaR for States 1 and 2 respectively increases from 0.003 and 0.004 to 0.09 and 0.12 billion ZAR when moving from tranquil to extreme market stress conditions.

Conversely, when transitioning from tranquil to extreme market stress conditions, the DF ES increases from 0.013 and 0.014 to 0.36 and 0.38 billion ZAR for States 1 and 2, respectively. In State 3, the VaR increases from 0.01 to 0.23 billion ZAR when transitioning to extreme market stress from tranquil market conditions and the ES from 0.03 to 0.78 billion ZAR. It is clear that State 3 represents the high-risk state with a high exposure that increases as the number of steps ahead increases. Combining the IM and DF requirements denominated in GBP, the potential 1-day loss when in State 3 increases from 0.23 and 0.72 billion ZAR under tranquil market conditions for VaR and ES respectively, to 0.97 and 3.13 billion ZAR under extreme market stress.

As found in Chapter 4, changing the direct portfolio hedging assumption from 99% to 90% has a much higher impact on IM and DF requirements than changes in market volatility. As such, the 90% direct hedging portfolio has a much larger exchange rate exposure than the 99% direct hedging portfolio, see figures 5.8 and 5.9. The potential combined IM and DF 1-day loss when in State 3 assuming 90% direct hedging increases from 1.87 and 5.94 billion ZAR under tranquil market conditions for VaR and ES respectively, to 8.93 and 28.43 billion ZAR under extreme market stress.

The combined upper and lower bound VaR and ES GBP exchange rate exposure expressed in billions of ZAR for both direct hedging assumptions across volatility scenarios are presented below in table 5.11. State 3 represents the upper bound for ZARGBP exchange rate exposure, and State 1 represents the lower bound for ZARGBP exchange rate exposure. The VaR amount in billions of ZAR is presented on the left side of the hyphen, and the ES amount in billions of ZAR to the right side.

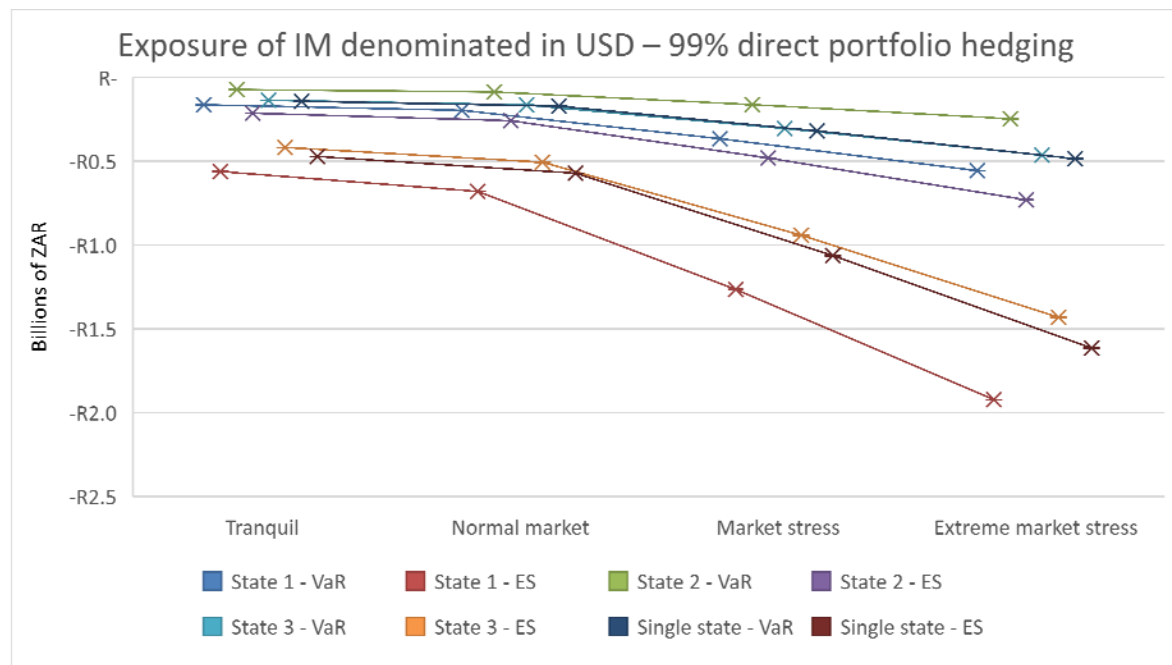
Table 5.11: VaR and ES upper and lower bounds for foreign exchange rate exposure in billions of ZAR when posting IM and DF denominated in GBP

VaR and ES upper and lower bounds for IM and DF denominated in GBP				
	Tranquil market	Normal market	Market stress	Extreme market stress
99% direct hedging Lower bound	0.093 – 0.33	0.13 – 0.46	0.27 – 0.98	0.40 – 1.46
99% direct hedging Upper bound	0.23 – 0.72	0.31 – 0.98	0.66 – 2.11	0.97 – 3.13
90% direct hedging Lower bound	0.77 – 2.77	1.11 – 4.01	2.48 – 8.93	3.68 – 13.28
90% direct hedging Upper bound	1.87 – 5.94	2.7 – 8.59	6.01 – 19.12	8.93 – 28.43

Source: Author's calculations.

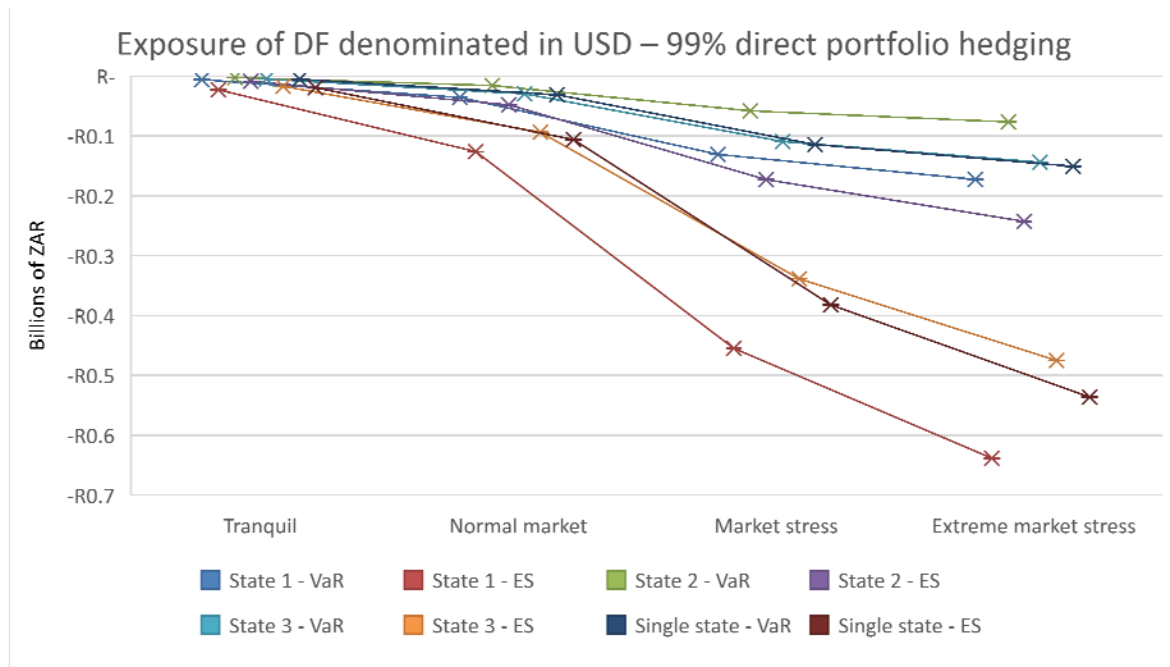
5.7.2 Foreign exchange rate exposure denominated in USD

Figure 5.10: Foreign exchange rate exposure of IM denominated in USD – 99% direct portfolio hedging



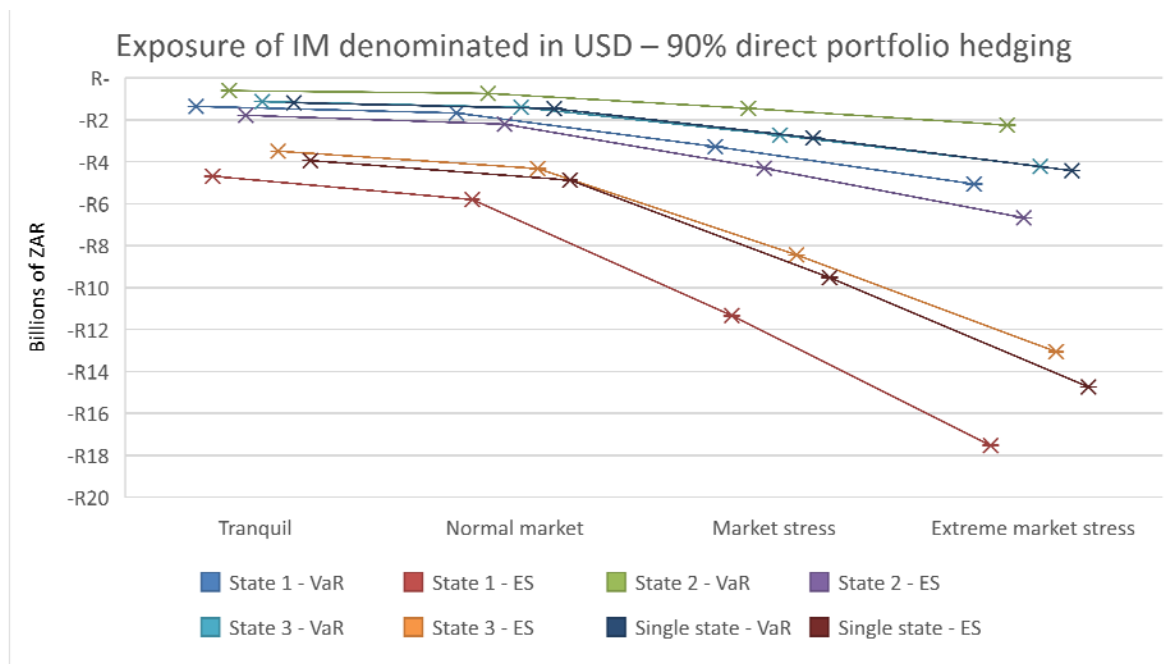
Source: Author's calculations.

Figure 5.11: Foreign exchange rate exposure of DF denominated in USD – 99% direct portfolio hedging



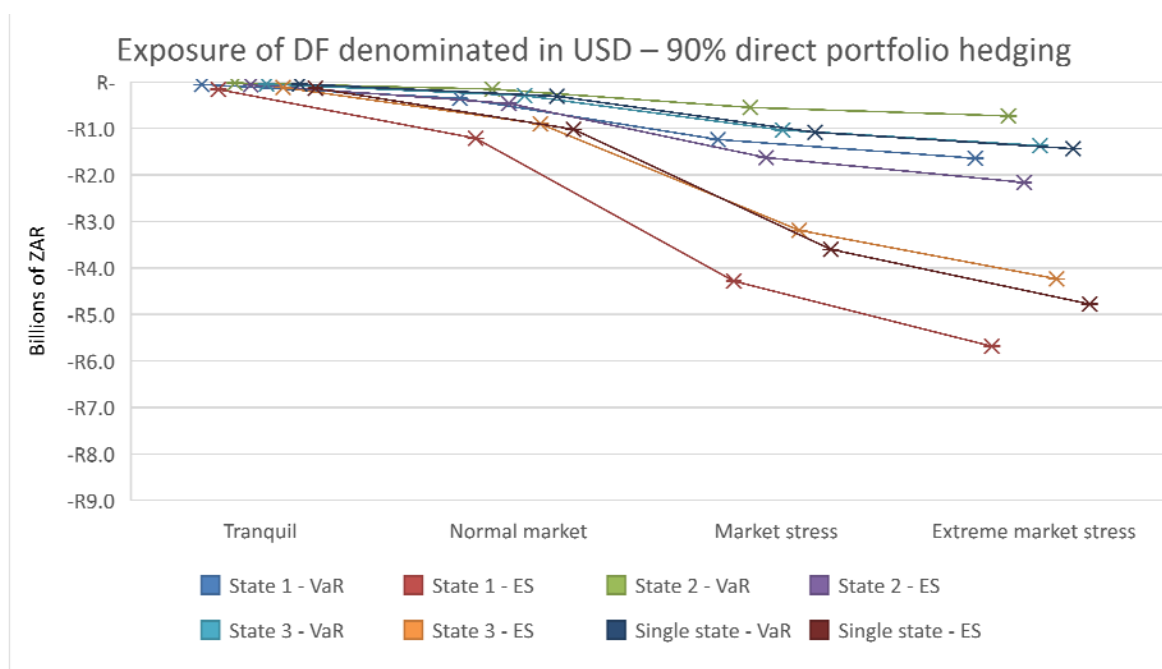
Source: Author's calculations.

Figure 5.12: Foreign exchange rate exposure of IM denominated in USD – 90% direct portfolio hedging



Source: Author's calculations.

Figure 5.13: Foreign exchange rate exposure of DF denominated in USD – 90% direct portfolio hedging



Source: Author's calculations.

Figure 5.10 represents the 1-day ahead foreign exchange rate exposure of IM requirements denominated in USD under a 99% direct portfolio hedging assumption. The VaR and ES per the three states of the 3-State GJR-GARCH SSTD (labelled State 1-3), as well as the single state of the 1-State GJR-GARCH SSTD (labelled Single state), are presented across volatility scenarios.

State 1 of the multi-state model characterises the largest exposure at 1 step ahead, however, with the lowest differential between mean and maximum volatility and the highest volatility persistence, there is a strong reversion to the mean percentage daily loss meaning that the exposure in this state is relatively constant through time. The VaR ranges between 0.16 and 0.56 billion ZAR as market conditions transition from tranquil to extreme market stress, conversely the ES ranges between 0.56 and 1.92 billion ZAR.

State 2 of the multi-state model is characterised by the lowest mean volatility, the highest maximum volatility, the lowest volatility persistence and the lowest VaR and ES for the portfolio denominated in USD. Thus, indicating that shocks in this state are large, rare and quickly dissipate. The VaR ranges between 0.07 and 0.25 billion ZAR as market conditions

transition from tranquil to extreme market stress, conversely the ES ranges between 0.21 and 0.73 billion ZAR.

State 3 exhibits the highest mean volatility and the second-highest maximum volatility. Despite a volatility persistence slightly below that of State 1, the differential between the mean and maximum volatility is high, resulting in a weak reversion to the mean percentage daily loss and an escalating exposure as the number of steps ahead increase. The VaR ranges between 0.14 and 0.46 billion ZAR as market conditions transition from tranquil to extreme market stress, conversely the ES ranges between 0.42 and 1.43 billion ZAR. The single state model reports VaR and ES exposures close to those reported by State 3 of the multi-state model. It is characterised by a small differential between mean and maximum volatility as well as an extremely high volatility persistence, as such it exhibits a strong reversion to the mean percentage daily loss (see table 5.9). The VaR ranges between 0.14 and 0.49 billion ZAR as market conditions transition from tranquil to extreme market stress, conversely the ES ranges between 0.47 and 1.62 billion ZAR. The single state ZARUSD model does not capture the extreme tail risk captured by the 3-state model. Therefore, although the presence of regime-switching is indeterminate, regime-switching models provide more information about possible tail losses.

Figure 5.11 illustrates the foreign exchange rate exposure of DF requirements denominated in USD under a 99% direct portfolio hedging assumption. In State 1, the DF VaR increases from 0.01 to 0.17 billion ZAR when transitioning to extreme market stress from tranquil market conditions and the ES from 0.02 to 0.64 billion ZAR. The transition from tranquil to extreme market stress results in an increase in VaR from 0.003 to 0.08 billion ZAR and in ES from 0.01 to 0.24 billion ZAR in State 2. The DF VaR for State 3 and the single regime state respectively increases from 0.005 and 0.01 to 0.14 and 0.15 billion ZAR when moving from tranquil to extreme market stress conditions. Conversely, when transitioning from tranquil to extreme market stress conditions, the DF ES increases from 0.02 and 0.02 to 0.48 and 0.54 billion ZAR for State 3 and the single regime state, respectively.

State 1 represents the high exposure state, and a quick reversion to the mean daily percentage loss, meaning the exposure stays relatively constant throughout the 10 steps ahead illustrated in table 5.10. Combining the IM and DF requirements denominated in USD,

the potential 1-day loss when in State 1 increases from 0.17 and 0.58 billion ZAR under tranquil market conditions for VaR and ES respectively, to 0.73 and 2.65 billion ZAR under extreme market stress. As for the GBP foreign exchange exposure discussed above, changing the direct portfolio hedging assumption from 99% to 90% has a much larger impact on IM and DF requirements than changes in market volatility. As such, the 90% direct hedging portfolio has a much larger exchange rate exposure than the 99% direct hedging portfolio, see figures 5.12 and 5.13. The potential 1-day loss when in State 1, assuming 90% direct hedging, increases from 1.41 and 4.85 billion ZAR under tranquil market conditions for VaR and ES respectively, to 6.71 and 23.23 billion ZAR under extreme market stress. The upper and lower bound VaR and ES expressed in billions of ZAR for both direct hedging assumptions across volatility scenarios is presented below in table 5.12. State 1 represents the upper bound for ZARUSD exchange rate exposure, and State 2 represents the lower bound for ZARUSD exchange rate exposure. The VaR amount in billions of ZAR is presented on the left side of the hyphen, and the ES amount in billions of ZAR to the right side for IM and DF combined.

Table 5.12: VaR and ES upper and lower bounds for foreign exchange rate exposure in billions of ZAR when posting IM and DF denominated in USD

VaR and ES upper and lower bounds for IM and DF denominated in USD				
	Tranquil market	Normal market	Market stress	Extreme market stress
99% direct hedging Lower bound	0.073 – 0.22	0.11 – 0.31	0.22 – 0.65	0.33 – 0.97
99% direct hedging Upper bound	0.17 – 0.58	0.06 – 0.81	0.5 – 1.72	0.73 – 2.56
90% direct hedging Lower bound	0.08 – 1.84	0.9 – 2.67	2 – 5.94	2.98 – 8.83
90% direct hedging Upper bound	1.41 – 4.85	2.03 – 7.02	4.51 – 15.62	6.71 – 23.23

Source: Author's calculations.

5.8 Conclusion

In this Chapter the one day ahead transaction foreign exchange rate exposure is estimated for local ODPs through membership to an international CCP, assuming either GBP or USD denominated collateral requirements. A contribution of this study is the analysis of volatility dynamics, accounting for regime shifts, asymmetry in the reaction to past negative observations and different conditional distributions. The results strongly indicate the

presence of regime-switching in the GBP data; however, the presence of regime-switching in the USD data is inconclusive. Regime-switching does appear to increase explanatory power when there is heterogeneity in a series, and its presence cannot be rejected for the USD data.

