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IFRS impact on Accounting Quality in Telecommunications Industry

Yusuf Mohammed Nulla[*]

ABSTRACT

Globally, the use of the IFRS in financial reporting is the requirement in many countries. However, the question of whether such a global transition towards a single set of accounting standards has been met by the presumed benefits of higher accounting quality and comparability yet remains unanswered. This paper primarily examines the effect of the mandatory IFRS adoption in Canada by the Canadian telecommunication companies. Since this research is an empirical study, this research has adopted quantitative research method. That is, by conducting survey, it has collected archival data from the eight large telecommunication companies of Toronto Stock Exchange (TSX/S&P) index. It was a comparative study between the Canadian GAAP financial reporting from 2008 to 2010 and IFRS financial reporting from 2011 to 2012. The research question of this research study is: Does IFRS adoption in the Canadian financial institutions improve financial reporting quality? This research finds that the adoption of the IFRS in telecommunication companies have resulted in lower persistency and predictability in earnings; increase in earnings influence to shareholder value; negative volatility in market price; better predictability of cash flow and financial forecasts; decrease in accruals and timeliness loss of recognition; increase in fair market valuation; significant increase in value relevance; increase in valuation usefulness of earnings to BVPS; and increase in operating capability and predictability.

Keywords: IFRS, GAAP, accounting quality, financial reporting, organizational performance, income smoothing, accruals, predictability, reporting aggressiveness, and timeliness loss recognition

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1. INTRODUCTION

Over the past decade, the International Financial Reporting Standards (IFRS) has emerged as the dominant reference for financial reporting in most countries around the world, perhaps due to the influence of investors/shareholders demand, cost minimization in financial reporting, security listings requirements, foreign investments, free trade, and global competition. In the case of the United States, the home of the leading global stock indexes, NYSE and NASDAQ, the Securities and Exchange Commission has publicly expressed its interest or in transition towards adopting the IFRS from the U.S. GAAP. While there is an extensive research worldwide on the impact of adopting IFRS, I believe that examining the adoption of the IFRS in the Canadian telecommunications industry companies since 2011, as one of the largest and influential sectors of the Canadian economy, may provide relevant information in terms of the nature and extent of the impact on the quality of financial reporting, which could also be used as a relevant benchmark to predict on other Canadian industries' quality of financial reporting. It is also believed that this research study results will provide relevant information to the United States accounting scholars and standard setter such as FASB, as both countries GAAPs are comparable and the respective capital markets are similar in nature. That is, research findings will provide some useful hints as to what the U.S. firms and markets will expect from the adoption of the IFRS. From 2011, the Canadian public companies are required to report the financial information using the International Financial Reporting Standards (IFRS) as mentioned earlier, a change of reporting culture from the Canadian GAAP. For two decades, Canada's accounting standard setter has a convergence policy towards the U.S. GAAP, primarily adopting the U.S. standards with some modification or reconciliation, primarily in the culture of rule-based standard, a stringent application of accounting regulations. The purpose of this preliminary empirical research on the IFRS, primarily characterized as principal-based standard (difficult to circumvent provision in the form of transaction), in Canada, to investigate whether the adoption of the IFRS by the Canadian telecommunication companies enhances accounting reporting quality. To examine this important quest, as demanded each time the IFRS is implemented in respective countries; this research has pursued a comparative approach. That is, first, it study the pre-IFRS period (2008-2010) under the Canadian GAAP and then compared with the IFRS period (2011-2012), to understand the nature of the accounting quality, along the defined accounting quality attributes of the reported earnings, accruals, persistency, value relevance, predictability, income smoothing, timeliness loss of recognition, and reporting aggressiveness. Previous studies concerning the European countries have shown an overall increase in earnings management in the post-adoption period, documented by an increase in income smoothing and no significant change in managing earnings towards a target. The findings deriving from the measurement of timely loss recognition indicate that the IFRS adoption is associated with a decrease in the timeliness of the recognition of large losses and with a contemporaneous increase in the timeliness in recognizing economic losses relative to gains in the reported income. As for the value relevance tests, results highlighted that the IFRS adoption increases the combined value relevance of the book value and earnings in particular, outcomes of relative value relevance analysis highlighted that earnings markedly improve its ability to explain stock prices in the post-adoption period compared to the pre-adoption one (Paglietti, P. 2009).

It is evident that the financial reporting presentation under the IFRS is much more detailed in nature relative to the Canadian GAAP (despite similar principle-based framework as IFRS) and the United States GAAP (rule-based framework). That is, under the IFRS, statement of operations items are detailed in nature such as amortization, purchases of materials, transportation costs, employee benefits, advertising costs, cost of sales, and cost of distribution. It is theoretically believed that the adoption of the IFRS is associated with the earnings becoming timelier, more volatile and more informative, making their introduction beneficial for investors and shareholders. The two most frequently claimed benefits associated with IFRS adoption are an increase in information quality, and an increase in accounting comparability. The highest quality standard indicates a standard that either reduces managerial discretion over accounting choices that are inherently disallowed smoothing or overstatement of earnings. According to Ball (2006) and Choi and Meek (2005), IFRS has the potential to facilitate cross-border comparisons, increase reporting transparency, decrease information costs, reduce information asymmetry and thereby increase the liquidity, competitiveness and efficiency of the markets.

The properties of the accounting numbers such as earnings smoothness and magnitude of accruals are affected not only by the underlying economic determinants and the exercise of the managerial judgments but also by the nature of the accounting standards. For example, the IFRS permits capitalizing development expenditures that were expensed under many domestic accounting standards. This has the effect on increasing earnings and reducing earnings volatility. Similarly, IFRS requires goodwill impairment rather than systematic amortization. Again, this would increase accruals and earnings except during periods when goodwill is impaired. Another example of a potential significant change in accruals is recognition of employee benefit expenses that were not recognized prior to the IFRS adoption. This would reduce accruals and earnings but potentially increase smoothing. The broader point is that the adoption of certain standards could alter the properties of earnings without necessarily changing the accounting quality. According to Schipper and Vincent (2003), earnings are important to a firm for the reason that they are used as a summary measure of the performance of a firm by a large variety of users. Persistency of the earnings is said to be persistent when they recur over time, or when they are sustainable or permanent. It also refers to the extent to which an innovation (unexpectedness) in the earnings series causes investors to revise their future earnings expectations (Boonlert, 2004). Researchers measure the persistency of earnings by looking at the explanatory power of the past earnings to present earnings. When the past earnings are not associated with the present earnings, the earnings are not persistent or not recurring. Predictability is defined as the ability of current earnings to predict future earnings and cash flows from operations. Current and also past earnings are the input to forecasting the future earnings/cash flows. Smoothness is measured by the amount of variability of the cash flow and the variability of earnings (Leuz et al., 2003). Smoothness can be seen as a desirable earning attribute as managers use information about their future income to smooth out momentary fluctuations. This will give more representative reported earnings, as these earnings contain future information. Value relevance is determined by measuring the correlation between the income variables (e.g. EPS) and the market price per share. According to Lang (1991) it is proven that the stock prices can be explained as a multiple of earnings. Market prices follow earnings, i.e. changes in earnings will affect the market prices. The higher the explanatory power of the earnings, the more value relevant the earnings are. Since more value relevant earnings would describe the firm's asset price more accurately, earnings are judged to be of high quality when they are high value relevant. Warfield and Wild (1992) suggests that the market returns should lead annual earnings and have a predictive power over the investors. If earnings have a greater predictive power under IFRS they should be anticipated much more before the release of the annual report under IFRS than under Canadian GAAP.