A key finding is the relatively higher exchange rate risk, as measured in VaR and ES, for GBP over USD against the ZAR during the period under observation, this is supported by the relatively higher volatility found in the GBP data. As a result of the relatively higher exchange rate risk it may be beneficial for South African ODPs to become clearing members of CME based in the USA, the second largest clearer of IRDs rather than the UK based SwapClear (a subsidiary of LCH.Clearnet Ltd). The relative netting benefits of SwapClear would have to be fully offset by the exchange rate risk differential of transacting only in USD. Although IRDs are the largest derivative asset class in South Africa, the netting benefits for other derivative classes might be larger at CME than at SwapClear again making it a worthwhile consideration. Brexit provides another reason to consider the second largest clearer of IRDs (CME) over the largest. SwapClear grew to be the largest clearer of IRDs because of its ability to “passport” into the rest of the EU. Following Brexit however, the EU has not granted equivalence to SwapClear which could threaten its market dominance.

The cause of the relative stability in the ZARUSD over the ZARGBP is an area for future research; however, the relative stability of the ZARUSD may be due to the USD’s position as the world’s top reserve currency. The disparity in the volatility of the two exchange rates against the ZAR indicates that the ZAR volatility dynamics may be driven primarily by foreign rather than domestic shocks. This suggests that although domestic political stability would reduce foreign exchange rate volatility, external factors which can not be influenced by the South African government such as global economic shocks and commodity prices may have a greater impact.

The impact of regime specific volatility dynamics on exchange rate risk measured by VaR and ES is explored. For both exchange rates studied during the period under observation, it was found that the higher the mean volatility, the higher the exchange rate risk, and therefore the larger the exposure. The high exposure state for the ZARUSD data (State 1 of the multi-state model) exhibits an extremely high volatility persistence and a strong

reversion to the mean percentage daily loss, indicating that even during times of high USD exchange rate exposure, the VaR and ES are relatively stable through time. In contrast, the high exposure state for the ZARGBP data (State 3) exhibits a lower volatility persistence and a weak reversion to the mean, displaying a more explosive exchange rate risk. This indicates a deviation from the mean percentage daily loss in the high ZARGBP exposure state resulting in increasing VaR and ES through time.

Concerningly, major depreciations and high exchange rate volatility appear to occur simultaneously (see section 5.3) while the research results show that the higher the mean volatility, the higher the exchange rate risk. Therefore, a shock may lead to a simultaneous depreciation, an increase in exchange rate volatility and an increase in exchange rate risk, compounding the increase in collateral requirements. In addition, a large global shock may decrease foreign exchange market efficiency in developing markets, decreasing liquidity and the supply of HQLA (CGFS, 2013). An international CCP exposes South African ODP's to economic exchange rate exposure because the amount payable increases when there is an increase in the volatility of the foreign exchange rate as well as a depreciation of the rand. A sustained period of depreciation would expose ODPs to increasing economic exchange rate risk, which is difficult to hedge against. Thus, understanding the volatility dynamics of foreign exchange rates and its effect on the value of foreign currency-denominated capital requirements is important for individual ODPs in order to limit the misallocation of capital as well as by monetary and fiscal Authorities to limit systemic risk.

CHAPTER 6

CONCLUSION

6.1 Research purpose

During the Great Financial Crisis, redundant and insufficiently collateralised OTC derivative contracts exacerbated CCR resulting in potentially avoidable defaults and increased systemic risk. In response, the G20 issued directives for the regulation of OTC derivatives markets in its member's jurisdictions. The national authorities in each jurisdiction are tasked with the implementation of the directives, after taking their unique market conditions into account. A critical decision pending for South African Authorities is how many CCPs to licence (if any) to provide central clearing services in the domestic market. Authorities have indicated that they will, at least at first, only licence an international CCP. This decision has implications for dealer banks (ODPs), including the cost of participating in the derivatives market through collateral requirements, as well as the exposure to foreign exchange rate risk as presently margining requirements are not accepted in ZAR at the leading international IRD CCP. In addition, Authorities must decide whether to authorise the use of QPMM models, and which QPMM models, to estimate IM requirements on non-centrally cleared derivatives or whether ODPs should use the SMS approach. Thus, the identified research gap is to determine the impact of margining requirements on collateral demand for ODPs in three potential market structure scenarios identified from the literature as well as the potential foreign exchange rate risk emanating from licencing an international CCP to inform South African Authorities.

6.2 Research objectives

Following the identified gap, three research objectives were identified to contribute to the body of knowledge in this emerging field. First, to analyse the volatility dynamics of the underlying asset of South African interest rate derivatives and estimate various market stress scenarios. Second, to estimate the collateral demands on South Africa ODPs that will result from the enforcement of IM on non-centrally (using the QPMM and SMS approaches)

as well as IM and DF contributions on centrally cleared derivatives (using a CCP's margin model). Third, to quantify and examine the foreign exchange rate risk that ODPs would be exposed to should an international CCP be licenced by national Authorities.

6.3 Research findings

The first research objective is addressed in Chapter 3, where a GARCH model was used to estimate the volatility of the Jibar interbank interest rate. The methodology allowed for regime-switching in the conditional variance as well as allowing the volatility dynamics to follow five GARCH type models and six different conditional distributions. A total of 120 models were tested to determine which GARCH type model, distribution and number of states best fit the Jibar 3-month data in order to extract the most accurate estimation of historical volatility. The best performing model was the 4-State T-GARCH with Student's t distribution, indicating the presence of regime-switching, an asymmetric effect and a non-gaussian conditional distribution in the data. The four states identified represent tranquil, normal, market stress and extreme market volatility conditions. The volatility estimates of these market stress scenarios were then used as a model input for the QPMM approach in Chapter 4.

To address the second research objective, collateral demands that could result from the enforcement of margining requirements on South African ODP's were estimated under three potential market structure scenarios in Chapter 4. In market structure scenario 1 the IM requirements for centrally cleared and non-centrally cleared portfolios, as well as DF requirements for the centrally cleared portfolio, were calculated using the QPMM approach with two assumptions of the degree of direct hedging. The resulting estimates were found to be sensitive to the market volatility scenarios, highlighting the pro-cyclical nature of these requirements. Collateral requirements were less sensitive to changes in the decay factor and the confidence level. Ultimately, the most significant contributor to the size of collateral requirements was the degree of direct hedging. Therefore, ODPs can limit their own collateral exposure on non-centrally cleared derivatives when using the QPMM approach by using a higher decay factor and VaR risk measure (if not prescribed by Authorities). The most significant reduction of IM on both centrally and non-centrally cleared derivatives can be achieved by ODPs balancing their books instead of relying on more complicated delta

hedging techniques when using the QPMM approach. In contrast, collateral requirements for non-centrally cleared derivatives calculated using the SMS approach are not pro-cyclical, nor are they sensitive to model inputs other than the NGR. However, they are more conservative under tranquil and normal market conditions but do not spike under market stress or extreme market stress assuming 90% direct hedging.

The third research objective is addressed in Chapter 5 by estimating and examining the foreign exchange rate risk for local ODPs through membership to an international CCP, assuming either GBP or USD denominated collateral requirements. The transaction foreign exchange rate exposure was found to be greater as measured in VaR and ES for GBP than for USD denominated collateral. The volatility dynamics are regime dependent, however, the GBP data exhibited a higher overall volatility than the USD data. This would suggest that IM posted in USD would have a lower and relatively more stable exchange rate exposure than IM posted in GBP. Contributions to the DF are however only accepted in GBP at SwapClear. This provides the grounds for further research to investigate the relative costs of licencing CME rather than SwapClear, in addition to the implications of Brexit. The results suggested that the rand volatility dynamics may be driven primarily by foreign rather than domestic shocks. A large shock may lead to a simultaneous depreciation, an increase in exchange rate volatility and an increase in exchange rate risk, compounding the increase in collateral requirements. In addition, a large global shock may decrease foreign exchange market efficiency in developing markets, decreasing liquidity and the supply of HQLA.

The scope of the study is limited to the impact of IM margining requirements on the OTC derivatives market and therefore, does not extend to other post-crisis reforms that will affect the South African financial system. SwapClear's model for IM and DF is proprietary and impossible to fully replicate. It makes use of various anti-procyclicality features which this study was unable to replicate and therefore acknowledges that estimates would be biased upwards in times of market stress. In addition, the ISDA's SIMM for the calculation of IM on non-centrally cleared derivatives has recently gathered momentum and is the dominant model globally. The margining requirements on IRD were calculated for the entire market; however, IRD make up approximately 88% of the total OTC derivatives market. As seen in table 4.9, other classes of derivatives are subject to a higher IM rate when using the SMS approach; therefore, the collateral costs on approximately 12% of the market is

understated. The study does not attempt to predict any changes in behaviour resulting from the implementation of the new regulations, thus gross notional outstanding amounts held by ODPs are assumed unchanged. Once a South African trade repository is established, the market data should be used to provide a more refined assessment of the collateral demands that will result from new regulations on the OTC derivatives market. A trade repository will also provide a more accurate picture of systemic risk concentrations and exposures through the interconnectivity of market participants. The study did not consider IM on end-users, nor did it consider VM because it is already largely in practice and readily re-hypothecated; therefore, the collateral costs from margining requirements in its entirety are understated, except perhaps during periods of market stress due to the limitations of the model.

6.4 Policy implications and recommendations

Collateral demand internationally is structurally higher as a result of post-crisis reforms, and risk-sensitive IM models will increase cyclical collateral demands as market risk and CCR increase. In contrast, the SMS approach to calculating IM requirements is not pro-cyclical; however, collateral requirements are higher during tranquil and normal market conditions. This trade-off between microprudential and macroprudential goals should be weighed by Authorities as they decide whether to mandate central clearing and which approach should be used by local ODPs to calculate IM on non-centrally cleared derivatives. In addition, Authorities should consider a more prescriptive approach when approving and monitoring QPMM models for non-centrally cleared derivatives with respect to the decay factor and risk measure, as the estimates are sensitive to these model inputs. For instance, a lower decay factor results in more conservative IM requirements than a higher decay factor; however, it is also more pro-cyclical. While on average, moving to an ES risk measure increases IM demands by 2.7 times the VaR amount. However, this is a moot point if Authorities license the globally popular SIMM methodology for non-centrally cleared derivatives.

ODPs who use the SMS approach to calculate margin requirements on non-centrally cleared derivatives are incentivised to centrally clear contracts during tranquil and normal market conditions due to the relatively lower capital requirements however these requirements are surpassed by the risk-sensitive approaches under a 90% direct hedging assumption during

market stress and extreme market stress. For this reason, ODPs using the SMS approach are incentivised to clear those contracts that are initiated during tranquil and normal market conditions under a 90% direct hedging assumption and they are always incentivised to centrally clear under a 99% direct hedging assumption. In addition, local ODPs would be required to centrally clear when the counterparty is subject to a foreign clearing mandate. Thus, if Authorities only approve the standardised method, the incentive to centrally clear is present, and a clearing mandate may not be necessary. Authorities could allow participants to choose whether to centrally clear or not for themselves while establishing a trade repository to monitor systemic risk.

Should an international CCP be licenced, National Treasury may consider foreign-denominated capital requirements in its exchange control legislation, and monetary Authorities should be prepared for a substantial increase in the demand for foreign currency. In addition, foreign exchange market efficiency may decrease in developing markets during times of extreme market stress, decreasing the supply of HQLA. The SARB acts as a foreign currency clearing house for the South African economy; therefore, it must be prepared to meet rising foreign-denominated regulatory capital requirements should a significant period of market stress and a depreciation of the ZAR occur simultaneously. Several sources of liquidity may be considered, for instance, a drawdown on foreign currency reserves held by the SARB, swap facilities with other central banks or support from an international body. As at 30 September 2019, the SARB held 48.9 billion USD in foreign currency reserves (see figure 5.3); however, this is not an inexhaustible supply of foreign currency and can only be used to a limited extent as deemed necessary by the SARB. Therefore, should an international CCP be licensed, the foreign exchange demands would warrant a larger SARB balance sheet.

The alternative for Authorities is to allow ODPs to default on their foreign-denominated regulatory capital requirements. This should only be considered in the most-dire circumstances as a large-scale default in the OTC derivatives market will have a lasting negative impact on this important market for risk management as well as the broader financial system and the real economy. Ultimately, this study finds that the amount of capital required from a CCP is influenced more by the direct hedging practices of ODPs than

it does on market stress, placing the onus on ODPs to prudently manage their exposure to regulatory capital requirements and Authorities to monitor their exposure.

If Authorities find that the foreign exchange rate exposure of licensing an international CCP is too large, then they could license and encourage the use of a local CCP. This arrangement could potentially lead to lower costs for local end users, for example, as in Brazil. Licensing a local CCP also allows the domestic Authorities the greatest degree of supervision and control over the clearing platform. However, domestic Authorities would be the sole lender of last resort in the event of a large defaults.

As a by-product of the research, a secondary finding revealed that the SARB should not intervene in the foreign exchange market to stabilise the value of the rand because of the risk of a speculative attack in addition to the possibility that rand volatility is primarily externally driven.

This study contributes to the knowledge of how margining requirements would impact collateral demand for South African ODPs, in three potential market structures, in order to inform Authorities. In addition to a rich analysis of IRD market volatility and the potential foreign exchange rate exposure from licencing an international CCP.

6.5 Recommendations for further research

During the development and conduct of this research, each of the three research objectives was achieved; however, as outlined in this section, further work is desirable for the development of this research area. For example, the impact of Covid-19 on the South African derivatives market. The establishment of a trade repository would allow researchers access to granular data which is detailed at the transaction level as opposed to the currently reported aggregated data. This would allow, amongst others, an analysis of the network structure of the SA derivatives market and the impact of changes in trading liquidity in cleared and uncleared markets (bifurcation) due to reforms on the availability of efficient risk transfer for small end-users. Further research into the costs and benefits of interoperability between local CCPs is necessary to make an informed recommendation to Authorities.

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Appendix A: Results of in-sample model testing from Chapter 3

Table A.1: AIC and BIC results for each of the GARCH-type models tested

Model			AIC	BIC
1-State	ARCH	Normal	-3323.727	-3314.1763
2-State	ARCH	Normal	-4456.8897	-4428.2375
3-State	ARCH	Normal	-4454.2869	-4396.9825
4-State	ARCH	Normal	-4043.1072	-3947.5999
1-State	ARCH	Student's t	-4669.7947	-4655.4686
2-State	ARCH	Student's t	-5435.7283	-5397.5253
3-State	ARCH	Student's t	-5550.0003	-5478.3698
4-State	ARCH	Student's t	-5731.6621	-5617.0533
1-State	ARCH	GED	-4946.9775	-4932.6514
2-State	ARCH	GED	-5657.0886	-5618.8856
3-State	ARCH	GED	-5585.2236	-5513.5931
4-State	ARCH	GED	-5536.548	-5421.9392
1-State	ARCH	Skewed Normal	-3357.9975	-3343.6714
2-State	ARCH	Skewed Normal	-3685.7232	-3647.5203
3-State	ARCH	Skewed Normal	-3983.5187	-3911.8882
4-State	ARCH	Skewed Normal	-4080.6067	-3965.9979
1-State	ARCH	Skewed Student's t	-4668.8176	-4649.7162
2-State	ARCH	Skewed Student's t	-5163.0647	-5115.311
3-State	ARCH	Skewed Student's t	-5302.4147	-5216.4581
4-State	ARCH	Skewed Student's t	-5256.0476	-5122.3373
1-State	ARCH	Skewed GED	-4943.7662	-4924.6647
2-State	ARCH	Skewed GED	-5616.5612	-5568.8075
3-State	ARCH	Skewed GED	-5451.1697	-5365.2131
4-State	ARCH	Skewed GED	-5314.4201	-5180.7098
1-State	GARCH	Normal	-3429.5019	-3415.1758
2-State	GARCH	Normal	-4869.6446	-4831.4417
3-State	GARCH	Normal	-4664.1143	-4592.4838
4-State	GARCH	Normal	-3989.9904	-3875.3816
1-State	GARCH	Student's t	-5063.9492	-5044.8477
2-State	GARCH	Student's t	-5634.8962	-5587.1426
3-State	GARCH	Student's t	-5685.4722	-5599.5156

4-State	GARCH	Student's t	-4775.6281	-4641.9179
1-State	GARCH	GED	-4944.9751	-4925.8737
2-State	GARCH	GED	-5804.5938	-5756.8401
3-State	GARCH	GED	-5788.0663	-5702.1097
4-State	GARCH	GED	-6002.6079	-5868.8977
1-State	GARCH	Skewed Normal	-3451.2373	-3432.1358
2-State	GARCH	Skewed Normal	-4683.5004	-4635.7468
3-State	GARCH	Skewed Normal	-4726.4295	-4640.4729
4-State	GARCH	Skewed Normal	-4232.8412	-4099.131
1-State	GARCH	Skewed Student's t	-4830.9698	-4807.093
2-State	GARCH	Skewed Student's t	-5862.3356	-5805.0312
3-State	GARCH	Skewed Student's t	-5336.6339	-5236.3512
4-State	GARCH	Skewed Student's t	-6005.3204	-5852.5087
1-State	GARCH	Skewed GED	-5145.8819	-5122.0051
2-State	GARCH	Skewed GED	-5304.5827	-5247.2783
3-State	GARCH	Skewed GED	-5407.0603	-5306.7776
4-State	GARCH	Skewed GED	-5860.4319	-5707.6202
1-State	E-GARCH	Normal	-3491.8357	-3472.7342
2-State	E-GARCH	Normal	-4405.7948	-4358.0411
3-State	E-GARCH	Normal	-4317.834	-4231.8774
4-State	E-GARCH	Normal	-4113.0419	-3979.3317
1-State	E-GARCH	Student's t	-4875.456	-4851.5791
2-State	E-GARCH	Student's t	-6317.0747	-6259.7703
3-State	E-GARCH	Student's t	-5615.7922	-5515.5095
4-State	E-GARCH	Student's t	-5581.8848	-5429.0731
1-State	E-GARCH	GED	-4998.8754	-4974.9986
2-State	E-GARCH	GED	-6206.5154	-6149.211
3-State	E-GARCH	GED	-5409.6772	-5309.3945
4-State	E-GARCH	GED	-5305.8768	-5153.0651
1-State	E-GARCH	Skewed Normal	-3494.3544	-3470.4776
2-State	E-GARCH	Skewed Normal	-4332.6692	-4275.3648
3-State	E-GARCH	Skewed Normal	-4216.2828	-4116.0001
4-State	E-GARCH	Skewed Normal	-4408.5682	-4255.7565
1-State	E-GARCH	Skewed Student's t	-4880.3785	-4851.7263
2-State	E-GARCH	Skewed Student's t	-6282.7303	-6215.8752
3-State	E-GARCH	Skewed Student's t	-5446.2887	-5331.6799
4-State	E-GARCH	Skewed Student's t	-5427.3738	-5255.4606
1-State	E-GARCH	Skewed GED	-4995.4721	-4966.8199

2-State	E-GARCH	Skewed GED	-5772.323	-5705.4679
3-State	E-GARCH	Skewed GED	-5406.3235	-5291.7148
4-State	E-GARCH	Skewed GED	-5322.0586	-5150.1454
1-State	GJR-GARCH	Normal	-3318.5438	-3299.4423
2-State	GJR-GARCH	Normal	-4824.916	-4777.1624
3-State	GJR-GARCH	Normal	-4656.3639	-4570.4074
4-State	GJR-GARCH	Normal	-4704.3109	-4570.6006
1-State	GJR-GARCH	Student's t	-5060.3614	-5036.4846
2-State	GJR-GARCH	Student's t	-5745.3222	-5688.0178
3-State	GJR-GARCH	Student's t	-5544.9469	-5444.6642
4-State	GJR-GARCH	Student's t	-5089.7412	-4936.9295
1-State	GJR-GARCH	GED	-5146.0264	-5122.1496
2-State	GJR-GARCH	GED	-5868.1286	-5810.8242
3-State	GJR-GARCH	GED	-5768.7268	-5668.4441
4-State	GJR-GARCH	GED	-5804.3064	-5651.4947
1-State	GJR-GARCH	Skewed Normal	-3449.247	-3425.3702
2-State	GJR-GARCH	Skewed Normal	-4713.1894	-4655.885
3-State	GJR-GARCH	Skewed Normal	-3480.6027	-3380.32
4-State	GJR-GARCH	Skewed Normal	-4792.336	-4639.5243
1-State	GJR-GARCH	Skewed Student's t	-4980.0462	-4951.394
2-State	GJR-GARCH	Skewed Student's t	-5605.3549	-5538.4997
3-State	GJR-GARCH	Skewed Student's t	-5155.334	-5040.7252
4-State	GJR-GARCH	Skewed Student's t	-4750.1728	-4578.2597
1-State	GJR-GARCH	Skewed GED	-5142.4531	-5113.8009
2-State	GJR-GARCH	Skewed GED	-5885.9502	-5819.095
3-State	GJR-GARCH	Skewed GED	-5657.2097	-5542.601
4-State	GJR-GARCH	Skewed GED	-5530.9493	-5359.0362
1-State	T-GARCH	Normal	-3512.2893	-3493.1878
2-State	T-GARCH	Normal	-4672.6212	-4624.8676
3-State	T-GARCH	Normal	-4562.1034	-4476.1468
4-State	T-GARCH	Normal	-4353.6031	-4219.8929
1-State	T-GARCH	Student's t	-5045.2892	-5021.4123
2-State	T-GARCH	Student's t	-7230.7734	-7173.469
3-State	T-GARCH	Student's t	-5771.0687	-5670.786
4-State	T-GARCH	Student's t	-8153.5823	-8000.7706
1-State	T-GARCH	GED	-5131.1014	-5107.2246
2-State	T-GARCH	GED	-5397.1094	-5339.805
3-State	T-GARCH	GED	-6234.9244	-6134.6417

4-State	T-GARCH	GED	-5805.3561	-5652.5444
1-State	T-GARCH	Skewed Normal	-3516.935	-3493.0582
2-State	T-GARCH	Skewed Normal	-4854.2182	-4796.9138
3-State	T-GARCH	Skewed Normal	-4530.6532	-4430.3706
4-State	T-GARCH	Skewed Normal	-3947.9316	-3795.1199
1-State	T-GARCH	Skewed Student's t	-5048.502	-5019.8498
2-State	T-GARCH	Skewed Student's t	-7228.827	-7161.9718
3-State	T-GARCH	Skewed Student's t	-6552.7525	-6438.1437
4-State	T-GARCH	Skewed Student's t	-7009.412	-6837.4988
1-State	T-GARCH	Skewed GED	-5136.1692	-5107.517
2-State	T-GARCH	Skewed GED	-6220.4927	-6153.6376
3-State	T-GARCH	Skewed GED	-6160.9199	-6046.3111
4-State	T-GARCH	Skewed GED	-6189.0816	-6017.1684

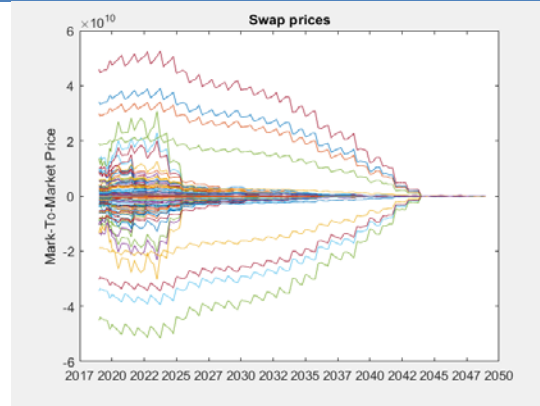
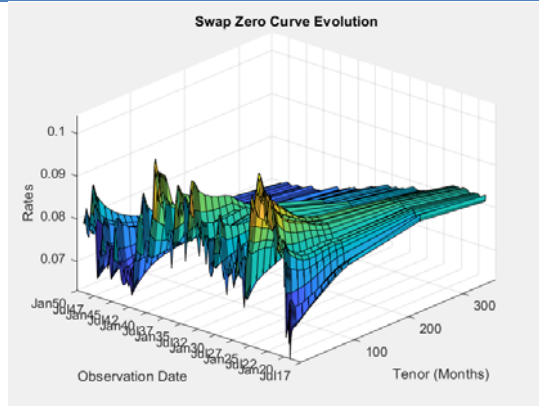
Source: Author's calculations.

**The models were estimated using the MSGARCH package in R (Ardia et al., 2018), all output results are available on request.*

Appendix B: IM and DF estimation results under varying volatility scenarios from Chapter 4

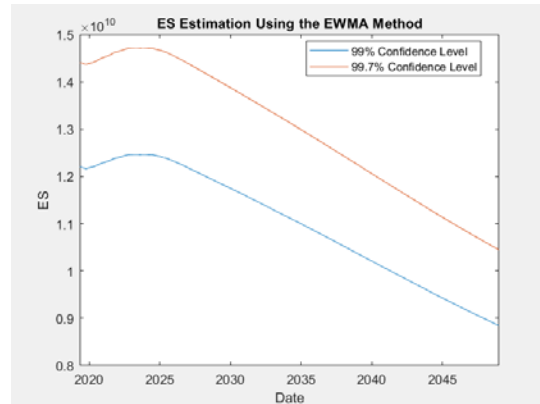
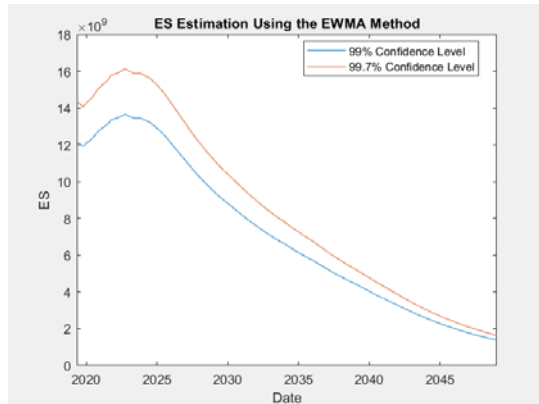
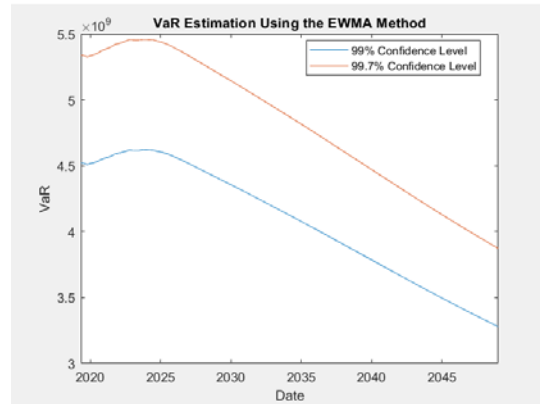
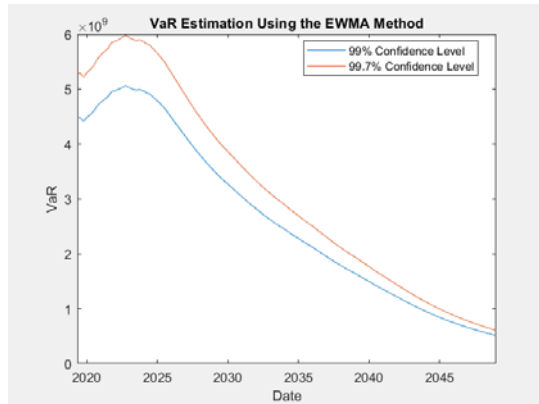
Table B.1: IM results for Cleared 99% Portfolio (#1) under tranquil market conditions

Cleared 99% Portfolio (#1)
Volatility scenario: Tranquil market



$\lambda = 0.94$

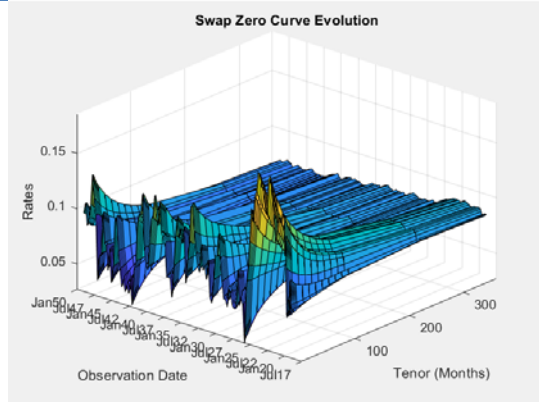
$\lambda = 0.992$



Source: Author's calculation

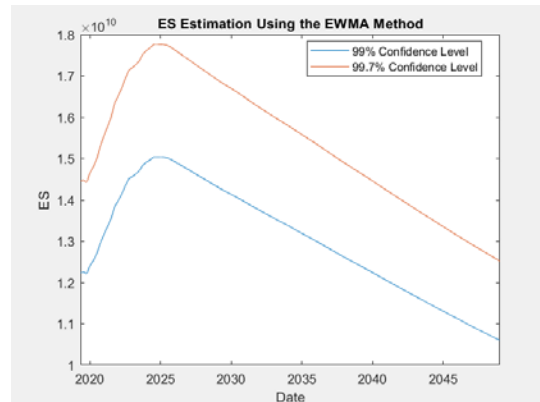
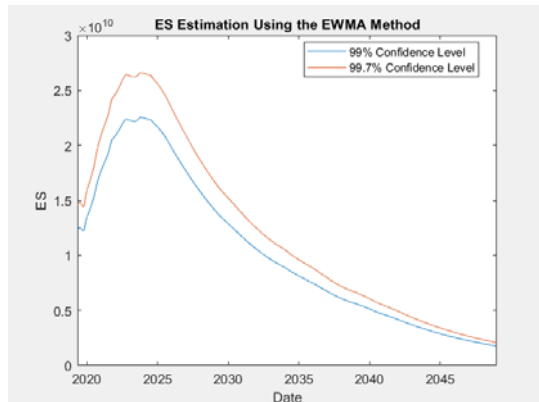
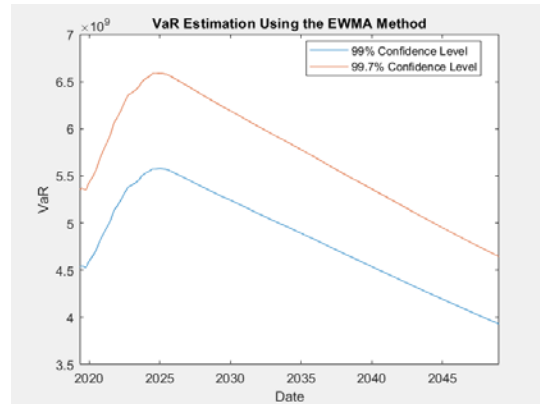
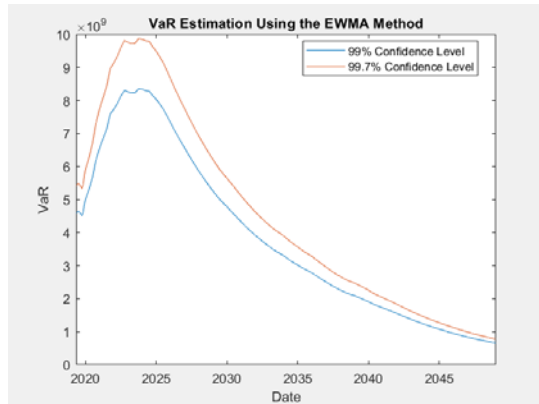
Table B.2: IM results for Cleared 99% Portfolio (#1) under normal market conditions

Cleared 99% Portfolio (#1)
Volatility scenario: Normal market



$\lambda = 0.94$

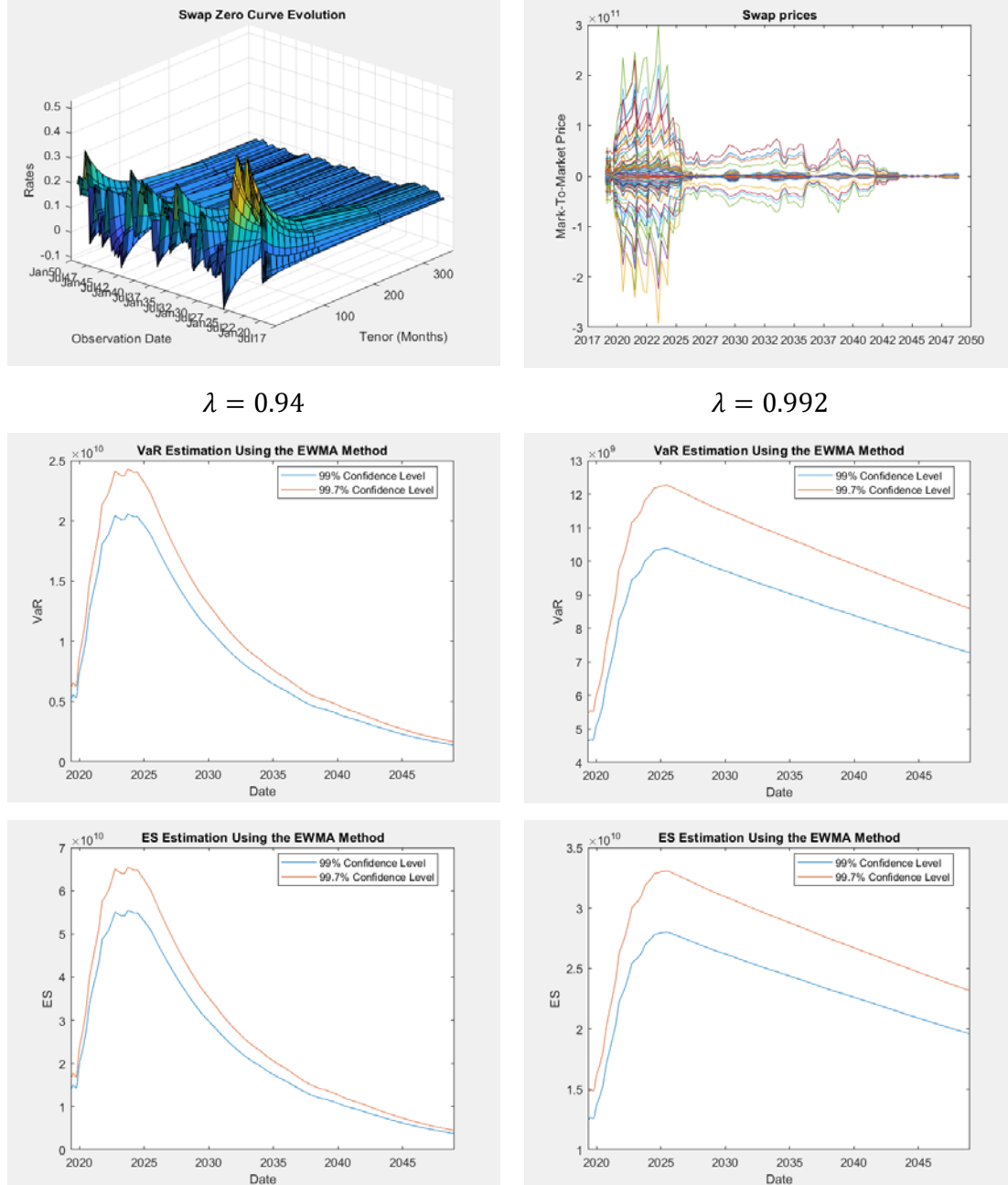
$\lambda = 0.992$



Source: Author's calculation

Table B.3: IM results for Cleared 99% Portfolio (#1) under market stress conditions

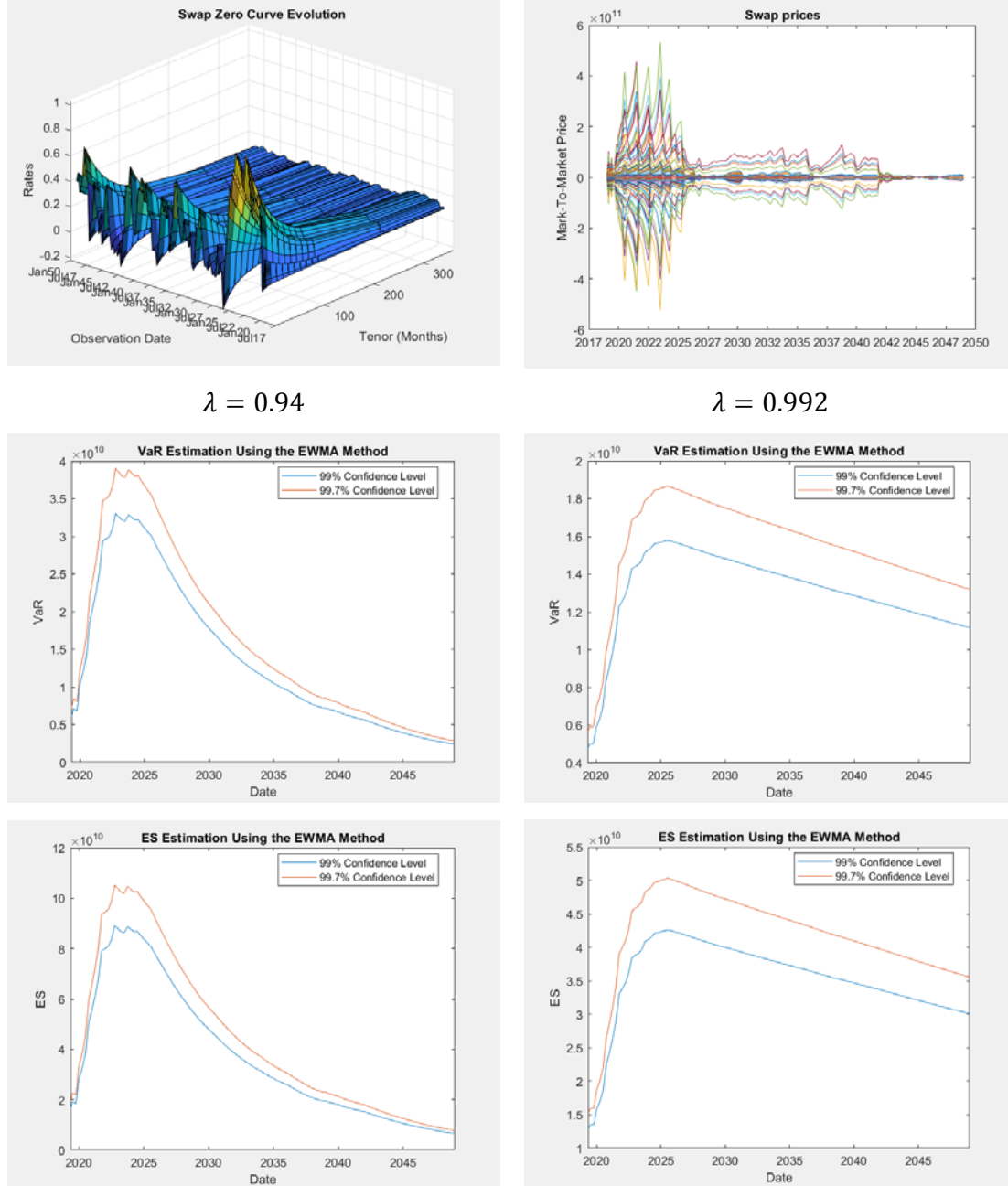
Cleared 99% Portfolio (#1)
Volatility scenario: Market stress