2. LITERATURE REVIEW

2.1 Quality of Earnings in IFRS reporting

According to Penman (2002), who stated that, the quality of the earnings is based on the earnings persistency, predictive ability of the earnings. They view that earnings are to be of high quality when the firm's past earnings are strongly associated with its future earnings. Other researchers view earnings to be of higher quality when earnings are value relevant, for example, the earnings are strongly associated with the security's price (Francis and Schipper, 1999). Voulgaris, Stathopoulos, and Walker (2011) believed that IFRS adds noise to accounting numbers that makes reported earnings less useful for evaluating managerial performance. This is mainly due to the adoption of the fair value accounting, which potentially makes accounting numbers more value-relevant, but also more volatile and sensitive to market movements. In addition, they believed that whilst the IFRS may have made accounting earnings more useful for stock market valuation purposes, this may have been achieved at the expense of other purposes that accounting serves, i.e., stewardship/performance contracting. In other words as accounting numbers are designed to conform more and more closely with market values, then the less they are able to provide information over what is complementary to market values for evaluating performance. Similarly, Kim and Suh (1993) believed that if accounting numbers become more sensitive to market movements than the accounting related signals, provides little additional information about managing performance, as they no longer screen out market related noise. Moreover, the move to fair value accounting makes accounting earnings figures more volatile (Barth et al. 2011). If the increase in earnings volatility is driven by events almost entirely outside the control of management then this also reduces the attractiveness of the earnings, as a basis for performance-based contracts. Ball (2006) and Choi and Meek (2005) believed that the IFRS has the potential to facilitate cross border comparability, increase reporting transparency, decrease information costs, reduce information asymmetry and thereby increase the liquidity, competition and efficiency of markets. In addition, Ball (2006) notes that the fair value orientation of the IFRS could add volatility to the financial statements, in the form of both good and bad information, the latter consisting of noise which arises from inherent estimation error and possible managerial manipulation. Ahmed, Neel, and Wang (2012) states that, the effects of the mandatory IFRS adoption on the accounting quality critically depend upon whether the IFRS is of higher or lower quality than domestic GAAP and how they affect the efficacy of enforcement mechanisms. By a higher quality standard they mean a standard that either reduces managerial discretion over accounting choices or inherently disallows smoothing or overstatement of earnings. If IFRS is of higher quality than domestic GAAP, and they are appropriately enforced, then we expect mandatory adoption of IFRS to improve accounting quality. On the other hand, if IFRS are of lower quality than domestic GAAP or if IFRS weaken enforcement (for example because of increased discretion or flexibility) then it would expect to reduce accounting quality. Thus, the impact of IFRS on the accounting quality is an empirical question. This is supported by Leuz, Nanda, and Wysocki (2003), Barth, Landsman, and Lang (2008), Christenson, Lee, and Walker (2008), and Chen, Tang, Jiang, and Lin (2010), who believed that accounting choices that result in greater income smoothing, greater management of earnings to meet a target, and overstatement of earnings (or delayed recognition of losses) as compromising faithful representation of the underlying economics therefore, reduce accounting quality. Similarly, Barth et al. (2008) presents three reasons why the adoption of the IFRS could lead to improvements in the accounting quality. First, the IFRS eliminates certain accounting alternatives thereby reducing managerial discretion. This could reduce the extent of opportunistic earnings management and thus improve accounting quality (Ewert and Wagenhofer, 2005). Second, IFRS is viewed as principles-based standards and thus are potentially more difficult to circumvent. For example, under a principles-based standard it should be more difficult to avoid recognition of a liability through transaction structuring. Third, IFRS permits measurements such as, use of fair value accounting which may better reflect the underlying economics than domestic standards. At the same time, Barth et al. (2008) also note two reasons why the adoption of IFRS may reduce accounting quality. First, IFRS could eliminate accounting alternatives that are most appropriate for communicating the underlying economics of a business thus forcing managers of these firms to use less appropriate alternatives thus resulting in a reduction in accounting quality. Second, because IFRS is principles-based, they inherently lacked detailed implementation guidance and thus afford managers greater flexibility (Langmead and Soroosh, 2009). For some important areas such as revenue recognition for multiple deliverables, the absence of implementation guidance would significantly increase discretion and allowable treatments, depending upon how they are interpreted and implemented. Given managers' incentives to exploit accounting discretion to their advantage documented in prior studies such as Leuz et al. (2003), the increase in discretion due to lack of implementation guidance is likely to lead to more earnings management and thus lower accounting quality, ceteris paribus.

2.2 Accounting quality under IFRS

Ahmed, Neel, and Wang (2012) stated that previous studies focused on a number of institutional factors that have impacted accounting quality. The evidence in previous studies suggests that the accounting quality is generally higher in strong enforcement countries relative to weak enforcement countries. This in turn suggests that there may be systematic differences in the effects of the IFRS adoption in strong enforcement versus weak enforcement countries. However, it is very difficult to make definitive predictions because the change in accounting quality from the pre-IFRS periods to the post-IFRS periods depends upon: (i) whether the IFRS is of higher or lower quality than the domestic GAAP, for example, whether they increase or decrease overall managerial discretion; and (ii) on the efficacy of enforcement mechanisms. For strong enforcement countries, if IFRS is of higher quality than domestic GAAP and they are appropriately enforced, expect an improvement in accounting quality. For example, if IFRS eliminates accounting alternatives that were opportunistically used by the managers, elimination of these alternatives would improve the accounting quality. They also believed that strong enforcement partition has a significantly higher average rule of law score. That is, firms in the strong enforcement partition have lower (higher) average total assets, book-to-market, growth rates, and leverage (market values) relative to the weak enforcement partition. In addition, they believed that if the IFRS are of lower quality than domestic GAAP in the sense that they increase managerial discretion, accounting quality would decline even in strong enforcement countries given that managers have incentives to exercise their discretion in their own interests. Furthermore, the accounting quality may decline after the mandatory IFRS adoption because principles-based standards are looser, on average, than domestic standards and thus, more difficult to enforce. Nelson (2003) concludes that aggressiveness of reporting decisions increases with the imprecision of the relevant reporting standard, based on a survey-based research. In addition, they believed that even in strong enforcement countries, relatively loose standards can result in more opportunistic choices. This is supported by Paananen and Lin (2008), who find that evidence of a decline in accounting quality in Germany, strong enforcement country, after the mandatory IFRS adoption. Ball (2006) believes that in the absence of suitable enforcement mechanisms, real convergence and harmonization is infeasible, resulting in diminished comparability. Collectively, these studies suggest that loose standards can lead to a decline in accounting quality even in strong enforcement countries. On the other hand, in the weak enforcement countries, previous research studies such as of Leuz et al. (2003), Burgstahler et al. (2006), Holthausen (2009), and Hope (2003) argue that rules or standards are generally not effective, that is, without adequate enforcement, even the best accounting standards will be inconsequential. Extending this logic, even if the IFRS is of a higher quality than a domestic GAAP, they are unlikely to result in improvements in accounting quality in weak enforcement countries because they are unlikely to be properly enforced. Therefore, do not expect a change in accounting quality after the mandatory IFRS adoption for firms in weak enforcement countries. Armstrong et al. (2009) and Soderstrom and Sun (2007) believed that cultural, political and business differences may also continue to impose significant obstacles in the progress towards this single global financial communication system, since a single set of accounting standards cannot reflect the differences in the national business practices arising from differences in the institutions and cultures.

2.3 Variables effected financial reporting under IFRS

Ahmed, Neel, and Wang (2012) also finds in their study that there is an increase in income smoothing for the IFRS firms relative to benchmark firms after the mandatory IFRS adoption. Specifically, they find a significant decrease in the volatility of net income, the volatility of net income relative to the volatility of cash flows, and the correlation between cash flows and accruals for the IFRS firms relative to benchmark firms. Second, they find evidence of a significant increase in aggressive reporting of accruals for the IFRS firms relative to benchmark firms. Third, they find evidence of a significant reduction in timeliness of loss recognition for the IFRS firms relative to benchmark firms consistent with the increase in reporting aggressiveness suggested by the accrual tests. Finally, they believed that their evidence is consistent with meeting or beating earnings targets after controlling for variable, management, in benchmark firms. In addition, they stated that while the evidence is not fully consistent across all proxies, taken together the results suggest that the accounting quality decreased after the mandatory IFRS adoption. Ball et al. (2000) finds that timeliness of loss recognition decreases significantly after the mandatory IFRS adoption relative to benchmark firms. Similarly, Paananen (2008) and Paananen and Lin (2008) find in their results that there is a decrease in financial reporting quality, an increase in earnings management, and a reduction in timeliness of loss recognition in Germany, following mandatory IFRS. Jeanjean and Stolowy (2008) find no decline in the pervasiveness of the earnings management in Austria and UK but an increase in France. Christensen et al. (2008) finds that the incentives dominate standards in determining accounting quality around mandatory IFRS adoption. Daske et al. (2008) shows that the capital market benefits around the mandatory adoption of the IFRS are unlikely to exist primarily because of IFRS adoption. Daske (2006) finds no evidence that the IFRS adoption decreases a firm's cost of capital. Atwood et al. (2010) finds that the earnings reported under the IFRS are no more or less persistent and are no more or less associated with the future cash flows than earnings reported under the local GAAP. In addition, they suggest that the documented increase in analyst forecast accuracy following the IFRS is not the result of the differences in the underlying persistence of those earnings. Barth et al. (2008) show that the voluntary adoption of the IFRS is associated with less earnings management (i.e. less earnings smoothing), timelier loss recognition and higher value relevance of accounting earnings. Hung and Subramanyam (2007) reach similar conclusions about accounting quality for German voluntary adopters between 1998 and 2002. Horton, Serafeim, and Serafeim (2012) find that forecast accuracy improves significantly after the mandatory IFRS adoption relative to firms that do not adopt IFRS. In addition, the larger the difference between IFRS and local GAAP earnings the larger is the improvement in forecast accuracy, increasing the confidence that it is the IFRS adoption that causes the improvement in the information environment. Forecast accuracy improves more for analyst-firm pairs that are affected by either information or comparability benefits. Overall, they find that the increase in forecast accuracy is driven by manipulation.

3. RESEARCH METHODOLOGY

This research is an empirical comparative study between Canadian GAAP (2008-2010) and IFRS (2011-2012) periods, to understand the effect of IFRS adoption on the Canadian telecommunication companies that are listed on the Toronto Stock Exchange (TSX), in terms of accounting quality reporting. Fielding and Fielding (1986, pp. 34) stated that: “what is important is to choose at least one method which is specifically suited to explore structural aspects of the problem and at least one which can capture the essential elements of its meaning”. This research study requires collecting, counting, and classifying data, and performing analyses on statistical findings. It requires a process to include a method of deductive reasoning by the use of the measurement tools to collect the relevant data. In addition, it requires only establishing associations among variables using effect statistics such as correlations. As such, the quantitative research method will be selected for this research study. Bryman (1989) explained that the quantitative research method tests hypotheses and identifies patterns in variables whereas the qualitative method validates corporate information and informs some of the methodological decisions. With its origins in the scientific empirical tradition, the quantitative approach relies on the numerical evidence to draw conclusions, to test hypotheses or theory, and is concerned with: measurement, causality, generalization, and replication. Burns (2000) believed that the quantitative research method is infused with positivism and is based on a collection of quantifiable observations, which permits deduction of the laws and the establishment of relationships. In addition, Creswell (2009) stated that if problem calls for identification of factors that influence an outcome, the utility of an intervention, or understanding clear outcomes, then a quantitative approach is most suitable. Within a quantitative research method framework, longitudinal study approach will be adopted to collect five years of data from 2008 to 2012. According to Zanaida and Fernando (2000), longitudinal design is seldom used in social science research; however, it is typically within financial investigations that have adopted positivist research philosophy. Buck et al. (2003) and McKnight and

Tomkins (2004) believed that financial research is very typical for a positivist investigation. This is supported by Main & Johnson (1993), who believed that companies' annual reports are a common resource tool when examining archival data. Accordingly, this study will collect financial data of companies from highly credible SEDAR (represents the Canadian Securities Commission) database. The sample will consist of eight firms from the TSX/S&P index. The eight largest companies in this research represents majority market shares of the Canadian telecommunications industry, a non-oligopoly industry structure as such increasing firms in the research sample would not enhance the findings of the research. The random sample method will be selected for this research study to avoid selection bias, as it is the purest form of probability sampling. Yates (2008, p. 27) believed that an unbiased random selection of individuals is important so that in the long run sample represents the population. Groves et al. (2004, pp. 4) stated: "survey is a systematic method for gathering information from (a sample of) entities for the purpose of constructing quantitative descriptors". As such, this research study will use the survey method to collect data from 2008 to 2012. In addition, this research will use regression models for the modeling and analysis of the numerical data, and will assume a confidence interval or alpha of five percent (typical in academic research).