Source: Author's calculation

Table B.4: IM results for Cleared 99% Portfolio (#1) under extreme market stress conditions

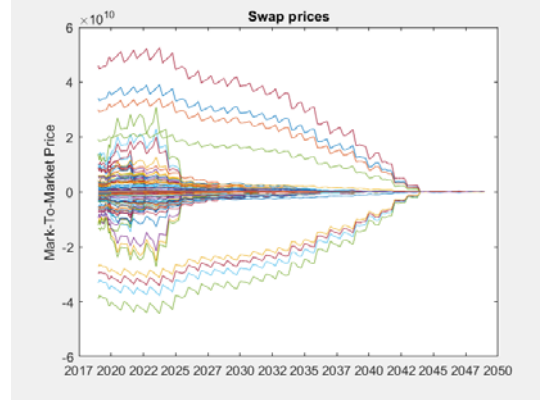
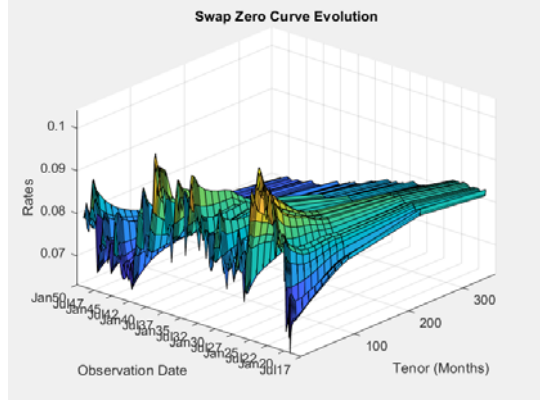
Cleared 99% Portfolio (#1)
Volatility scenario: Extreme market stress



Source: Author's calculation

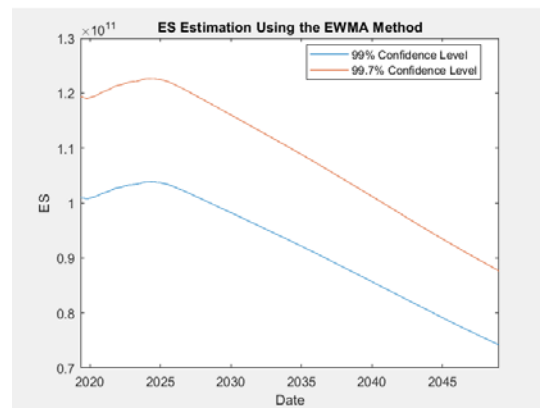
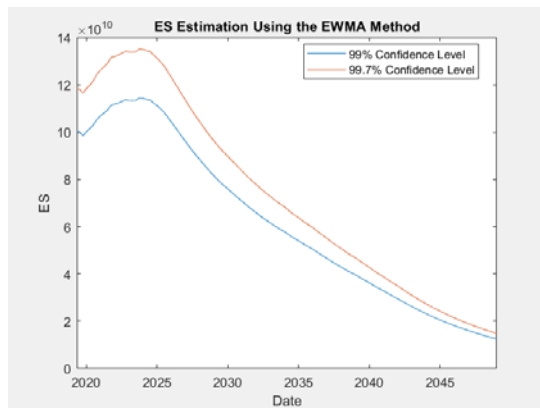
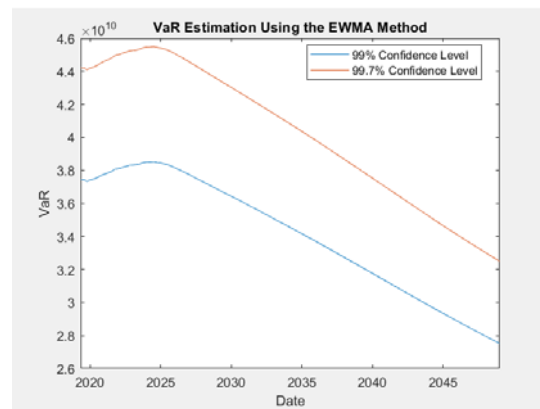
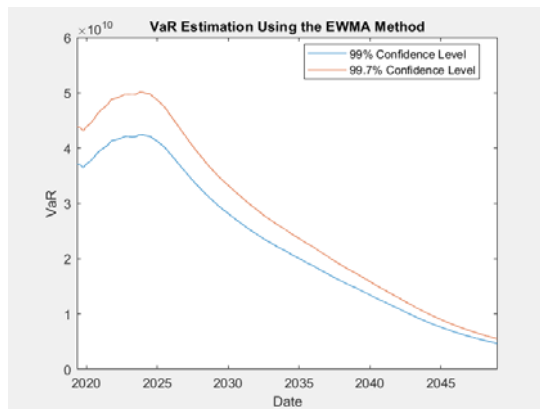
Table B.5: IM results for Cleared 90% Portfolio (#2) under tranquil market conditions

Cleared 90% Portfolio (#2)
Volatility scenario: Tranquil market



$\lambda = 0.94$

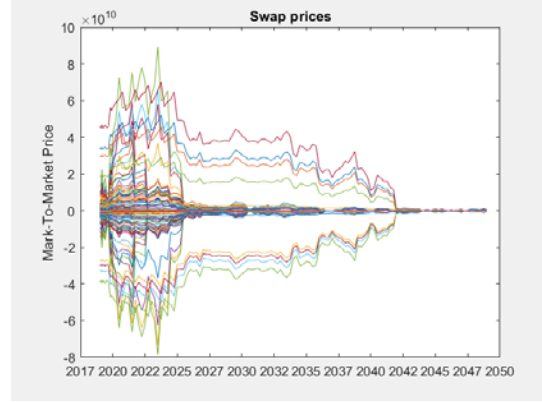
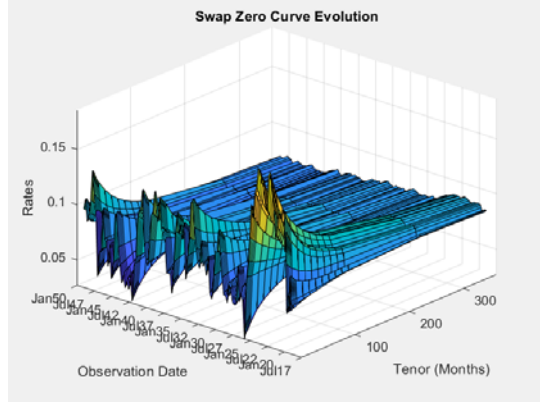
$\lambda = 0.992$



Source: Author's calculation

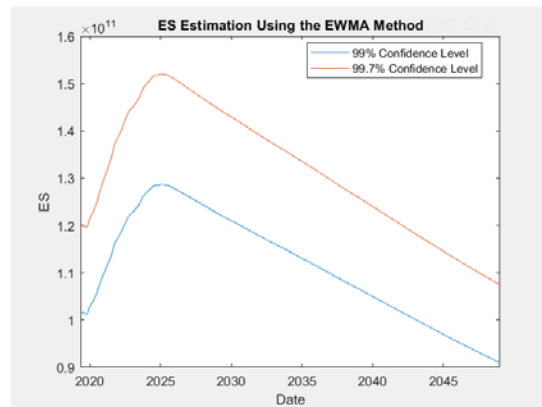
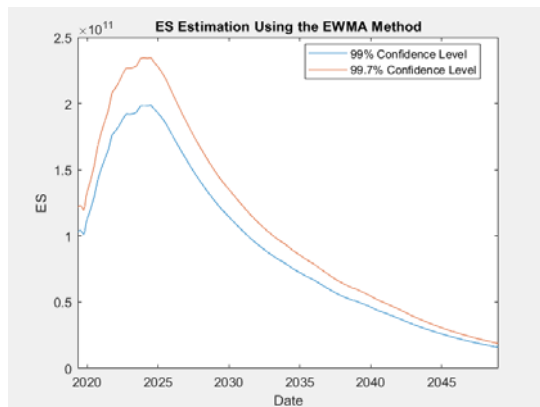
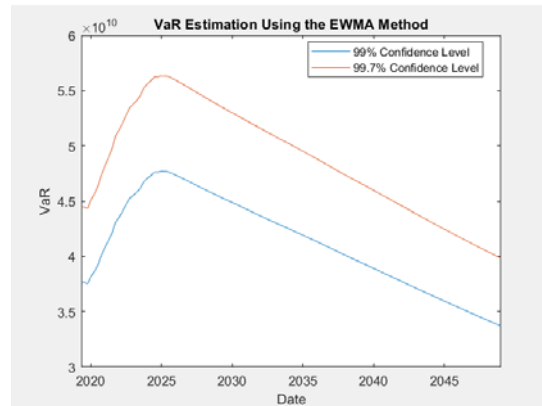
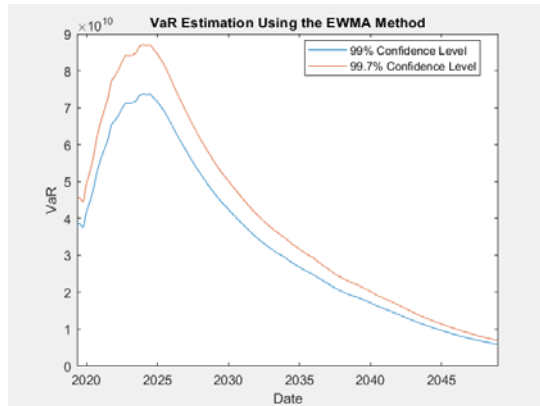
Table B.6: IM results for Cleared 90% Portfolio (#2) under normal market conditions

Cleared 90% Portfolio (#2)
Volatility scenario: Normal market



$\lambda = 0.94$

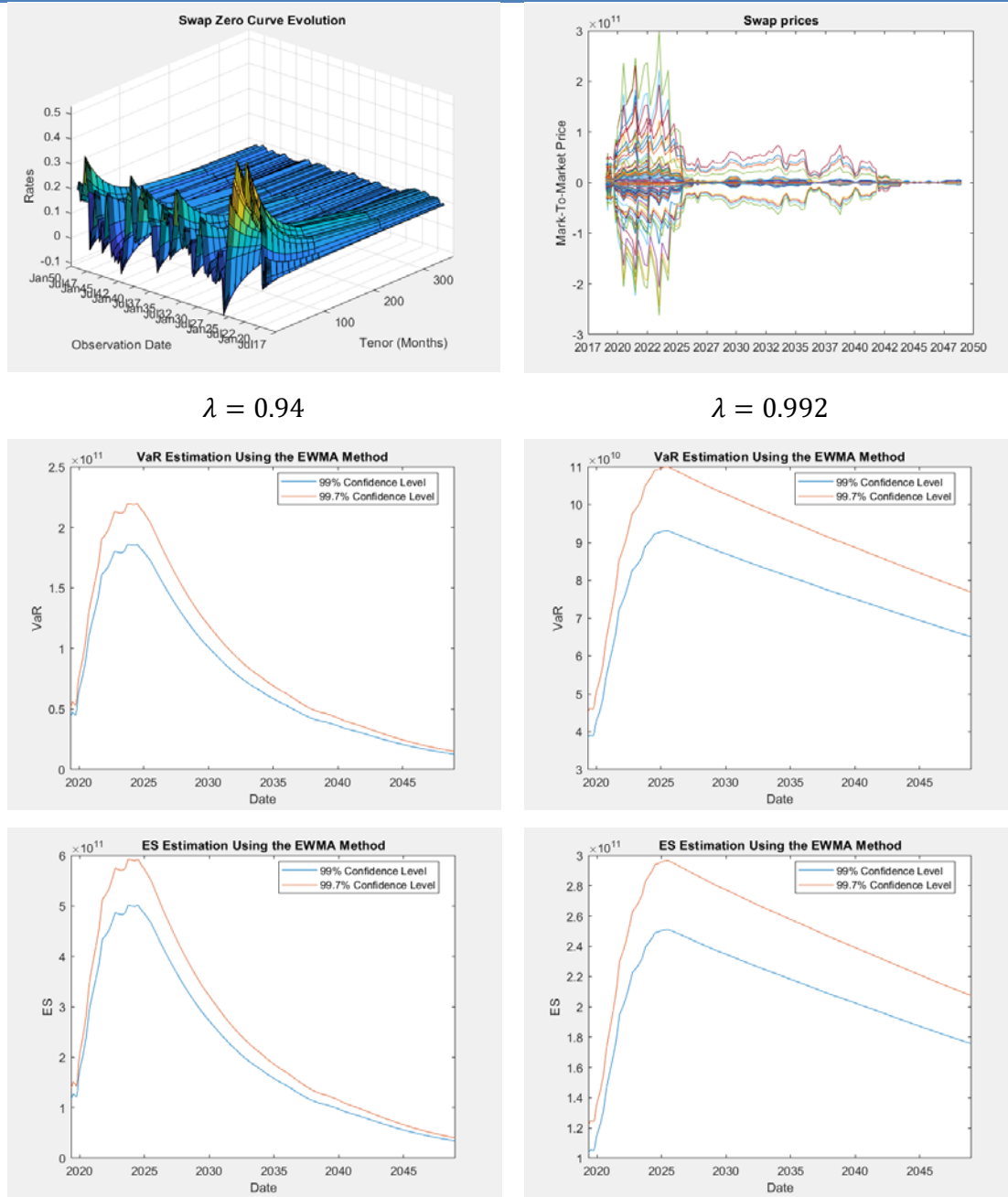
$\lambda = 0.992$



Source: Author's calculation

Table B.7: IM results for Cleared 90% Portfolio (#2) under market stress conditions

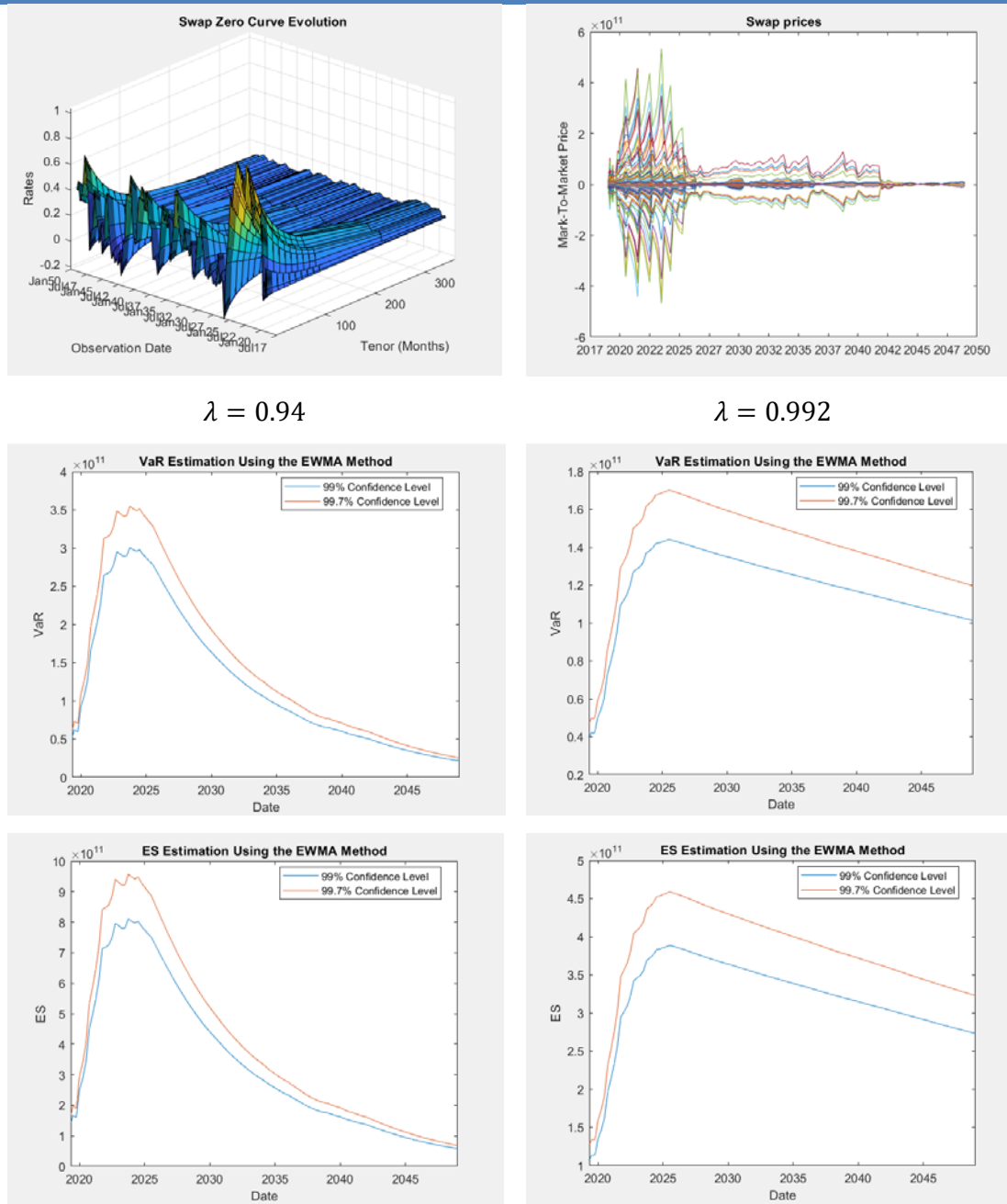
Cleared 90% Portfolio (#2)
Volatility scenario: market stress



Source: Author's calculation

Table B.8: IM results for Cleared 90% Portfolio (#2) under extreme market stress conditions

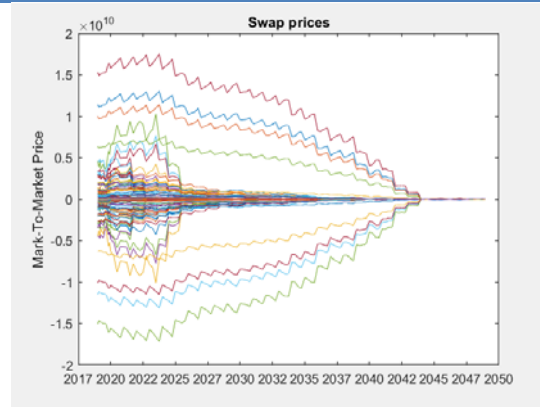
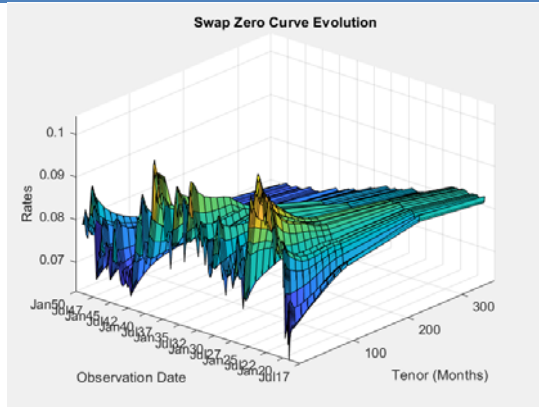
Cleared 90% Portfolio (#2)
Volatility scenario: Extreme market stress



Source: Author's calculation

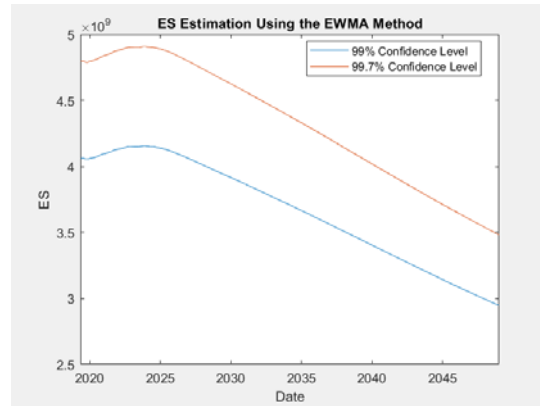
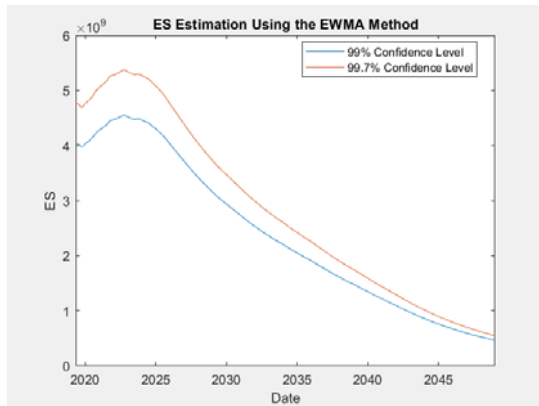
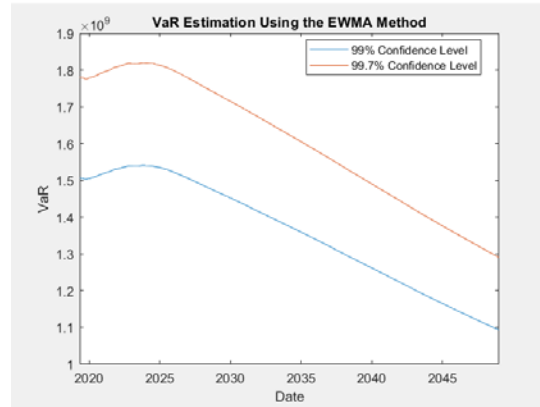
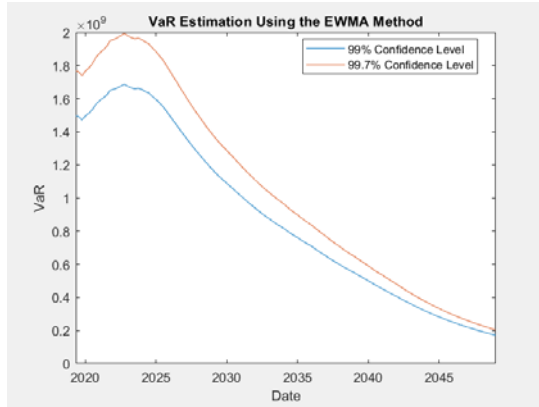
Table B.9: IM results for Uncleared 99% Portfolio (#3) under tranquil market conditions

Uncleared 99% Portfolio (#3)
Volatility scenario: Tranquil market



$\lambda = 0.94$

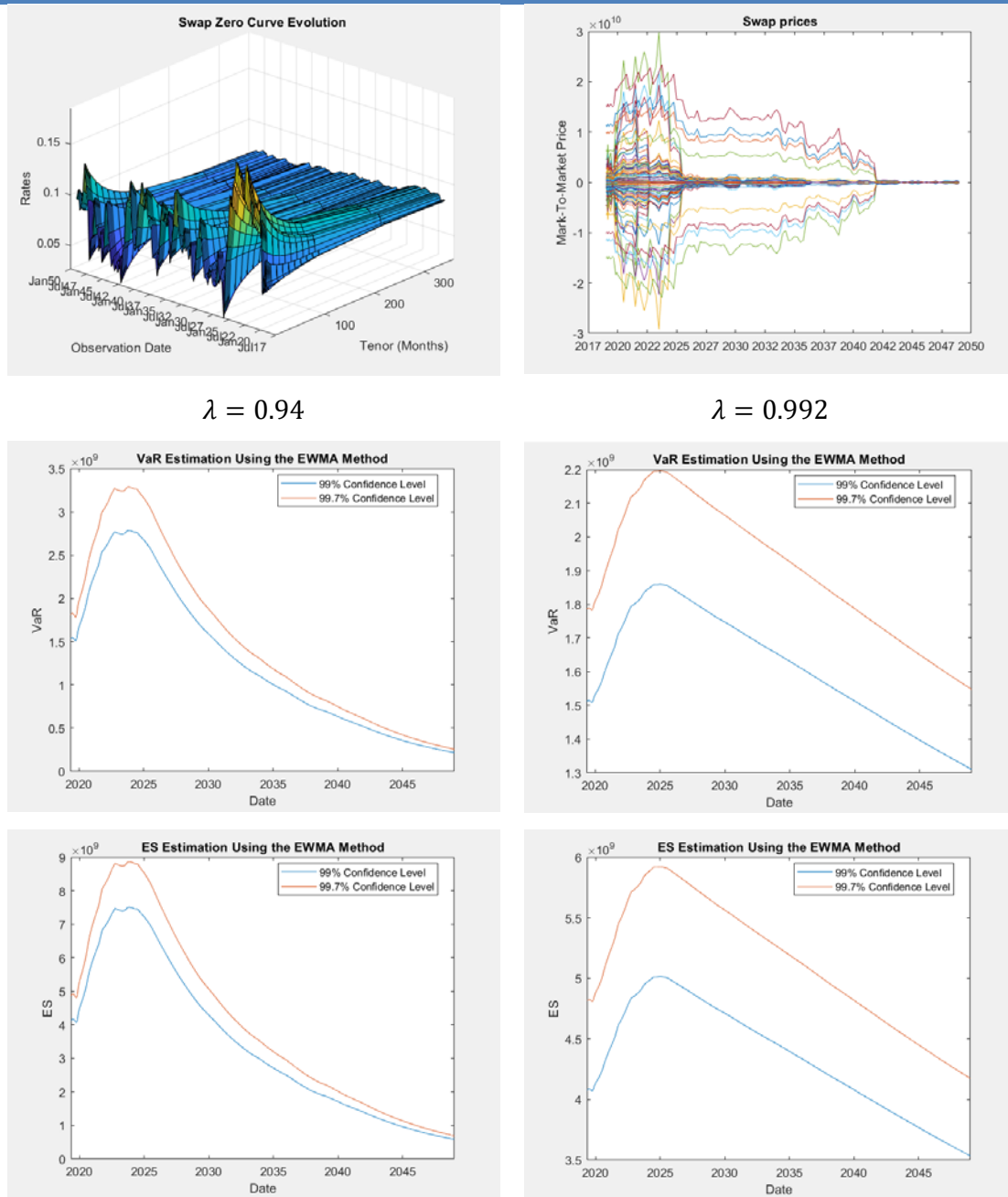
$\lambda = 0.992$



Source: Author's calculation

Table B.10: IM results for Uncleared 99% Portfolio (#3) under normal market conditions

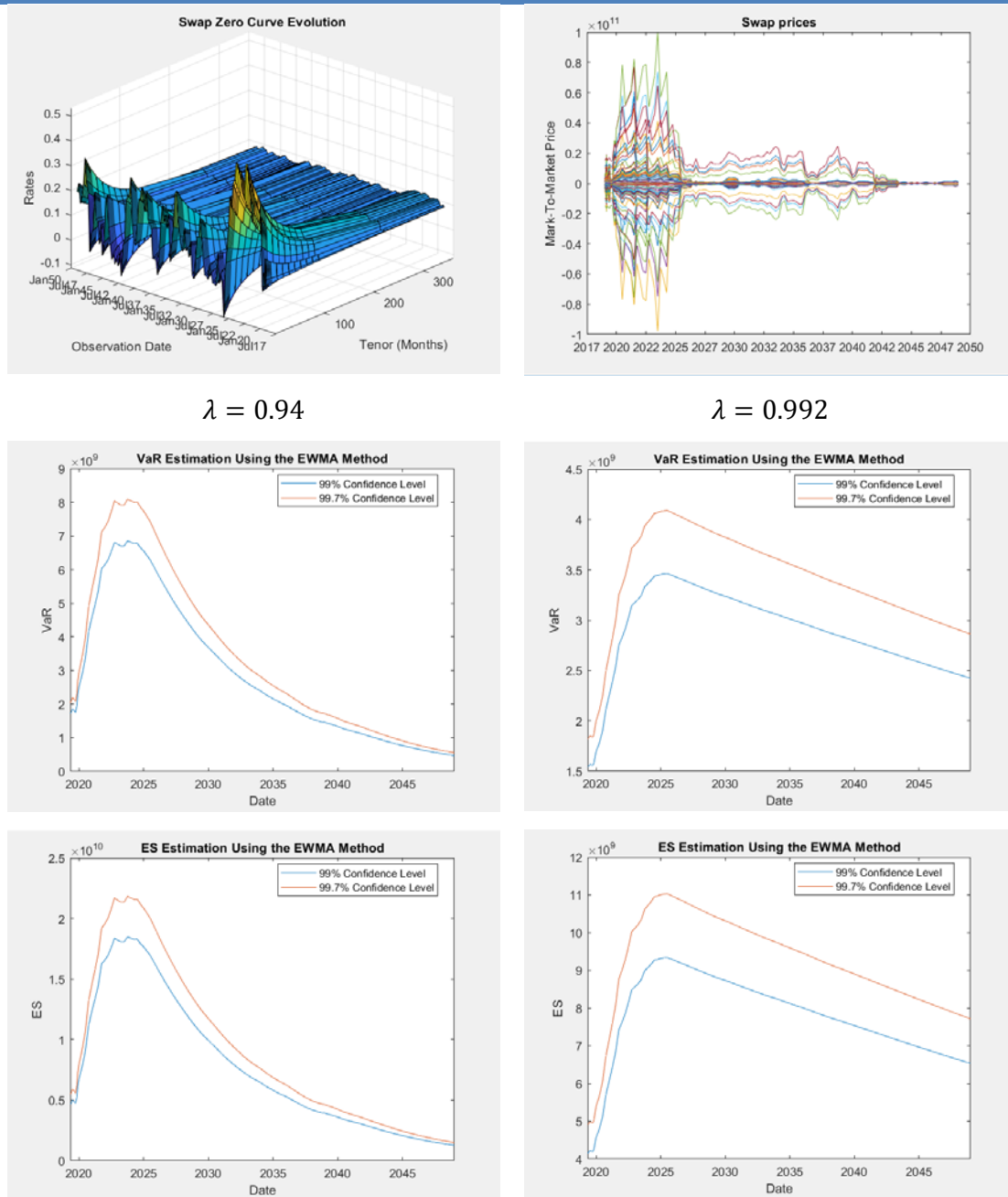
Uncleared 99% Portfolio (#3)
Volatility scenario: Normal market



Source: Author's calculation

Table B.11: IM results for Uncleared 99% Portfolio (#3) under market stress conditions

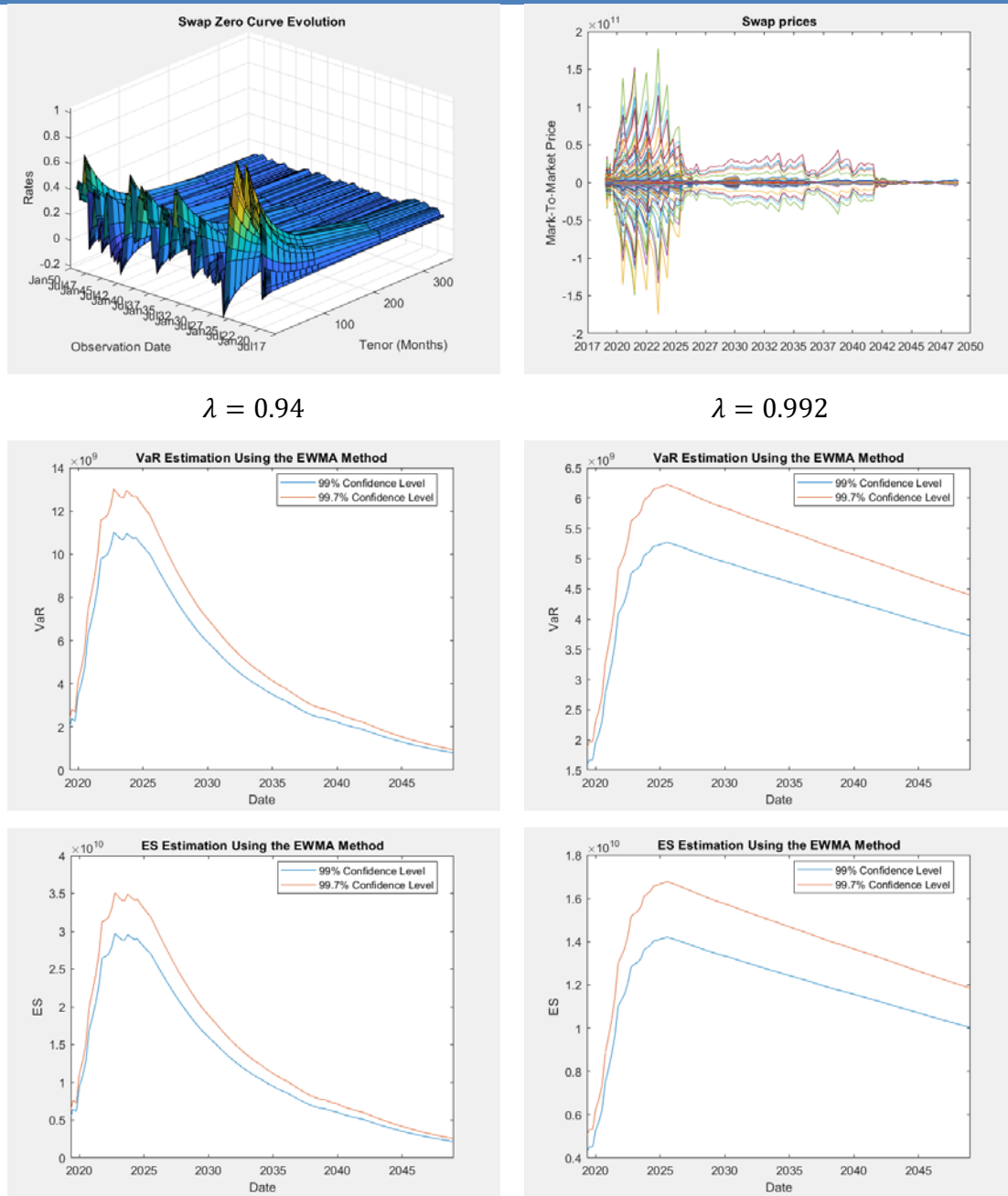
Uncleared 99% Portfolio (#3)
Volatility scenario: Market stress



Source: Author's calculation

Table B.12: IM results for Uncleared 99% Portfolio (#3) under extreme market stress conditions