3.1 Research question:

Does IFRS adoption in the Canadian telecommunication companies improve financial reporting quality?

3.2 Hypotheses:

H_0: Accounting quality has not improved after IFRS adoption in telecommunication companies from 2011 to 2012.

H_1: Accounting quality has improved after IFRS adoption in telecommunication companies from 2011 to 2012.

3.3 Statistical Models:

This research study will try to understand the accounting quality in two approaches.

1) ***Statement of Financial Position (Balance Sheet) approach:***

$\Delta NI/\Delta TA = \Delta NI/\Delta OCF + \Delta OCF/\Delta Accruals + \Delta OCF/\Delta TA + \Delta NI/\Delta Accruals + \Delta EPS/\Delta MP + \Delta NI/\Delta BVPS$.

2) ***Statement of Operations (Income Statement or Profit/Loss) approach:***

$\Delta NI = \Delta EPS + \Delta BVPS + \Delta MP + \Delta OCF + \Delta Accruals$.

Where:

NI=Net income; TA=Total Assets; OCF=Operating Cash Flow; EPS=Earnings per share; BVPS=Book value per share; MP=Market price.

Regression Model 1 (Statement of Financial Position approach):

Y_1=c+ B_1X_1+B_2X_2+B_3X_3+B_4 X_4+B_5X_5+B_6X_6 +ϵ

Y_1= ΔNI/ΔTA; c=constant predictor; B_1=influential factor for ΔNI/ΔOCF; B_2=influential factor for ΔOCF/ΔAccruals; B_3=influential factor for ΔOCF/ΔTA; B_4=influential factor for ΔNI/ΔAccruals; B_5=influential factor for ΔEPS/ΔMP; B_6=influential factor ΔNI/ΔBVPS; ϵ=error; X_1=value of ΔNI/ΔOCF; X_2=value of ΔOCF/ΔAccruals; X_3=value of ΔOCF/ΔTA; X_4=value of ΔNI/ΔAccruals; X_5=value of ΔEPS/ΔMP; and X_6=value of ΔNI/ΔBVPS. Confidence level (α) was set at 5 percent.

ΔNI/ΔTA is a dependent variable in the statement of financial position approach. It represents as an accounting quality. Δ in NI represents the equity component, and Δ in TA represents one component of the statement of financial position as such, the combination of these components represents added value for the statement of financial position. ΔNI/ΔOCF represents operating capabilities and predictability and ΔOCF/ΔAccruals are an independent variable and represents the ratios between the operating cash flows and accruals and have an indirect impact on the accounting quality in terms of cash and non-cash transactions. ΔOCF/ΔTA is an independent variable and represents liquidity and future earnings. ΔNI/ΔAccruals is a dependent variable and represents reporting aggressiveness and timeliness of loss recognition. ΔEPS/ΔMP is a dependent variable and represents the earnings value relevance (earnings sensitivity or usefulness to market price). ΔNI/ΔBVPS is a dependent variable and represents earnings sensitivity to book value per share.

Regression Model 2 (Statement of Operations approach)

Y_2=c+ B_1X_1+B_2 X_2+B_3X_3+B_4 X_4+B_5X_5+ϵ

Y_2= ΔNI; c=constant predictor; B_1=influential factor for ΔEPS; B_2=influential factor for ΔBVPS; B3=influential factor for ΔMP; B_4=influential factor for ΔOCF; B_5=influential factor ΔAccruals; ϵ=error; X_1=value of ΔEPS; X_2=value of ΔBVPS; X_3=value of ΔMP; X_4=value of ΔOCF; and X_5=value of ΔAccruals. Confidence level (α) was set at 5 percent.

Δ in NI is a dependent variable and represents the macro effect or added value to equity component. Δ in EPS is an independent variable and represents earnings persistency and predictability through net income and shares outstanding, provided shares does not change materially to influence EPS. Δ in BVPS is an independent variable and represents the accounting value for the shareholders. Δ in MP is an independent variable and represents a fair value measurement of the firm. Δ in OCF is an independent variable and represents operating capabilities and future cash earnings. Δ in Accruals is an independent variable and represents reporting aggressiveness and income smoothing.

3.4 IFRS variables from literature

Paananen (2008) and Paananen and Lin (2008) in their IFRS research have used variables related to financial reporting quality, earnings management, and a timeliness of loss recognition to assess financial reporting quality. Barth et al. (2008) in their IFRS research has used variables of volatility of net income, ratio of volatility of net income to the volatility of cash flows, and the correlation between cash flows and accruals. Ball et. al (2000) in their IFRS research has used timely loss recognition (measured by net income and the asymmetric incorporation of economic gains and losses into the reported income) to assess accounting quality. Beaver (2002) in their IFRS research has used value relevance (statistical association between accounting information and market prices or returns) as a variable to assess accounting quality. Ahmed, Neel, and Wang (2012) in their IFRS research study has used variables related to income smoothing: volatility of net income, volatility of net income relative to volatility of cash flows, correlation between cash flows and accruals.

4. RESULTS

4.1 Correlations Analysis: Statement of Operations Approach

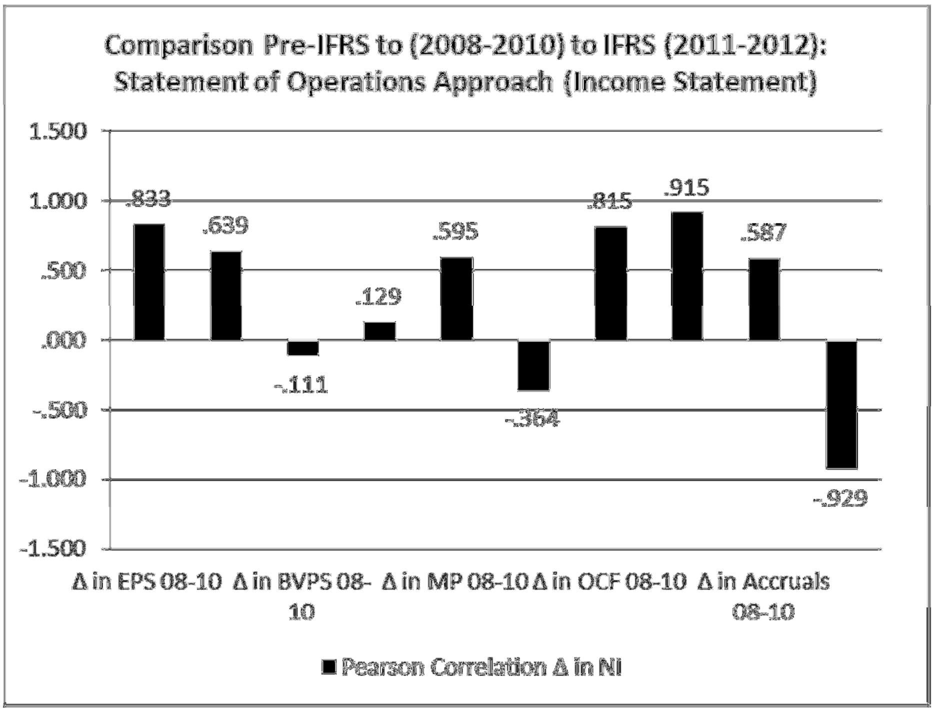
Table 1: Correlations

Statement of Operations Approach:		Δ NI 08-10	Δ NI 11-12	Δ in EPS 08-10	Δ in EPS 11-12	Δ in BVPS 08-10	Δ in BVPS 11-12	Δ in MP 08-10	Δ in MP 11-12	Δ in OCF 08-10	Δ in OCF 11-12	Δ in Accruals 08-10	Δ in Accruals 11-12
Pearson Correlation	Δ in NI	1.000	1.000	.833	.639	-.111	.129	.595	-.364	.815	.915	.587	-.929
	Δ in EPS	.833	.639	1.000	1.000	.343	.155	.616	-.095	.793	.352	.529	-.463
	Δ in BVPS	-.111	.129	.343	.155	1.000	1.000	-.025	-.011	-.083	.034	.044	.111
	Δ in MP	.595	-.364	.616	-.095	-.025	-.011	1.000	1.000	.407	-.418	.324	.402
	Δ in OCF	.815	.915	.793	.352	-.083	.034	.407	-.418	1.000	1.000	.412	-0.932
	Δ in Accruals	.587	-.929	.529	-.463	.044	.111	.324	.402	.412	-.932	1.000	1.000

The table 1 had shown the correlation results (statement of operations approach) for the Canadian GAAP (pre-IFRS) period from 2008 to 2010 and the IFRS period from 2011 to 2012. Δ in EPS had changed from .833 under Canadian GAAP period to .639 under IFRS period, indicated that differences with respect to the persistency and predictability were found concerning the reported earnings under the Canadian GAAP and IFRS. Although these results at first sight had shown that under IFRS earnings exhibited lower persistency and predictability, perhaps due to the use of fair value accounting under IFRS period had created volatility. Therefore, these attributes had shown accounting quality had declined under IFRS. According to Schipper and Vincent (2003), permanent and less transitory earnings are more useful to the valuation process of a company, the earnings are judged to be of high (information) quality when they are highly persistent. Δ in BVPS had changed from -.111 under Canadian GAAP period to .129 under IFRS period, indicated that under IFRS earnings had influenced the book value per share for shareholder value, therefore, the quality of accounting had been improved. Δ in MP had changed from .595 under Canadian GAAP period to -.364 under IFRS period, indicated that under IFRS, the market price movement is negative and more volatile or sensitive, therefore reported earnings were less useful under IFRS period. Δ in OCF had changed from .815 under Canadian GAAP period to .915 under IFRS period, indicated that operating capability and future cash earnings had slightly increased under the IFRS accounting as such provides healthier cash predictability or financial cash outlook, and perhaps less manipulation of income by the management. Δ in Accruals had changed from .587 under Canadian GAAP period to .929 under IFRS period, indicated that under IFRS, had decreased accruals (decreased income smoothing, less timely loss recognition, and increased certain accounting incentives) therefore, decrease in accounting quality. This result is similar to the result found by Ahmed, Neel, and Wang (2012) who stated that, the IFRS firms exhibit significant increases in income smoothing and aggressive reporting of accruals, and a significant decrease in timeliness of loss recognition. It is believed that the properties of accounting numbers such as earnings smoothness and magnitude of accruals are affected not only by the underlying economic determinants and exercise of managerial judgments but also by the nature of accounting standards. For example, the IFRS permits capitalizing development expenditures that were expensed under many domestic accounting standards. This has the effect of increasing earnings and reducing earnings volatility. Similarly, the IFRS requires goodwill impairment rather than systematic amortization. Again, this would increase accruals and earnings except during periods when goodwill is impaired. Another example of a potentially significant change in accruals is recognition of employee benefit expenses that were not recognized prior to IFRS adoption. This would reduce accruals and earnings, but potentially increase smoothing. The broader point is that the adoption of certain standards could alter the properties of earnings without necessarily changing accounting quality.

Following figure 1 is the comparative results as discussed:

Figure 1



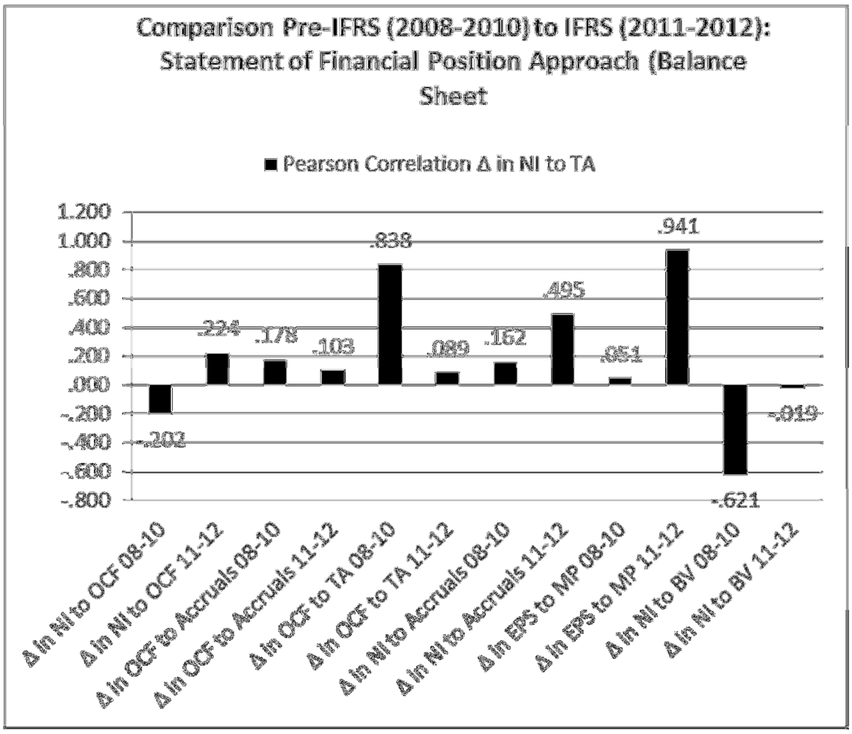
4.2 Correlations Analysis: Statement of Financial Position Approach

Table 2: Correlations

Statement of Financial Position Approach:		ΔNI to ΔTA 08-10	ΔNI to ΔTA 11-12	ΔNI to ΔOCF 08-10	Δ in NI to ΔOCF 11-12	Δ in OCF to ΔAccruals 08-10	Δ in OCF to ΔAccruals 11-12	ΔOCF to ΔTA 08-10	ΔOCF to ΔTA 11-12	ΔNI to ΔAccruals 08-10	ΔNI to ΔAccruals 11-12	ΔEPS to ΔMP 08-10	ΔEPS to ΔMP 11-12	ΔNI to ΔBV 08-10	ΔNI to ΔBV 11-12
Pearson Correlation	ΔNI to ΔTA	1.000	1.000	-.202	.224	.178	.103	.838	.089	.162	.495	.051	.941	-.621	-.019
	ΔNI to ΔOCF	-.202	.224	1.000	1.000	.082	.285	-.083	-.176	.277	.687	.152	.201	.565	-.169
	ΔOCF to ΔAccruals	.178	.103	.082	.285	1.000	1.000	.084	-.950	.269	.290	-.022	.130	.058	-.178
	ΔOCF to ΔTA	.838	.089	-.083	-.176	.084	-.950	1.000	1.000	-.028	-.120	-.029	.080	-.613	.167
	ΔNI to ΔAccruals	.162	.495	.277	.687	.269	.290	-.028	-.120	1.000	1.000	-.128	.607	.086	.057
	ΔEPS to ΔMP	.051	.941	.152	.201	-.022	.130	-.029	.080	-.128	.607	1.000	1.000	.009	-.004
	ΔNI to ΔBV	-.621	-.019	.565	-.169	.058	-.178	-.613	.167	.086	.057	.009	-.004	1.000	1.000

The table 2 had shown the correlation results (statement of financial position approach) for the Canadian GAAP (pre-IFRS) period from 2008 to 2010 and the IFRS period from 2011 to 2012. ΔNI to ΔOCF had changed from -.202 under Canadian GAAP period to .224 under IFRS period, indicated that under IFRS, cash earnings, operating capabilities, and predictability of earnings had increased as such, the earnings are characterized as higher quality. ΔOCF to ΔAccruals had changed from .178 under Canadian GAAP period to .103 under IFRS period, indicated that correlations between them had decreased, however, no direct effect on accounting quality. ΔOCF to ΔTA had changed from .838 under Canadian GAAP period to .089 under IFRS period, indicated that significant decreased in this correlation was perhaps due to the fair market valuation of the assets. ΔNI to ΔAccruals had changed from .162 under Canadian GAAP period to .495 under IFRS period, indicated that significant increase in reporting aggressiveness (more accruals) and decreased timeliness of loss recognition, consistent with the earlier finding on Δ in Accruals under statement of operations approach. Therefore, had decreased the quality of accounting, perhaps indicated that the Canadian GAAP is more stringent towards managerial discretion than IFRS in financial institutions. ΔEPS to ΔMP had changed from .051 under Canadian GAAP period to .941 under IFRS period, indicated that there was a significant increase in value relevance (earnings sensitivity or usefulness to market price). That is, the accounting earnings are more useful to market valuation purposes; however, the earnings may provide little additional information about managing performance. Nevertheless, significant increase in value relevance under IFRS had improved the accounting quality. According to Ball and Brown (1968), if efficient capital market will adjust to newly released information that is, useful in forming asset prices from reported earnings, indicative of higher accounting quality earnings. ΔNI to ΔBVPS had changed from -.621 under Canadian GAAP period to -.019 under IFRS period, indicated that the valuation usefulness of IFRS earnings to book value per share had improved, therefore, accounting quality had increased under IFRS. Following figure 2 is the comparative results as discussed:

Figure 2



4.3 Statistical Regression Analysis

1) ***Statement of Operations Approach***

Canadian GAAP: $Y_{2008\text{-}2010}$=.521+1.155X_1-1.236X_2-.188X_3-.007X_4 +.042X_5 (Table 6 in appendix D)

IFRS: $Y_{2011\text{-}2012}$=-.795+.547X_1+.012X_2+.029X_3+.010X_4-.299X_5

(Table 6 in appendix D)

2) ***Statement of Financial Position Approach***

Canadian GAAP:

$Y_{2008\text{-}2010}$=.731-.082X_1+.014X_2+.175X_3+.514X_4+2.797X_5-.003X_6

(Table 6 in appendix D)

IFRS:

$Y_{2011\text{-}2012}$=.115+.448X_1-.012X_2-.019X_3-.157X_4+.991X_5+.003X_6

(Table 6 in appendix D)