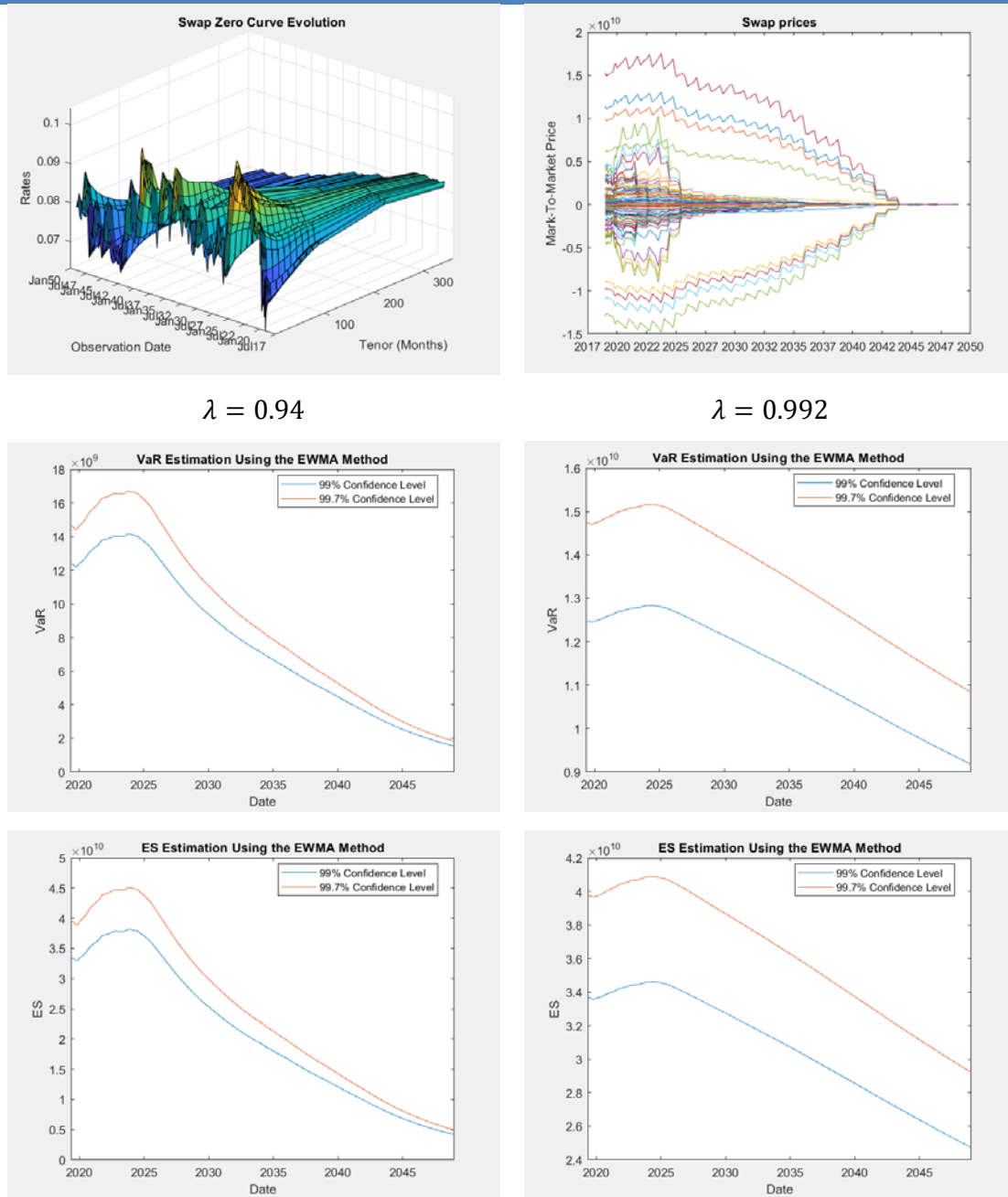
Uncleared 99% Portfolio (#3)
Volatility scenario: Extreme market stress



Source: Author's calculation

Table B.13: IM results for Uncleared 90% Portfolio (#4) under tranquil market conditions

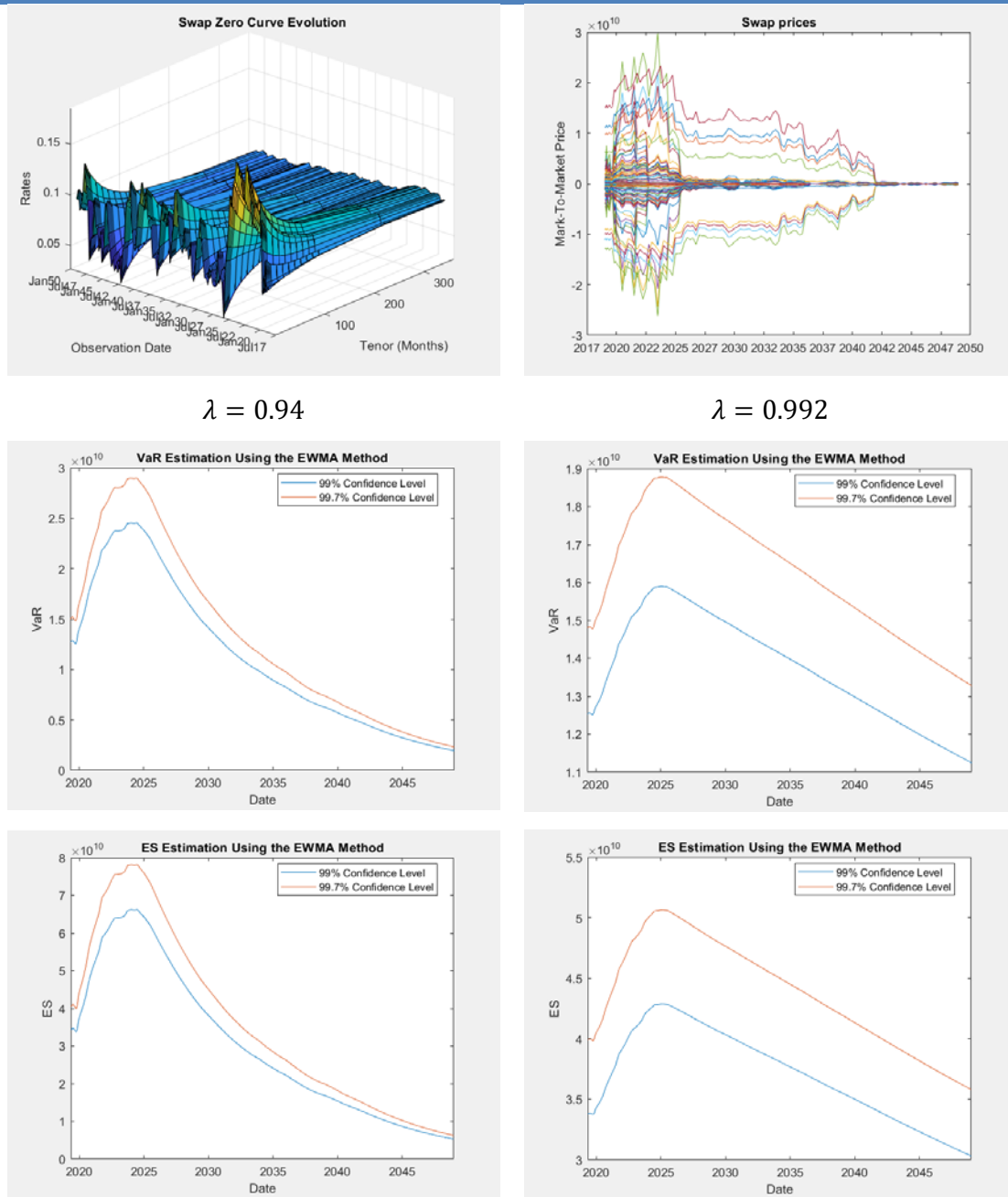
Uncleared 90% Portfolio (#4)
Volatility scenario: Tranquil market



Source: Author's calculation

Table B.14: IM results for Uncleared 90% Portfolio (#4) under normal market conditions

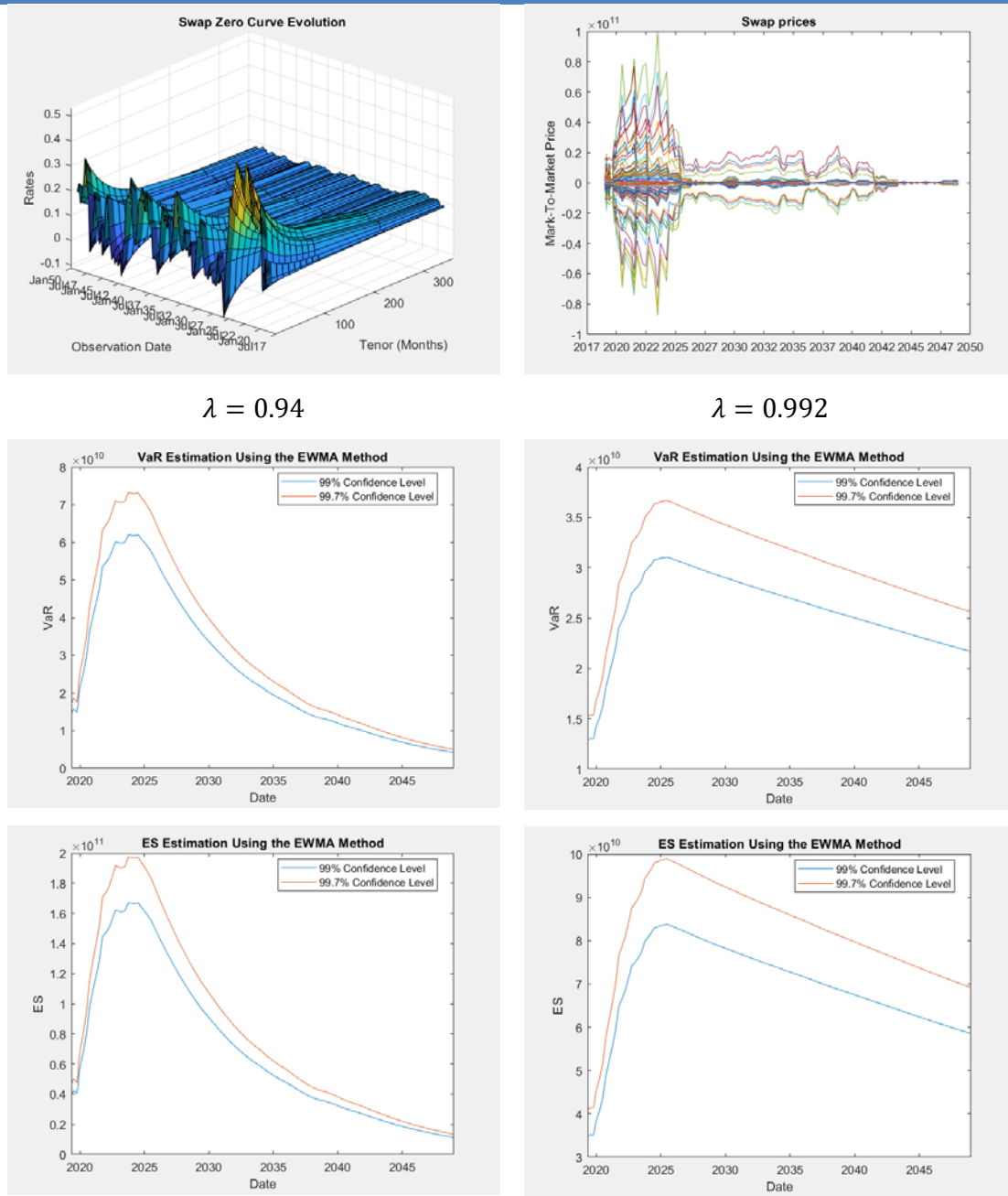
Uncleared 90% Portfolio (#4)
Volatility scenario: Normal market



Source: Author's calculation

Table B.15: IM results for Uncleared 90% Portfolio (#4) under market stress conditions

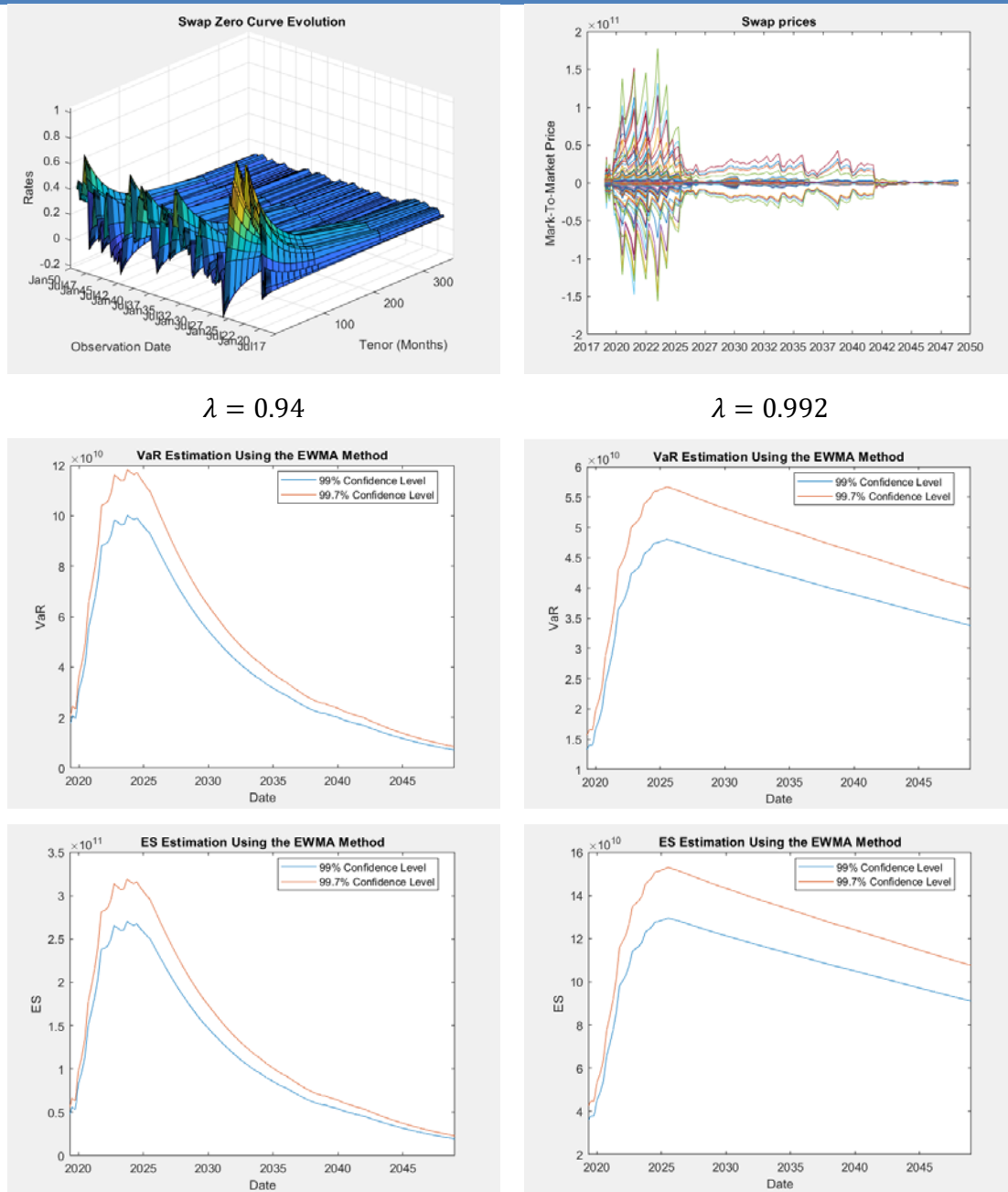
Uncleared 90% Portfolio (#4)
Volatility scenario: Market stress



Source: Author's calculation

Table B.16: IM results for Uncleared 90% Portfolio (#4) under extreme market stress conditions

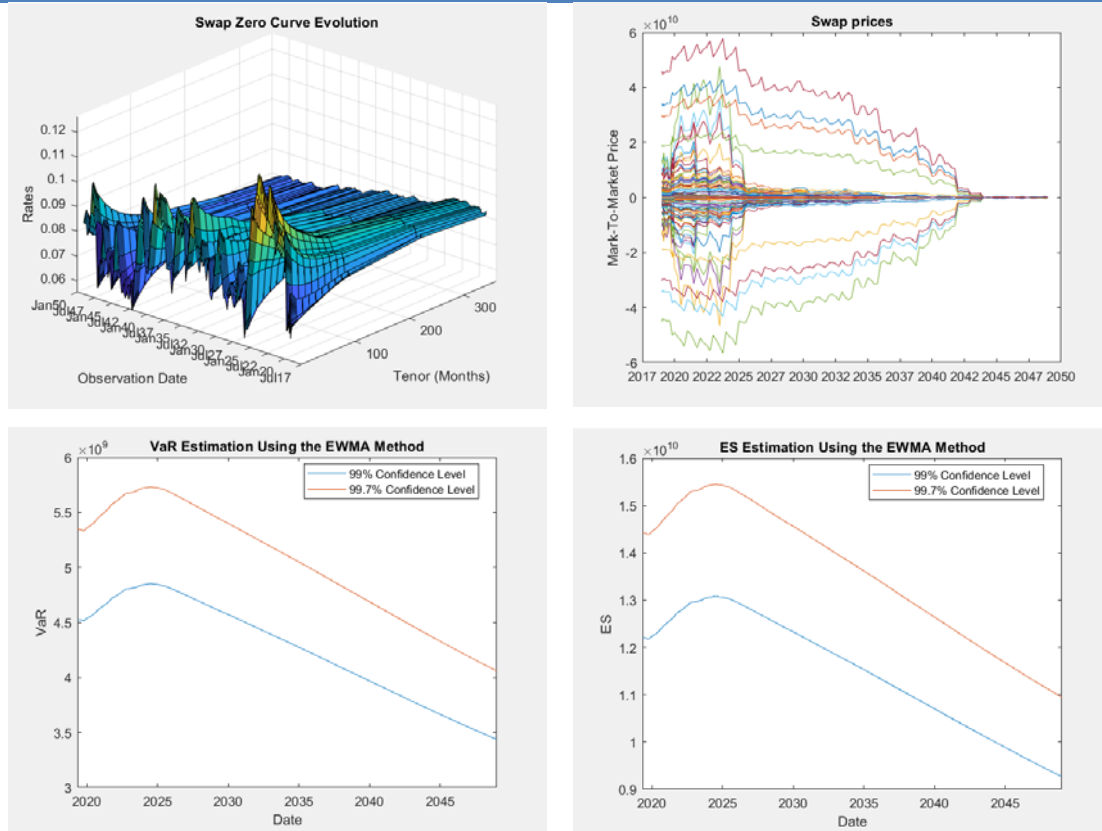
Uncleared 90% Portfolio (#4)
Volatility scenario: Extreme market stress



Source: Author's calculation

Table B.17: DF results for Cleared 99% Portfolio (#1) under tranquil market conditions