The regression coefficients under the statement of operations approach for the IFRS period in the table 6 (appendix D), it was found that B_1, B_2, B_3, and B_4 were higher relative to the Canadian GAAP indicated that these betas were significant in the regression, providing much clearer evidence that positive shocks are transitory for the IFRS firms. However, it was found that B_5 was lower, a negative transitory shock, relative to the Canadian GAAP. According to Brauer and Westermann (2010), who stated that a negative coefficient on the betas would imply a smooth (non-oscillating) impulse-response pattern. The larger the B, the faster is the reversion to the mean. B_1 (ΔEPS), B_2 (ΔBVPS), B_3

(ΔMP), and B_4 (ΔOCF) are > 0 indicated that, positive influence to: earnings predictability, shareholder valuation, predictability and value relevance, and cash forecasting, in the IFRS regression model. However, B_5 (ΔAccruals) was < 0 indicated that, it had negative influence, that is, negative losses had been recognized more timely than gains, in the IFRS regression model. In the statement of financial position approach for the IFRS period in the table 6 (appendix D), B_1, B_5, and B_6 were higher relative to the Canadian GAAP, indicated that these betas had positive influence in the IFRS regression model. However, B_2, B_3, and B_4 were lower relative to the Canadian GAAP, indicated that these betas had weak influence in the IFRS regression model. In the IFRS regression model, B_1 (ΔNI to ΔOCF), B_5 (ΔEPS to ΔMP), and B_6 (ΔNI to ΔBVPS) were > 0 indicated that, positive influence of these betas concerning cash forecasting, value relevance, and usefulness of earnings to book value per share would be persistent, in the IFRS regression model. However, B_2 (ΔOCF to ΔAccruals), B_3 (ΔOCF to ΔTA), and B_4 (ΔNI to ΔAccruals) were < 0 indicated that persistence of negative influence to fair market valuation and negative shocks would influence the IFRS regression model. The F-tests results (large numbers characterized statistical model's usefulness) as provided in the table 5 (appendix C), had shown that the IFRS models were relatively less useful in both approached of the statements of operations and statement of financial position. That is, the Canadian regression models had a relatively stronger relationship between independent and independent variables than IFRS regression models, yet both types of regression models were statistically valid to draw conclusions on the accounting quality between the Canadian GAAP and IFRS.

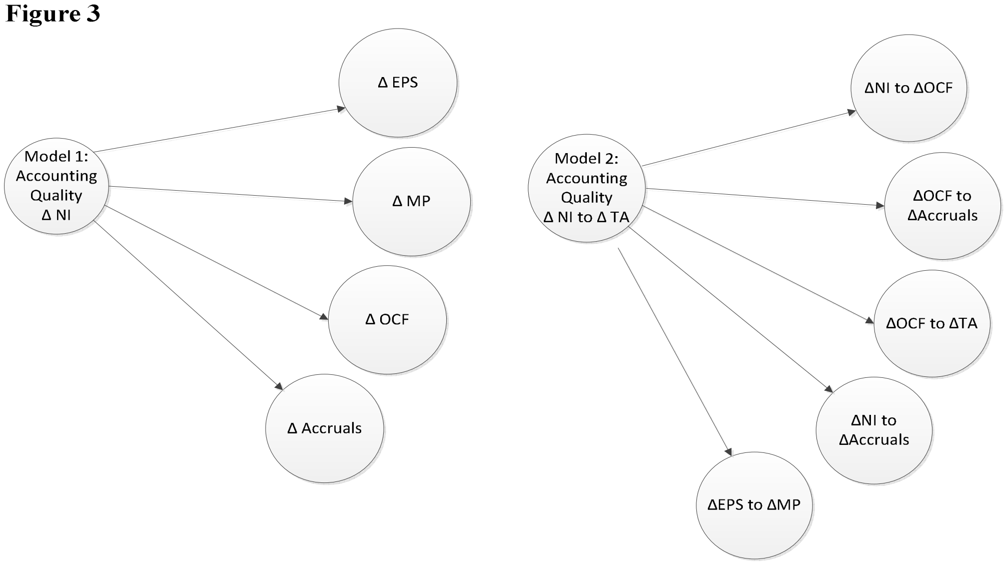
The table 3 (appendix A), under the Canadian GAAP period, had shown average R^2 for the timeliness of 88.4%; and under IFRS GAAP period, had shown average R^2 for the timeliness of 96.9%. The table 4 (appendix B) under the Canadian GAAP period, had shown average R^2 for the timeliness of 79.7%; and under the IFRS period, had shown average R^2 for the timeliness of 92.12%. All these R^2, especially under IFRS period, had indicated higher persistent earnings; that is, the predictive value of earnings, represented by the variance in the persistency of the earnings had a high certainty (low degree of variance) in the future earnings. Beijerink (2008) found in his research that both IFRS and US-GAAP earnings were highly persistent, that is, R^2 of 82.6% for the IFRS pooled sample relative to 65.9% for the US-GAAP pooled sample. In the research of Jennings (2003) the researchers found similar results for the timeliness. However, Francis et al. (2004) found an average R^2 for the timeliness of 21.9% for the sample consisting of a large number of US firms for the period 1975-2001.

4.4 Statistical Models

Following figure 3 is the derived statistical models for the accounting quality resulted from the correlation results. That is, the accounting quality can be determined through the application of variables in the respective models for accruals (income smoothing and timeliness loss recognition);

reporting aggressiveness; earnings persistency; value relevance; predictability; managerial discretion; and enforcement.

Figure 3



5. CONCLUSION

Globally, the use of the IFRS in financial reporting is the requirement for many countries, primarily due to the influence of investors/shareholders demand, cost minimization in financial reporting, security listings requirements, foreign investments, free trade, and global competition. However, the question of whether such a global transition towards a single set of accounting standards has been met by the presumed benefits of higher accounting quality and comparability yet remains unanswered. To contribute to our knowledge in this important topic I have investigated whether mandatory IFRS adoption in the Canadian telecommunication companies improves firms' accounting quality. This research finds that lower persistency and predictability in earnings; increase in earnings influence to shareholder value; negative volatility in market price; better predictability of cash flow and financial forecasts; decrease in accruals and timeliness loss of recognition; increase in fair market valuation; significant increase in value relevance; increase in valuation usefulness of earnings to BVPS; and increase in operating capability and predictability. Following table 7 summarizes the results:

Table 7: Summary of Accounting Quality Regression Results under IFRS relative to Canadian GAAP			
Statement of Operations Approach		Statement of Financial Position Approach	
Δ EPS	Lower persistency and predictability in earnings; lower accounting quality under IFRS.	ΔNI to ΔOCF	Increase in operating capability and predictability; increase in quality of reporting under IFRS.
ΔBVPS	Increase in earnings influence to shareholders value; higher accounting quality under IFRS.	ΔNI to ΔBVPS	Increase in valuation usefulness of earnings to BVPS; higher accounting quality under IFRS.
ΔMP	Negative volatility in market price; lower accounting quality under IFRS.	ΔEPS to ΔMP	Significant increase in value relevance (earnings influence to market price); higher accounting quality under IFRS.
ΔOCF	Better predictability of cash flow and financial forecasting; higher accounting quality under IFRS.	ΔOCF to ΔTA	Increase in fair market valuation; higher accounting quality under IFRS.
ΔAccruals	Decrease in accruals; lower accounting quality under IFRS.	ΔNI to ΔAccruals	Decrease in accruals and timeliness loss of recognition; lower accounting quality under IFRS.
		ΔOCF to ΔAccruals	Decrease in correlation; no direct effect on accounting quality under IFRS.

Moreover, this research finds that the results are consistent with both information and comparability effects between the two approaches of the statement of operations and the statement of financial position, as illustrated in the above table. Forecast accuracy improves more for liquidity than earnings. This research finds no evidence suggesting that the decrease in earnings forecast accuracy is driven by earnings manipulation, as have an increased correlation between earnings and market price. Overall, this research concludes that accounting quality has been affected both positively and negatively after mandatory IFRS adoption, in contrast to previous studies that document evidence suggesting an increase or decrease in accounting quality after IFRS adoption. The quality of the accounting information is very often determined by the quality of the reported earnings. For this matter, researchers have made the quality of accounting information empirically operations by developing several attributes in order to determine the earnings quality. Because earnings can be decomposed into cash flows and accruals, several researchers use accruals quality to draw conclusions about the earnings quality (Dechow, Dichev, 2002, and Francis et al., 2004). On the other hand, Richardson (2003) interprets the quality of earnings when earnings are persistent, predictive ability of the earnings. They view that earnings be of high quality when a firm's past earnings are strongly associated with its future earnings. Other researchers view earnings to be of higher quality when earnings are value relevant, i.e. the earnings are strongly associated with the security's price (Francis and Schipper, 1999). This research finds that the results are consistent with both information and comparability effects between the two approaches of the statement of operations and the statement of financial position, as illustrated in the above table. Forecast accuracy improves for both liquidity and earnings. Overall, this research concludes after the adoption of the IFRS, the accounting quality has a positive influence on the financial reporting of the Canadian telecommunication companies.

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APPENDICES

Appendix A:

Table 3										
Model Summaryb Canadian (2008-2010): Statement of Operations Approach										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.940[a]	.884	.852	1.07388	.884	27.429	5	18	.000	1.325
Model Summaryb IFRS (2011-2012): Statement of Operations Approach										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.984[a]	.969	.953	.77010	.969	61.993	5	10	.000	1.794
a. Predictors: (Constant), Δ in Accruals, Δ in BVPS, Δ in MP, Δ in OCF, Δ in EPS										
b. Dependent Variable: Δ in NI										

Appendix B:

Table 4										
Model Summaryb Canadian (2008-2010): Statement of Financial Position Approach										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.893[a]	.797	.725	1.48748	.797	11.124	6	17	.000	.791
Model Summaryb IFRS (2011-2012): Statement of Financial Position Approach										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.960[a]	.921	.868	.60447	.921	17.414	6	9	.000	2.368
a. Predictors: (Constant), Δ in EPS to MP, Δ in OCF to Accruals, Δ in NI to OCF, Δ in OCF to TA, Δ in NI to Accruals										
b. Dependent Variable: Δ in NI to TA										

Appendix C:

Table 5											
ANOVAa Canadian GAAP (2008-2010): Statement of Operations Approach						ANOVAa IFRS (2011-2012): Statement of Operations Approach					
	Sum of Squares	df	Mean Square	F	Sig.		Sum of Squares	df	Mean Square	F	Sig.
Regression	158.159	5	31.632	27.429	.000[b]	Regression	183.829	5	36.766	61.993	.000[b]
Residual	20.758	18	1.153			Residual	5.931	10	0.593		
Total	178.917	23				Total	189.759	15			
ANOVAa Canadian GAAP (2008-2010): Statement of Financial Position Approach						ANOVAa IFRS (2011-2012): Statement of Financial Position Approach					
	Sum of Squares	df	Mean Square	F	Sig.		Sum of Squares	df	Mean Square	F	Sig.
Regression	147.677	6	24.613	11.124	.000[b]	Regression	38.177	6	6.363	17.414	.000[b]
Residual	37.614	17	2.213			Residual	3.289	9	0.365		
Total	185.292	23				Total	41.465	15			
a. Dependent Variable: Δ in NI to TA											
b. Predictors: (Constant), Δ in EPS to MP, Δ in OCF to Accruals, Δ in NI to OCF, Δ in OCF to TA, Δ in NI to Accruals											

How Do Risk Attitudes of Clearing Firms Matter for Managing Default Exposure in Futures Markets?[†*]

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Abstract

This article proposes a theoretical framework that is built upon extreme value theory to study three instruments (i.e., margin, capital requirement and price limits) to mitigate default risk in futures markets. Specifically, exceedances over a high threshold are modeled using a generalized Pareto distribution, and the models are static (one-period). In particular, we incorporate risk attitudes of clearing firms that indicate their concerns about market conditions and funding liquidity into the framework to assess the efficacy of these instruments under several risk measures, including value-at-risk measures (VaRs), expected-shortfall measures (ESs) and spectral risk measures (SRMs). It is shown that risk attitudes of clearing firms affect margin, capital requirement and price limits, and may further cause interaction effects among these instruments, which casts new light on the economic rationale of price limits. It thus enriches the literature on clearinghouse regulation by investigating the effectiveness of three risk management instruments and their interaction effects in futures markets where investors may show heterogeneous risk attitudes. An empirical study is conducted using VIX futures (or VX) data.

JEL classification: C61, G13, G32

Keyword: Clearing Margin; Capital requirement; Price limits; Risk attitude; Extreme value; Risk measures

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1 Introduction

The 2008 financial crisis reminds us the importance of reviewing the public risk management practice relating to financial intermediaries, in particular towards those financial derivatives markets which may spread the originally limited underlying risk to a much wider range and level of beyond control. For the purpose of default exposure management, the most widely used market instruments include margin, capital requirement and price limits in financial derivatives markets, especially in futures markets, which in itself is not new, but their interaction effects under various market circumstances when investors show heterogeneous risk attitudes are not very well studied yet, which could make regulators tend to under(over)value the effectiveness of these instruments. This article investigates the performance of these three market instruments in an extreme value context, and proposes a theoretical framework to study their effects on market integrity and contract effectiveness in dynamic market situations.

Futures clearinghouses usually require an initial margin to be collateralized in order to open a new position. This initial margin is set to cover the vast majority, usually at least 99%, of potential exposures to default risk that could arise from valuation changes over an appropriate resolution period (see Hedegaard (2011) and Heller and Vause (2012)). Previous studies have proposed a number of theoretical (statistical) models to facilitate margin setting.[1] Among them, Longin (1999) suggests that there is a persistent underestimation bias in margin levels that are calculated assuming normality. Also, Lam et al (2004) empirically compare three margin-setting methodologies (e.g., simple moving averages, exponentially weighted moving averages and a GARCH model) and find that a GARCH-based approach gives the lowest average overcharge in margin. These findings show that extreme movements in futures prices indeed play a central role in margin setting in that large losses (hence possible defaults) may occur as a result of large price variations. Most recent researches then apply extreme-value statistical techniques to clearinghouses' margin-setting decision in diverse futures markets (see Booth et al (1997), Cotter (2001), Cotter and Dowd (2006) and Bystrom (2007) among others).

[1] These alternative methods include the normal distribution (Figlewski (1984)), the historical distribution (Warshawsky (1989)) and the generalized logistic distribution (Shanker and Balakrishnan (2005)). Day and Lewis (2004) contend that the cash flows generated from a futures trading position is similar to the payoffs to a barrier option, and propose two option-based standards for setting initial margin.

In providing a contract performance guarantee, clearinghouses also have to bear the residual default risk when price changes exceed initial margin due to large market risk. They therefore may further charge additional deposits, called capital requirement or default funds defined in Heller and Vause (2012), to cover the residual risk that is not covered by initial margin. In particular, Gemmill (1994) examines the magnitude of capital requirement imposed by the International Commodities Clearing House (ICCH) in London to cover the risk exposures when price movements exceed initial margin. Given the level of initial margin in 1987, the ICCH had a significant exposure to the residual default risk (e.g., £40 million about once per year and £200 million once per thirty years). Bates and Craine (1999) further focus on valuing the default exposure in terms of the expectation of additional required funds, conditional on margin being exceeded. For instance, an additional $10.4 billion was expected to weather another crash on October 20, 1987 when the S&P 500 futures price declined 29% (the largest daily price change since trading began according to SEC Report (1988), p2-12).

Whilst adequate capital deposits enable clearinghouses to manage default risk effectively, they pose a heavy capital burden on clearing firms, which could reduce the competitiveness of futures markets and consequently hinder their growth. Price limits have been accepted widely as an alternative instrument that can lower capital requirement but still make default risk under control (see Telser (1981), Brennan (1986), Chou et al (2000), Broussard (2001), Chen (2002) and Shanker and Balakrishnan (2005)). Although price limits do not change the risk of underlying positions (Telser (1981)), Brennan (1986) suggests that since price limits may lead to an ambiguity effect towards trading firms and make it more difficult for a losing party to project his true loss, he would have less incentive to default on his position and then the possibility of reneging is mitigated. Moreover, Chowdhry and Nanda (1998) argue that while it is appropriate to have initial margin that is proportional to the value of the underlying asset to take care of fundamental risks, price limits are useful to enhance market stability by excluding potentially destabilizing market prices even in the presence of non-fundamental factors.

This study is rooted in the work of Brennan (1986) and Shanker and Balakrishnan (2005). Brennan (1986) proposes a model to explain how a clearinghouse sets margin and price limits that make a futures contract self-enforcing (a property under which two parties adhere to the contract's terms without possible legal actions) so that conditional on a price limit being breached, the expected loss to a trading firm is covered by initial margin. This firm's capital costs, including the opportunity cost, the liquidity cost occurring due to trading interruption and other legal costs, can hence be minimized. Shanker and Balakrishnan (2005) extend Brennan (1986)'s model by introducing capital requirement in addition to margin and price limits. Capital requirement, as the additional contribution fund, is actually a measure of conditional exposure initiated by Bates and Craine (1999), and is used to mitigate the residual default risk which cannot be covered by initial margin alone.

Indeed, the residual default risk strongly depends on the probability distribution of underlying futures prices, particularly on the extreme tails of this distribution (see Shanker and Balakrishnan (2005)). In this study, extreme value theory is used to model the distribution of extreme price movements.[2] The conventional approaches, such as a normal distribution or the historical distribution, aim to model the full distribution of futures prices and tend to underestimate the fatness of futures tail returns. Unlike these traditional alternatives, extreme value theory concentrates on those extreme events in the tails of a price distribution. So it is regarded as an appropriate candidate for modelling extreme price movements. More specifically, we employ the conditional generalized Pareto distribution (GPD) in an extreme-value context, provided that the unconditional distribution may be less suitable to capture changes in dynamic market conditions, especially dramatic changes in market volatilities or large adverse price movements which in fact require the conditional modelling of price distribution (see Cotter and Dowd (2006)).