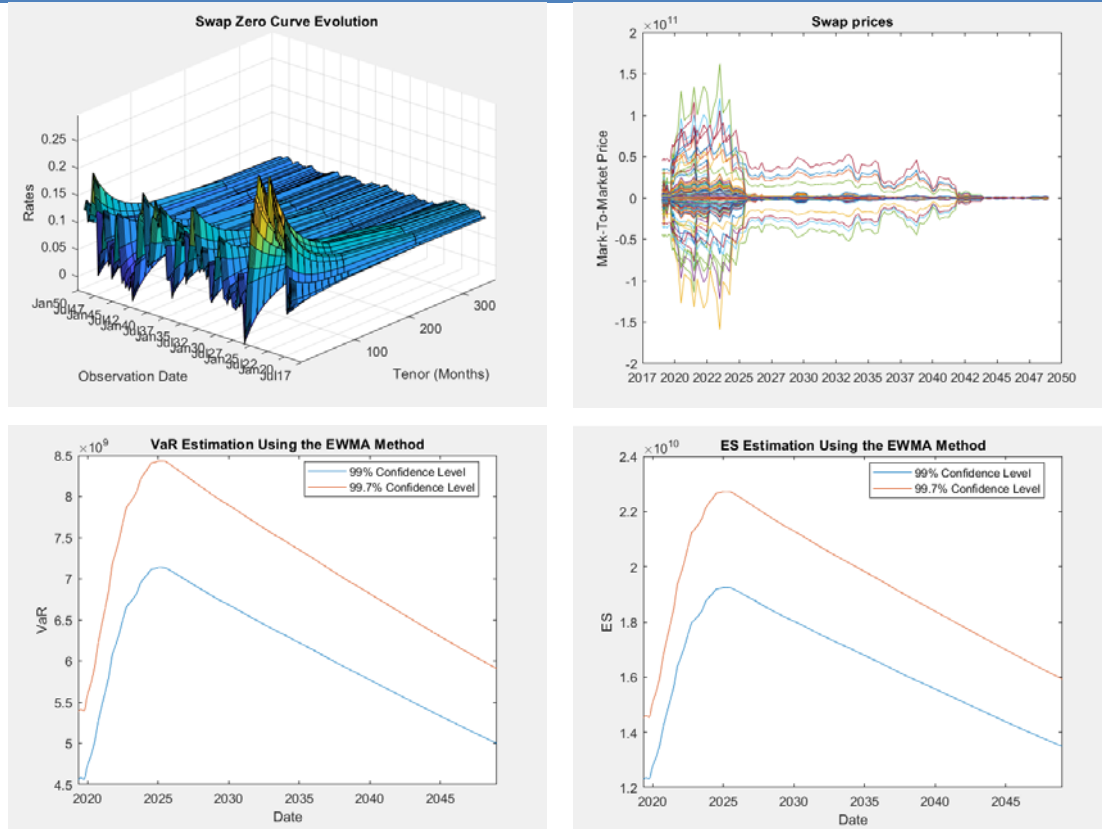
Cleared 99% Portfolio (#1)
Volatility scenario: Tranquil market (stressed)



Source: Author's calculation

Table B.18: DF results for Cleared 99% Portfolio (#1) under normal market conditions

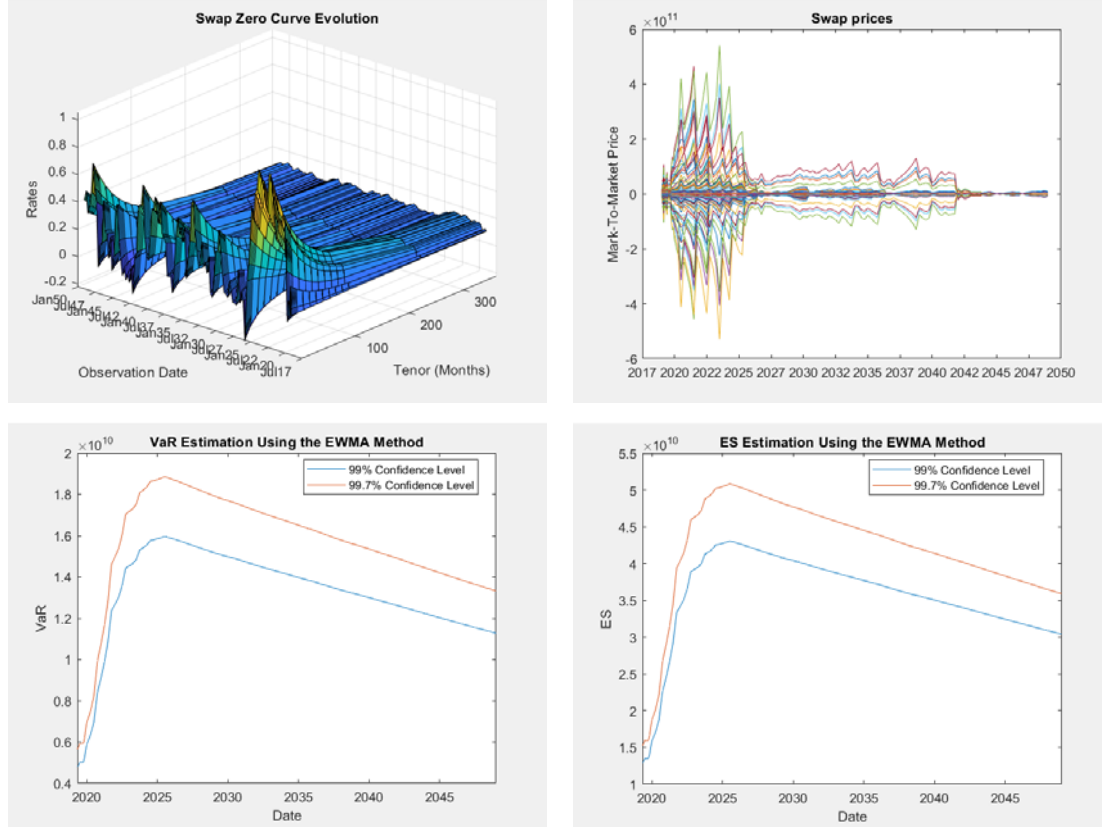
Cleared 99% Portfolio (#1)
Volatility scenario: Normal market (stressed)



Source: Author's calculation

Table B.19: DF results for Cleared 99% Portfolio (#1) under market stress conditions

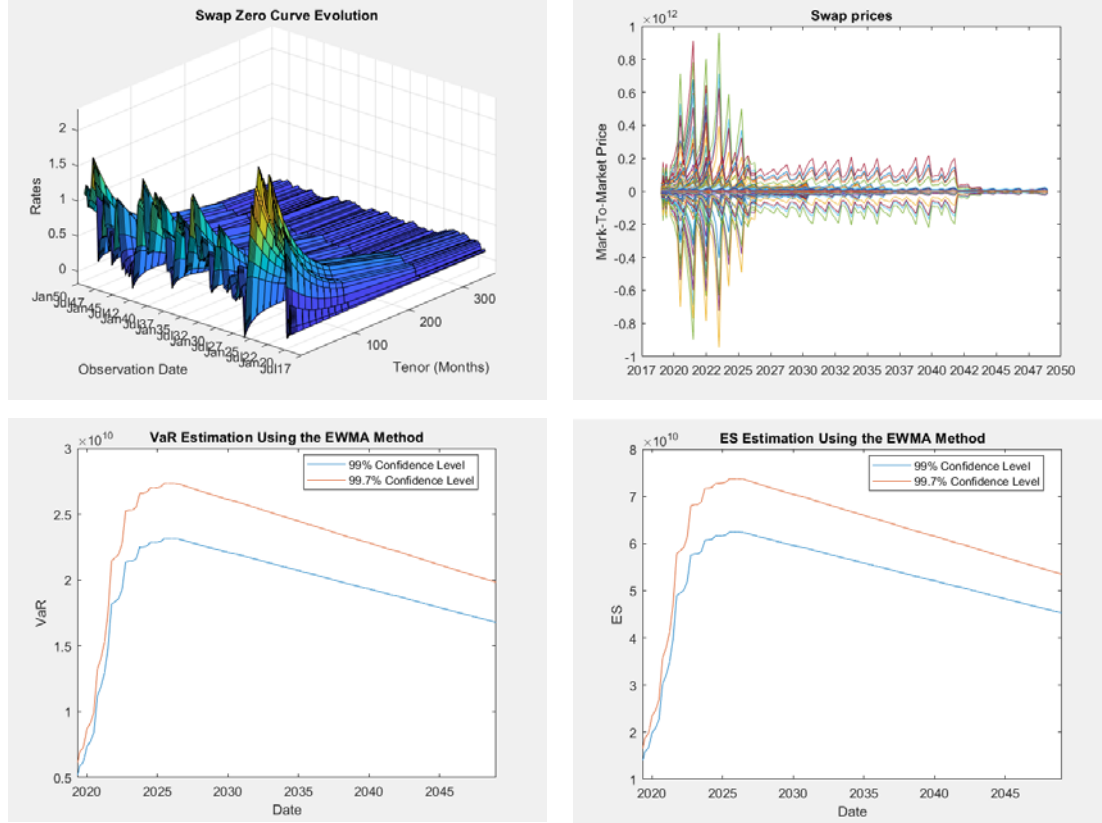
Cleared 99% Portfolio (#1)
Volatility scenario: Market stress (stressed)



Source: Author's calculation

Table B.20: DF results for Cleared 99% Portfolio (#1) under extreme market stress conditions

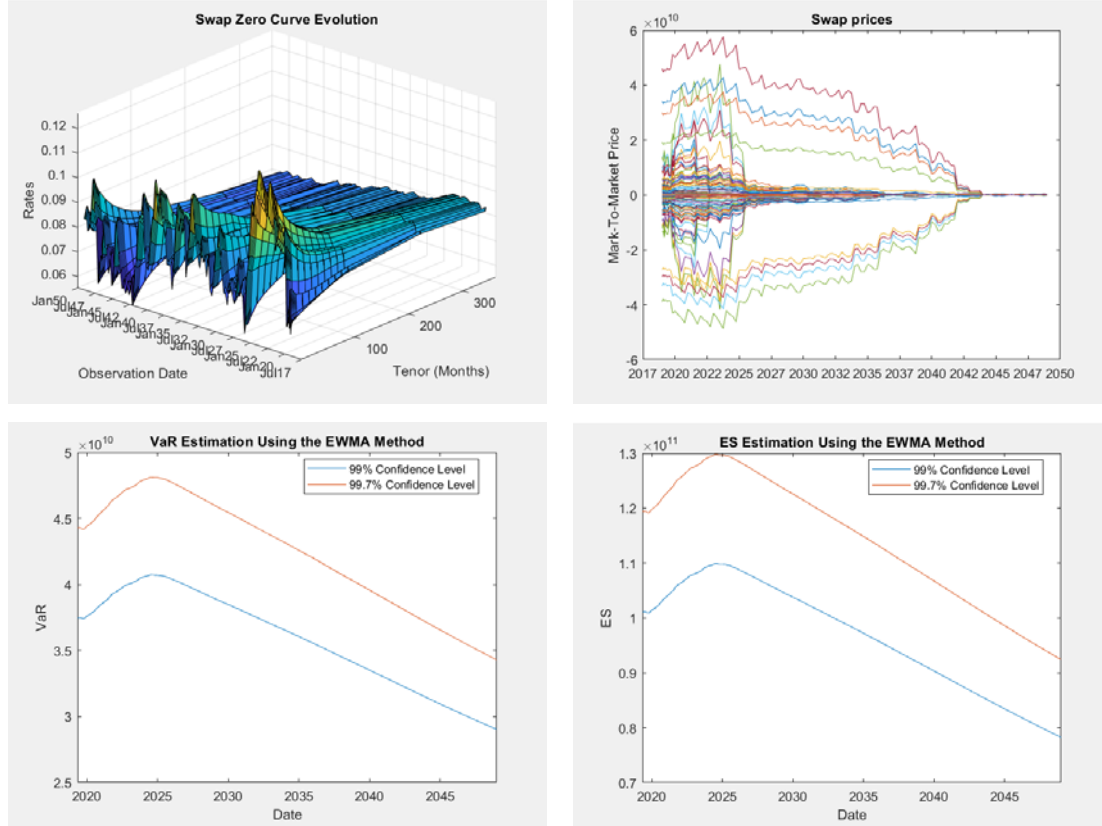
Cleared 99% Portfolio (#1)
Volatility scenario: Extreme market stress (stressed)



Source: Author's calculation

Table B.21: DF results for Cleared 90% Portfolio (#2) under tranquil market conditions

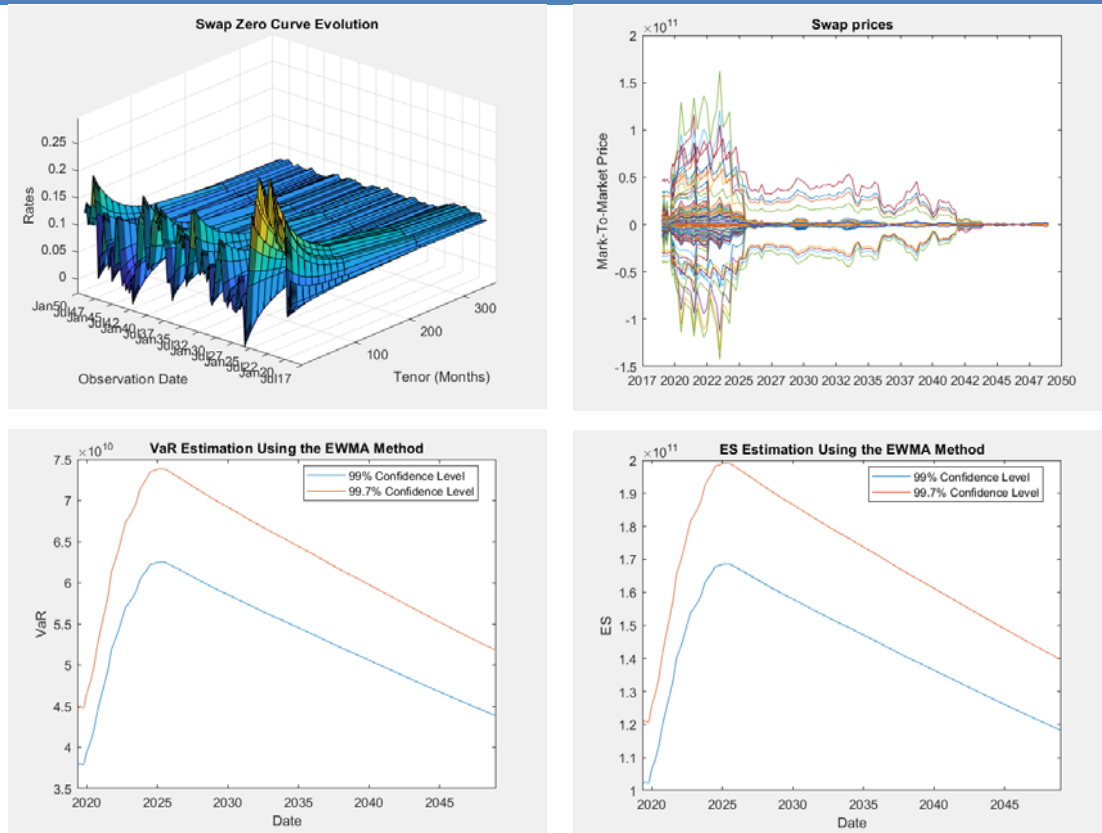
Cleared 90% Portfolio (#2)
Volatility scenario: Tranquil market (stressed)



Source: Author's calculation

Table B.22: DF results for Cleared 90% Portfolio (#2) under normal market conditions

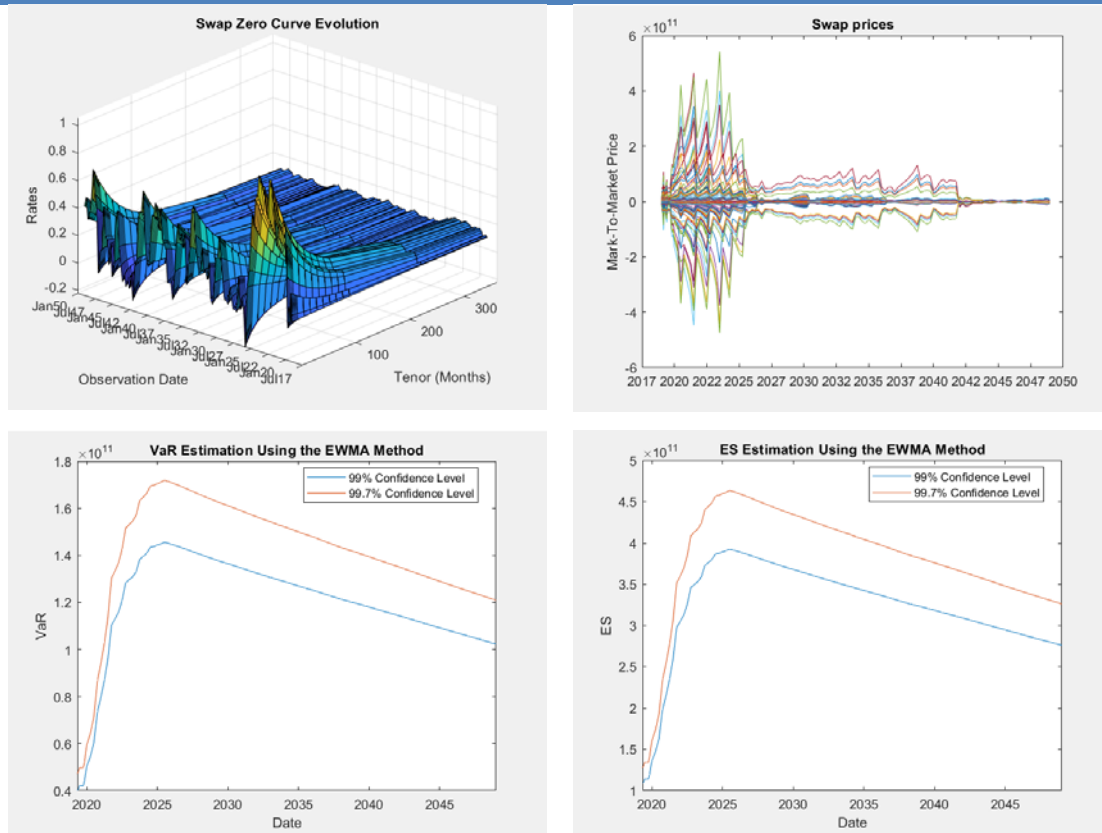
Cleared 90% Portfolio (#2)
Volatility scenario: Normal market (stressed)



Source: Author's calculation

Table B.23: DF results for Cleared 90% Portfolio (#2) under market stress conditions

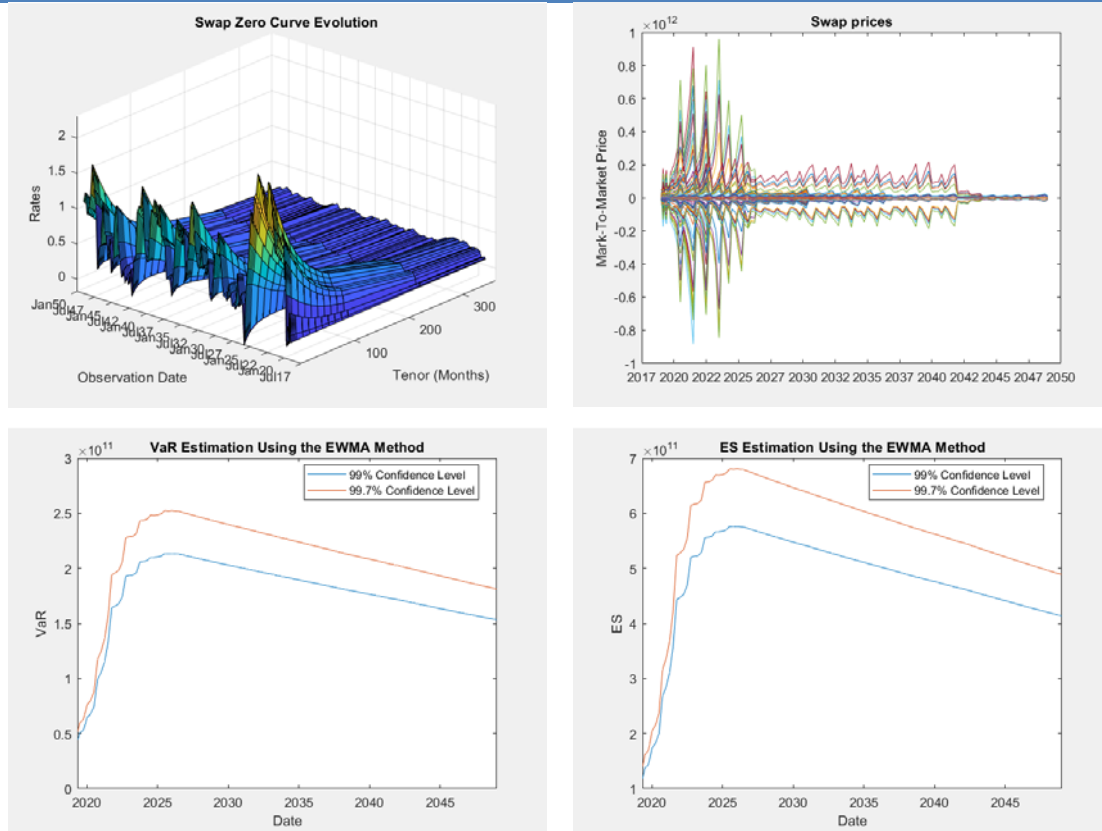
Cleared 90% Portfolio (#2)
Volatility scenario: Market stress (stressed)