As evidenced by the crash in 1987, Bates and Craine (1999) argue that focussing on tail probabilities alone is an inadequate criterion both for clearinghouse regulation and for the survival of all parties. Cotter and Dowd (2006) show that apart from the extreme characteristics of the underlying price distribution, the risk attitudes of clearinghouses have substantial impact on margin setting. Their study suggests that the increase in the coefficient of a clearinghouse's absolute risk aversion may dramatically shift up initial margins. Usually, the risk attitudes of clearinghouses can be partially reflected in the choice of confidence level. We further take into account clearing firms' risk attitudes. First, we argue that it is the risk attitudes of clearing firms that really matter in forming

[2] A number of studies follow this stream of inquiry, e.g., Booth et al (1997), Longin (1999,2000,2005), McNeil and Frey (2000), Broussard (2001), Cotter (2001) and Cotter and Dowd (2006) among others.

up their expected losses in trading, which in turn affects the risk appetite of clearinghouses in regulation. Second, Brunnermeier and Pedersen (2009) (see also Hedegaard (2011)) study the feedback effects between margins and market conditions (i.e., futures returns, price volatility, trader's losses and liquidity). For example, high margins may cause market illiquidity, and can reduce trading volume, increase price impact, and decrease open interest. In the presence of such effects, clearing firms' risk attitudes may promptly reflect the firms' concerns about both market conditions and funding constraints. Therefore, risk attitudes of clearing firms are incorporated into our framework in the way that two risk measures, the expected-shortfall measures (ESs) studied by Artzner et al (1999) and spectral risk measures (SRMs) proposed by Acerbi (2002) are employed.[3] Moreover, capital requirement that captures the changes in clearing firms' expectations about potential losses is charged to relieve the effect of "margin spiral" defined in Brunnermeier and Pedersen (2009).

We hence study the efficacy of three default exposure management instruments (e.g., initial margin, capital requirement and price limits) in futures markets where clearing firms may exhibit heterogeneous risk attitudes. The past financial crises demonstrate that clearing firms have experienced dramatic changes in their sentiments towards large price movements or volatile market conditions. In the presence of clearing firms' risk preference, clearinghouses are likely to under(over)value the effectiveness of specific instruments. More importantly, both how these market instruments interact with each other and how the interaction impacts on the performance of these tools have not been well understood in the literature.

We first establish a theoretical framework with the objective function of capital cost minimization, subject to effective self-enforcing futures contracts. The framework is similar in spirit to Brennan (1986) and Shanker and Balakrishnan (2005) with the added features that i) the risk attitudes of clearing firms are accommodated; and ii) the effects of these instruments on futures returns are considered. By considering the default exposure management practice, we are interested in the efficacy of daily margins, capital requirements and price limits and the interactive effects among them, and so the static (one-period) models that minimize the capital costs of clearing firms are proposed, while

[3] In particular, Grootveld and Hallerbach (2004) suggest that the former measures are closely associated with risk-neutral users, while the latter measures are directly related to users' risk-aversion.

exceedances over a high threshold are modeled using a conditional GPD.[4]

An empirical study is then conducted to the futures contracts on the volatility index ("VIX") or VX contracts which have been traded on the Chicago Board Options Exchange (CBOE) Futures Exchange since 2004. It is found that compared with initial margin, capital requirement may serve as an effective instrument for clearinghouses to dynamically accommodate clearing firms' sentiments towards volatile market conditions, but its effectiveness rests on both the risk attitudes of clearing firms and the tail fatness of futures price distribution.

Moreover, price limits may act as a partial substitute for initial margin for both risk-neutral and risk-averse clearing firms, yet dependent on the magnitude of the truncation effect caused by price limits. More specifically, the intensifying truncation effect may offset the impact of clearing firms' risk-aversion on the market instruments, and consequently weaken the effectiveness of initial margin and capital requirement in accommodating the shift in risk attitudes among clearing firms. In contrast, such a shift may significantly increase the requirements on both market instruments when the truncation effect is relatively weak. In particular, when clearing firms experience a substantial shift from risk neutrality to risk aversion, there exist certain circumstances under which price limits may work as the only alternative instrument for clearinghouses to incorporate investor's risk aversion into the regulatory system in order to stabilize markets and mitigate default risk, which provides new insights into the economic rationale of price limits.

We proceed as follows. Section 2 proposes two theoretical models to search for optimal margin and capital requirement as well as price limits. Section 3 further proposes a risk-aversion function so that a class of SRMs are constructed in order to extend the models developed in Section 2. Section 4 then presents the model implementation under GPDs. Section 5 reports all the empirical results using the VX contract data and discusses their policy-making implications for clearinghouse regulation. Section 6 draws conclusions.

[4]Brunnermeier and Pedersen (2009) employ a dynamic model where a multiple-period economy is set up such that the margins for both informed and uninformed "financiers" (or regulators) are obtained.

2 Theoretical Framework for Setting Optimal Margin, Capital Requirement and Price Limits

This section first describes the setup of our framework. We then propose two models to search for initial margin and capital requirement. The effect of price limits on margin and capital requirement is taken into account and discussed in the second model.

2.1 The Setup

After introducing the market structure, we discuss the way how to model distribution tails. The definition of self-enforcing futures contracts is further introduced.

2.1.1 Market Structure

We consider a discrete-time and continuous-space market. The discrete-time setting is consistent with the market observations, and is also convenient for numerical tractability. Continuous space ensures that the market structure itself does not impose any restriction on the volatility of the underlying futures price F when time is discrete.[5] This market is frictionless. That is, there are no restrictions on trading positions, transaction costs, taxes and other administrative costs.

The time period is discretized with a time interval δ so that all time points, indicated by the time index t, are equally spaced and the length of each time interval is set as $\delta = 1$ without loss of generality, as futures traders are required to mark-to-market daily. Let a real-valued random variable R denote the geometric return (taken as the log difference of end-of-day futures prices). Given the futures price at time t, F_t, the futures price at time $t+1$ then takes value from the set:

$$F_{t+1} \in \mathbb{F} = \{F_t e^{R_t} : R_t \in \mathbb{R}\},$$

with the initial futures price F_0.[6]

Within this market, we further make the following assumptions:

[A1] *The probability distribution of the return R_t is continuous for all t.*

[5] In this discrete-time continuous-space market, $(F_{t+\delta} - F_t)^2 \in \mathbb{R}^+$ is unbounded for a time interval δ.

[6] Approximately, $R_t \triangleq \log F_{t+1} - \log F_t = (\frac{F_{t+1}}{F_t} - 1) - o((\frac{F_{t+1}}{F_t} - 1)^2) \approx \frac{F_{t+1} - F_t}{F_t}$ for $|\frac{F_{t+1}}{F_t} - 1| \leq 1$. This approximation holds in real market situations.

[A2] *All the market participants have no external source of information about the equilibrium futures prices, apart from the market prices of futures contracts.*

[A3] *The interest rate of borrowing/lending is deterministic.*

The continuity of the distribution of futures returns (assumption [$A1$]) is required for modelling the tail distribution. Note that the lower and upper endpoints associated with the distribution of a variable (like R) may usually be set within the range of $(-\infty, +\infty)$. Moreover, assumption [$A2$] implies that all the risks faced by a clearing firm are derived from price movements so that in the occurrence of a large adverse price movement, this firm forms its conjecture about both future prices and potential losses, based only on the distribution of futures returns. The critical requirement we need in assumption [$A3$] is that interest rate is non-stochastic for the convenience of numerical tractability.

2.1.2 Modelling the Distribution Tails

In order to model the distribution tails of futures returns, we define extreme returns as exceedances over a threshold denoted by u. Positive u-exceedances correspond to all observations higher than the threshold (i.e., $R > u$). We therefore look at the case where the right tail of the distribution of returns that consist of all positive u-exceedances is defined, while all negative u-exceedances can be defined due to symmetry.

If the distribution of returns is known, the cumulative distribution of positive u-exceeding returns is determined as follows:

$$prob(R \leq x | R > u) = \frac{prob(R \leq x) - prob(R \leq u)}{1 - prob(R \leq u)}, \tag{1}$$

conditional on the return being greater than the threshold. However, it is usually not easy to acquire the precise full distribution of returns in empirical financial studies (see Cont (2001)), and thus neither is the exact distribution of exceeding returns. In statistics, extreme value theory studies the asymptotic behavior of return exceedances. This approach specifies the condition that a possible non-degenerate limit cumulative distribution of exceeding returns, denoted by G_R^u, should satisfy:

$$prob(R \leq x | R > u) \rightarrow G_R^u(x), \text{ for all } x > u, \tag{2}$$

as the threshold u approaches the upper endpoint of the return distribution.[7] Pickands (1975) further shows that the generalized Pareto distribution (GPD) is the only candidate

[7]See Pickands (1975) and Coles (2001) for the relevant proofs.

that satisfies the condition (2) and approximates the distribution of return exceedances. More specifically, Coles (2001) presents this limiting distribution function as follows:

$$G_R^u(x) = \begin{cases} 1 - (1 + \xi \frac{x-u}{\sigma})_+^{-\frac{1}{\xi}}, & \text{if } \xi \neq 0, \\ 1 - exp(-\frac{x-u}{\sigma}), & \text{if } \xi = 0, \end{cases} \tag{3}$$

defined on the domain $\{x : x - u \geq 0 \text{ and } (1 + \xi \frac{x-u}{\sigma}) \geq 0\}$, where the scale (dispersion) parameter, $\sigma(> 0)$, depends on both the threshold u and the distribution of returns, while the shape parameter, ξ, gives a precise characterization of the tail of the return distribution. Therefore, the marginal distribution of futures returns is approximated by

$$\widehat{prob}(R_t \leq x) = \begin{cases} prob(R_t \leq x), & \text{for } x \leq u, \\ 1 - [1 - prob(R_t \leq u)][1 - \hat{G}_R^u(R_t \leq x : \hat{\xi}, \hat{\sigma})], & \text{for } x > u, \end{cases} \tag{4}$$

where the cumulative distribution $prob(R_t \leq x)$ can be estimated empirically from the observations of the return R, and both $\hat{\xi}$ and $\hat{\sigma}$ are the GPD estimators.