Source: Author's calculation

Table B.24: DF results for Cleared 90% Portfolio (#2) under extreme market stress conditions

Cleared 90% Portfolio (#2)
Volatility scenario: Extreme market stress (stressed)



Source: Author's calculation

Appendix C: Results of in-sample model testing from Chapter 5

Table C.1: ZARGBP - AIC and BIC results for each of the GARCH-type models tested

ZARGBP Results				
	Model		AIC	BIC
1-State	ARCH	Normal	12816.165	12828.9019
2-State	ARCH	Normal	12303.738	12341.9488
3-State	ARCH	Normal	12867.1624	12943.5839
4-State	ARCH	Normal	12154.1305	12281.4998
1-State	ARCH	Student's t	12309.2811	12328.3865
2-State	ARCH	Student's t	12304.2739	12355.2215
3-State	ARCH	Student's t	12306.4286	12401.9555
4-State	ARCH	Student's t	12113.7534	12266.5964
1-State	ARCH	GED	12367.0296	12386.135
2-State	ARCH	GED	12692.8442	12743.7919
3-State	ARCH	GED	12706.8236	12802.3505
4-State	ARCH	GED	12296.132	12448.9751
1-State	ARCH	Skewed Normal	12768.7646	12787.87
2-State	ARCH	Skewed Normal	12348.0062	12398.9539
3-State	ARCH	Skewed Normal	12324.5026	12420.0295
4-State	ARCH	Skewed Normal	13203.8132	13356.6563
1-State	ARCH	Skewed Student's t	12303.9444	12329.4183
2-State	ARCH	Skewed Student's t	12107.7453	12171.4299
3-State	ARCH	Skewed Student's t	12090.6982	12205.3305
4-State	ARCH	Skewed Student's t	12291.979	12470.2959
1-State	ARCH	Skewed GED	12357.2699	12382.7437
2-State	ARCH	Skewed GED	12105.1844	12168.869
3-State	ARCH	Skewed GED	12483.8472	12598.4795
4-State	ARCH	Skewed GED	12336.6534	12514.9703
1-State	GARCH	Normal	12242.4941	12261.5995
2-State	GARCH	Normal	12067.1247	12118.0724
3-State	GARCH	Normal	12048.7444	12144.2713
4-State	GARCH	Normal	12149.8375	12302.6805
1-State	GARCH	Student's t	12022.8642	12048.3381
2-State	GARCH	Student's t	12010.8634	12074.548
3-State	GARCH	Student's t	12050.8641	12165.4964
4-State	GARCH	Student's t	12070.8641	12249.181
1-State	GARCH	GED	12061.6887	12087.1625
2-State	GARCH	GED	12004.115	12067.7996
3-State	GARCH	GED	11983.2399	12097.8722
4-State	GARCH	GED	12020.8133	12199.1302
1-State	GARCH	Skewed Normal	12202.5845	12228.0583
2-State	GARCH	Skewed Normal	12048.2626	12111.9472
3-State	GARCH	Skewed Normal	12036.2295	12150.8618

4-State	GARCH	Skewed Normal	12042.3346	12220.6515
1-State	GARCH	Skewed Student's t	12012.157	12043.9993
2-State	GARCH	Skewed Student's t	12026.1572	12102.5788
3-State	GARCH	Skewed Student's t	12044.1574	12177.8951
4-State	GARCH	Skewed Student's t	12066.157	12269.9477
1-State	GARCH	Skewed GED	12043.4087	12075.251
2-State	GARCH	Skewed GED	12016.9088	12093.3304
3-State	GARCH	Skewed GED	11995.5016	12129.2393
4-State	GARCH	Skewed GED	12010.078	12213.8688
1-State	E-GARCH	Normal	12243.6141	12269.088
2-State	E-GARCH	Normal	12046.4359	12110.1205
3-State	E-GARCH	Normal	12012.1291	12126.7614
4-State	E-GARCH	Normal	12015.0112	12193.3281
1-State	E-GARCH	Student's t	12029.4946	12061.3369
2-State	E-GARCH	Student's t	12003.7395	12080.161
3-State	E-GARCH	Student's t	12015.5534	12149.291
4-State	E-GARCH	Student's t	12023.5642	12227.355
1-State	E-GARCH	GED	12066.6732	12098.5155
2-State	E-GARCH	GED	12008.4358	12084.8574
3-State	E-GARCH	GED	11972.8095	12106.5472
4-State	E-GARCH	GED	12017.6563	12221.447
1-State	E-GARCH	Skewed Normal	12213.389	12245.2313
2-State	E-GARCH	Skewed Normal	12035.0882	12111.5097
3-State	E-GARCH	Skewed Normal	11995.3665	12129.1042
4-State	E-GARCH	Skewed Normal	12008.0267	12211.8175
1-State	E-GARCH	Skewed Student's t	12020.6489	12058.8596
2-State	E-GARCH	Skewed Student's t	11990.7018	12079.8603
3-State	E-GARCH	Skewed Student's t	12003.2069	12156.05
4-State	E-GARCH	Skewed Student's t	12012.6992	12241.9638
1-State	E-GARCH	Skewed GED	12051.6434	12089.8541
2-State	E-GARCH	Skewed GED	12006.7509	12095.9094
3-State	E-GARCH	Skewed GED	12018.1987	12171.0418
4-State	E-GARCH	Skewed GED	12051.8037	12281.0683
1-State	GJR-GARCH	Normal	12222.933	12248.4069
2-State	GJR-GARCH	Normal	12060.3472	12124.0318
3-State	GJR-GARCH	Normal	12025.9451	12140.5774
4-State	GJR-GARCH	Normal	12019.5179	12197.8348
1-State	GJR-GARCH	Student's t	12014.9112	12046.7535
2-State	GJR-GARCH	Student's t	11990.2192	12066.6407
3-State	GJR-GARCH	Student's t	12046.9112	12180.6489
4-State	GJR-GARCH	Student's t	12068.9112	12272.7019
1-State	GJR-GARCH	GED	12051.8335	12083.6758
2-State	GJR-GARCH	GED	12001.2665	12077.688
3-State	GJR-GARCH	GED	11960.7849	12094.5226
4-State	GJR-GARCH	GED	11976.703	12180.4937
1-State	GJR-GARCH	Skewed Normal	12186.4912	12218.3335
2-State	GJR-GARCH	Skewed Normal	12035.6905	12112.1121
3-State	GJR-GARCH	Skewed Normal	11998.3244	12132.0621

4-State	GJR-GARCH	Skewed Normal	11992.6253	12196.4161
1-State	GJR-GARCH	Skewed Student's t	12004.777	12042.9878
2-State	GJR-GARCH	Skewed Student's t	11977.202	12066.3605
3-State	GJR-GARCH	Skewed Student's t	12040.7773	12193.6204
4-State	GJR-GARCH	Skewed Student's t	12064.7771	12294.0417
1-State	GJR-GARCH	Skewed GED	12034.4754	12072.6861
2-State	GJR-GARCH	Skewed GED	12000.8475	12090.006
3-State	GJR-GARCH	Skewed GED	11985.8145	12138.6576
4-State	GJR-GARCH	Skewed GED	11992.0044	12221.269
1-State	T-GARCH	Normal	12253.1973	12278.6712
2-State	T-GARCH	Normal	12059.6298	12123.3144
3-State	T-GARCH	Normal	12024.8055	12139.4378
4-State	T-GARCH	Normal	12038.9964	12217.3133
1-State	T-GARCH	Student's t	12034.5509	12066.3932
2-State	T-GARCH	Student's t	12016.6478	12093.0693
3-State	T-GARCH	Student's t	12009.4291	12143.1668
4-State	T-GARCH	Student's t	12044.8926	12248.6834
1-State	T-GARCH	GED	12071.4987	12103.341
2-State	T-GARCH	GED	12117.4225	12193.844
3-State	T-GARCH	GED	11890.9276	12024.6653
4-State	T-GARCH	GED	11975.6018	12179.3926
1-State	T-GARCH	Skewed Normal	12224.3201	12256.1624
2-State	T-GARCH	Skewed Normal	12050.2235	12126.6451
3-State	T-GARCH	Skewed Normal	12013.1686	12146.9062
4-State	T-GARCH	Skewed Normal	12055.8683	12259.6591
1-State	T-GARCH	Skewed Student's t	12025.9113	12064.122
2-State	T-GARCH	Skewed Student's t	12006.3858	12095.5443
3-State	T-GARCH	Skewed Student's t	12013.9602	12166.8032
4-State	T-GARCH	Skewed Student's t	12023.054	12252.3186
1-State	T-GARCH	Skewed GED	12057.1383	12095.3491
2-State	T-GARCH	Skewed GED	12019.5749	12108.7333
3-State	T-GARCH	Skewed GED	12012.94	12165.7831
4-State	T-GARCH	Skewed GED	12030.1676	12259.4322

Source: Author's calculations.

Table C.2: ZARUSD - AIC and BIC results for each of the GARCH-type models tested

ZARUSD Results				
	Model		AIC	BIC
1-State	ARCH	Normal	13286.5185	13299.2554
2-State	ARCH	Normal	12775.0638	12813.2746
3-State	ARCH	Normal	13360.3872	13436.8087
4-State	ARCH	Normal	12813.469	12940.8382
1-State	ARCH	Student's t	12856.9524	12876.0578
2-State	ARCH	Student's t	12650.3437	12701.2914
3-State	ARCH	Student's t	12659.6966	12755.2236
4-State	ARCH	Student's t	12898.9524	13051.7955
1-State	ARCH	GED	12928.3289	12947.4343
2-State	ARCH	GED	13394.9637	13445.9114
3-State	ARCH	GED	13408.9415	13504.4684
4-State	ARCH	GED	12678.8967	12831.7398
1-State	ARCH	Skewed Normal	13203.6705	13222.7759
2-State	ARCH	Skewed Normal	12859.7144	12910.6621
3-State	ARCH	Skewed Normal	22834.9139	22930.4408
4-State	ARCH	Skewed Normal	12614.6568	12767.4999
1-State	ARCH	Skewed Student's t	13093.214	13118.6878
2-State	ARCH	Skewed Student's t	12631.4812	12695.1658
3-State	ARCH	Skewed Student's t	12638.9418	12753.5741
4-State	ARCH	Skewed Student's t	12648.3971	12826.714
1-State	ARCH	Skewed GED	12901.384	12926.8579
2-State	ARCH	Skewed GED	12657.6297	12721.3143
3-State	ARCH	Skewed GED	13066.839	13181.4713
4-State	ARCH	Skewed GED	12688.9601	12867.277
1-State	GARCH	Normal	12693.7524	12712.8578
2-State	GARCH	Normal	12635.467	12686.4147
3-State	GARCH	Normal	12590.337	12685.8639
4-State	GARCH	Normal	12570.7311	12723.5741
1-State	GARCH	Student's t	12556.7164	12582.1903
2-State	GARCH	Student's t	12568.7163	12632.4009
3-State	GARCH	Student's t	12558.8821	12673.5144
4-State	GARCH	Student's t	12604.7164	12783.0333
1-State	GARCH	GED	12591.2865	12616.7604
2-State	GARCH	GED	12557.6506	12621.3352
3-State	GARCH	GED	12562.4868	12677.1191
4-State	GARCH	GED	12612.4158	12790.7327
1-State	GARCH	Skewed Normal	12629.8523	12655.3261
2-State	GARCH	Skewed Normal	12545.4667	12609.1513
3-State	GARCH	Skewed Normal	12533.9957	12648.628
4-State	GARCH	Skewed Normal	12534.7443	12713.0612
1-State	GARCH	Skewed Student's t	12523.7872	12555.6295
2-State	GARCH	Skewed Student's t	12517.4225	12593.8441
3-State	GARCH	Skewed Student's t	12512.782	12646.5197

4-State	GARCH	Skewed Student's t	12510.0681	12713.8589
1-State	GARCH	Skewed GED	12550.1179	12581.9602
2-State	GARCH	Skewed GED	12529.1407	12605.5622
3-State	GARCH	Skewed GED	12521.0513	12654.789
4-State	GARCH	Skewed GED	12538.311	12742.1017
1-State	E-GARCH	Normal	12698.6057	12724.0796
2-State	E-GARCH	Normal	12562.5458	12626.2304
3-State	E-GARCH	Normal	12550.2384	12664.8707
4-State	E-GARCH	Normal	12564.779	12743.0959
1-State	E-GARCH	Student's t	12556.8731	12588.7154
2-State	E-GARCH	Student's t	12543.1805	12619.602
3-State	E-GARCH	Student's t	12548.8331	12682.5708
4-State	E-GARCH	Student's t	12550.8996	12754.6904
1-State	E-GARCH	GED	12592.6571	12624.4994
2-State	E-GARCH	GED	12553.9142	12630.3357
3-State	E-GARCH	GED	12542.4716	12676.2093
4-State	E-GARCH	GED	12549.4268	12753.2175
1-State	E-GARCH	Skewed Normal	12640.3447	12672.187
2-State	E-GARCH	Skewed Normal	12533.8288	12610.2504
3-State	E-GARCH	Skewed Normal	12506.3943	12640.132
4-State	E-GARCH	Skewed Normal	12517.5152	12721.306
1-State	E-GARCH	Skewed Student's t	12527.943	12566.1537
2-State	E-GARCH	Skewed Student's t	12504.6133	12593.7718
3-State	E-GARCH	Skewed Student's t	12507.6012	12660.4443
4-State	E-GARCH	Skewed Student's t	12520.7173	12749.9819
1-State	E-GARCH	Skewed GED	12555.539	12593.7498
2-State	E-GARCH	Skewed GED	12525.0851	12614.2436
3-State	E-GARCH	Skewed GED	12506.0939	12658.9369
4-State	E-GARCH	Skewed GED	12516.8882	12746.1528
1-State	GJR-GARCH	Normal	12676.2257	12701.6996
2-State	GJR-GARCH	Normal	12589.4007	12653.0853
3-State	GJR-GARCH	Normal	12552.09	12666.7223
4-State	GJR-GARCH	Normal	12557.5072	12735.8241
1-State	GJR-GARCH	Student's t	12544.0091	12575.8514
2-State	GJR-GARCH	Student's t	12558.0092	12634.4307
3-State	GJR-GARCH	Student's t	12576.0091	12709.7468
4-State	GJR-GARCH	Student's t	12598.0091	12801.7999
1-State	GJR-GARCH	GED	12577.9756	12609.8179
2-State	GJR-GARCH	GED	12542.9557	12619.3772
3-State	GJR-GARCH	GED	12552.1094	12685.8471
4-State	GJR-GARCH	GED	12594.5581	12798.3489
1-State	GJR-GARCH	Skewed Normal	12615.6538	12647.4962
2-State	GJR-GARCH	Skewed Normal	12541.8268	12618.2484
3-State	GJR-GARCH	Skewed Normal	12547.3618	12681.0995
4-State	GJR-GARCH	Skewed Normal	12624.3401	12828.1309
1-State	GJR-GARCH	Skewed Student's t	12513.5213	12551.7321
2-State	GJR-GARCH	Skewed Student's t	12491.3745	12580.5329
3-State	GJR-GARCH	Skewed Student's t	12490.291	12643.1341

4-State	GJR-GARCH	Skewed Student's t	12510.3315	12739.5961
1-State	GJR-GARCH	Skewed GED	12538.9402	12577.151
2-State	GJR-GARCH	Skewed GED	12506.5585	12595.7169
3-State	GJR-GARCH	Skewed GED	12498.14	12650.983
4-State	GJR-GARCH	Skewed GED	12501.7258	12730.9904
1-State	T-GARCH	Normal	12709.536	12735.0099
2-State	T-GARCH	Normal	12574.1728	12637.8574
3-State	T-GARCH	Normal	12558.1422	12672.7745
4-State	T-GARCH	Normal	12565.6946	12744.0115
1-State	T-GARCH	Student's t	12562.645	12594.4873
2-State	T-GARCH	Student's t	12538.2461	12614.6677
3-State	T-GARCH	Student's t	12544.9426	12678.6802
4-State	T-GARCH	Student's t	12556.8061	12760.5968
1-State	T-GARCH	GED	12598.7801	12630.6224
2-State	T-GARCH	GED	12553.398	12629.8195
3-State	T-GARCH	GED	12541.9531	12675.6908
4-State	T-GARCH	GED	12582.1939	12785.9847
1-State	T-GARCH	Skewed Normal	12653.4916	12685.334
2-State	T-GARCH	Skewed Normal	12542.7754	12619.197
3-State	T-GARCH	Skewed Normal	12523.9047	12657.6424
4-State	T-GARCH	Skewed Normal	12537.9389	12741.7297
1-State	T-GARCH	Skewed Student's t	12534.51	12572.7208
2-State	T-GARCH	Skewed Student's t	12520.7713	12609.9298
3-State	T-GARCH	Skewed Student's t	12519.9314	12672.7745
4-State	T-GARCH	Skewed Student's t	12545.1169	12774.3815
1-State	T-GARCH	Skewed GED	12563.0726	12601.2833
2-State	T-GARCH	Skewed GED	12537.1912	12626.3496
3-State	T-GARCH	Skewed GED	12523.8689	12676.7119
4-State	T-GARCH	Skewed GED	12525.9046	12755.1692

Source: Author's calculations.

**The models were estimated using the MSGARCH package in R (Ardia et al., 2018), all output results are available on request.*