In particular, the shape parameter ξ, or equivalently the tail index, determines the type (fatness) of the return distribution. As discussed by Longin (1999), distributions with an exponentially declining tail (thin-tailed distributions) lead to $\xi = 0$ which corresponds to a Gumbel distribution for return exceedances, while distributions with a power-declining tail (fat-tailed distributions) result in a positive ξ which implies a Fréchet distribution, and a negative ξ corresponds to a Weibull distribution that characterizes distributions without tails (finite distributions).

In general, the limit relationship in (2) relies on the assumption that the sequence of return observations follows an independent identical distribution (i.i.d.). This relationship has also been extended to non-i.i.d. processes. As suggested by Leadbetter et al (1983), a number of processes derived from the normal distribution, including autocorrelated normal processes, the discrete mixtures of normal distributions and mixed diffusion-jump processes, have thin tails and thus lead to a GPD with $\xi = 0$. De Haan et al (1989) also show that the extreme values of returns that follow GARCH processes have a GPD with $\xi < 0.5$. Longin (2000) further suggests that the result of asymptotic convergence towards a Fréchet-Gumbel-Weibull distribution still holds for stationary processes (see also Coles (2001), p96), while Longin and Solnik (2001) confirm that this convergence result is robust for those non-i.i.d. processes used in financial researches. In sum, the literature about extreme value theory shows that the distribution of return exceedances can converge to a GPD that is captured by two parameters: the dispersion parameter and the shape parameter (or the tail index), for a given threshold (u).

2.1.3 Self-Enforcing Futures Contract

Clearinghouses mainly adopt margin, capital requirement and price limits to enhance market stability and manage default exposure. To guarantee contract performance, suppose that clearing firms are required to open two accounts with a clearinghouse in order to enter a new futures position. A margin account is used to deposit initial margin, denoted by M, which is to facilitate the daily marking to market of the future position. Also, a capital requirement account is used to deposit additional default funds, denoted by C, which is to cover those daily losses that exceed the initial margin M. Otherwise, the clearinghouse has to fulfill its option-like guarantee.

The self-enforcement of futures contracts initiated by Brennan (1986) may improve the efficacy of risk management in the sense that this attribute helps reduce the incentives of clearing firms to renege on their obligations when the initial margin deposit has been fully depleted. Through the design of a self-enforcing futures contract, clearinghouses would encounter less default risk, as both parties to this contract have less incentive to renege.

Definition 1 (Self-Enforcing Futures Contract). *A futures contract is self-enforcing if the expected losses that are measured under the distribution G_R^u can be offset by the total collaterals in both the margin account (M) and the account of capital requirement (C) adherent to this contract.*

Note that this concept is defined in a narrow sense, as some other costs, such as the reputation and legal costs, are not counted due to the difficulty of measurement.

2.2 Margin and Capital Requirement in the Absence of Price Limits

We now present a model to seek the optimal margin and capital requirement in the absence of price limits. Since clearinghouses are concerned with both default risk and capital burden of clearing firms (due to the constraint on funding liquidity), this model is to strike a balance between risk exposure and capital cost. First, instead of imposing a confidence level on each trading position to the same futures contract, a clearinghouse may simply require that the overall probability of margin violation (daily price change exceeding margin) by two parties lies in an allowable range. So the opportunity costs of clearing firms, represented by total collaterals, are bounded below. Second, it is desirable if margin and capital requirement are set such that *i*) the futures contract is self-enforcing, and *ii*) the capital costs of two trading parties are minimized. Hence the model yields the lowest daily margin and capital requirement which is also in the interest of clearing firms. In this way, clearing firms' incentives to default are reduced and the performance of futures contracts can be guaranteed.

Let the symbol ι (ς) indicate a long (short) position in a futures contract, and so M_ι (M_ς) and $C_\iota(C_\varsigma)$ represent the margin and capital requirement deposited by a clearing firm that initiates such a trading position at the futures price F_t. From the clearinghouse's perspective, we then formulate a model that minimizes the daily capital costs of two parties to the same futures contract as follows:

$$\text{(P1)}\ \ \min \sum_{i\in\{\iota,\varsigma\}} (M_i + C_i)r,$$

with respect to M_ι, M_ς, C_ι and C_ς, subject to

1) $prob(R_t > M_\varsigma) + prob(R_t < -M_\iota) \leq \pi$;

2) $\mathbb{E}[R_t - M_\varsigma | R_t > M_\varsigma, R_t > u_\varsigma] \leq C_\varsigma$, for a short position;

3) $\mathbb{E}[(-R_t) - M_\iota | R_t < -M_\iota, R_t < -u_\iota] \leq C_\iota$, for a long position;

4) $M_\varsigma \geq u_\varsigma > 0$ and $M_\iota \geq u_\iota > 0$,

where r denotes the daily interest rate (a unit cost), and $\mathbb{E}$ is the expectation operator under the distribution of returns R_t.

In the nature of the opportunity cost of funds, the objective function in Model $P1$ represents the total collaterals with a daily settlement rule, subject to the four constraints. Among them, the constraint 4) requires that the optimal margin for either party should be greater than the threshold value. Margin is usually set against potential losses caused by adverse price movements. The threshold u_ς (u_ι) indicates the area in the right (left) tail of the return distribution in which extreme price changes may occur. If margin levels are set outside of these areas, such low margins would be insufficient to offset the losses the clearinghouse may suffer when default events occur. Motivated by these concerns, we impose the constraint 4). The constraint 1) that restricts the range of the overall probability of margin violation can then be re-expressed as follows:

$$prob(R_t > M_\varsigma | R_t > u_\varsigma) prob(R_t > u_\varsigma) + prob(R_t < -M_\iota | R_t < -u_\iota) prob(R_t < -u_\iota) \leq \pi,$$

which suggests that the overall probability of margin violation is bounded above by a prior probability π (implying a confidence level with at least $1-\pi$). Moreover, the conditional expectation in the constraint 2) (and the third one as well) measures expected loss when the margin deposit is fully depleted. Following the constraint 4), this expectation may be further reduced to the following form:

$$\mathbb{E}[R_t - M_\varsigma | R_t > M_\varsigma, R_t > u_\varsigma] = \mathbb{E}[R_t - M_\varsigma | R_t > M_\varsigma], \text{ for } M_\varsigma > u_\varsigma \ ,$$

while the inequality in the constraint ensures that the additional fund in the form of capital requirement can offset expected loss so that the futures contract is self-enforcing.

It is known from Section 2.1.2 that as the upper (lower) threshold value u_ς (u_ι) becomes larger, the distribution of those exceeding returns tends to a distribution $G_R^{u_\varsigma}$ ($G_R^{u_\iota}$) shown in (3). We hence may acquire the following results in order to solve Model $P1$:

Proposition 1. *Suppose the exceeding returns follow a distribution $G^u_{\xi,\sigma}$ in (3).*

i) If $prob(R_t > M) = \alpha > 0$ and $M > u$,

$$M = prob^{-1}(1-\alpha) = \begin{cases} u + \frac{\sigma}{\xi}\{(\frac{\alpha}{prob(R_t>u)})^{-\xi} - 1\}, & \textit{for } \xi \neq 0, \\ u - \sigma \ln(\frac{\alpha}{prob(R_t>u)}), & \textit{for } \xi = 0. \end{cases} \tag{5}$$

ii) The conditional expectation $\mathbb{E}[R_t | R_t > M]$ can be further expressed as follows:

$$\mathbb{E}[R_t | R_t > M] = \begin{cases} \frac{M}{1-\xi} + \frac{\sigma - u\xi}{1-\xi}, & \textit{for } \xi \neq 0, \\ M + \sigma, & \textit{for } \xi = 0. \end{cases} \tag{6}$$

Proof See Appendix B.

This proposition shows that the expectations in the constraints 2) and 3) are finite and thus bounded above. Since there always exist two margins that satisfy the constraint 1) given the appropriate threshold values and a margin violation probability, the capital requirement may be set equal to the conditional expectation in the constraint 2) or 3). This implies the existence of a feasible solution to Model $P1$ which yields a finite value for the objective function. This program therefore must have a solution.

2.3 Effects of Price Limit Rule on Margin and Capital Requirement

Brennan (1986) argues that price limits, in conjunction with margins, may lower default risk and reduce margin levels as well as improve futures contract performance. When a price limit is breached, the exact amount of losses that a clearing firm suffers is obscured, as the precise information about the true price becomes unobservable. This situation then causes an 'ambiguity effect'. Consequently, reneging might be avoided even when the clearing firm's expectation about potential losses exceeds the margin and capital requirement in deposit accounts. Yet, liquidity cost may result from a price limit breach due to trading interruption. Hence there exists a trade-off between default risk and liquidity cost. Meanwhile, extreme price movements in the same direction are eliminated by price limits, which in turn affects the underlying price-generating process. Price limits thus may alter the distribution of the underlying returns to some extent, which causes a 'truncation effect' (see Longin (1999)).

To establish a model in which the optimal margin and capital requirement are sought in the presence of price limits, we take care of the two effects mentioned above in different ways. To account for the ambiguity effect, the probability of a price limit breach is constrained so that the liquidity costs on both trading parties lie in a pre-determined range, which in fact sets up a range of price limits that are acceptable in futures markets. To accommodate the truncation effect, we introduce a new variable to measure the impact of price limits on the price-generating process, particularly on the tails of return distribution. By virtue of this variable, the expectation under a distribution of truncated returns can be linked back to the one under a distribution of unrestricted returns that may be estimated from market prices.

Let L_ι (L_ς) denote the upper (lower) price limit. A pair of variables $(\theta_\iota, \theta_\varsigma)$ is used to measure the magnitude of the truncation effect on the left (right) tail of the distribution. By resorting to the self-enforcement property of futures contracts, we formulate the model that minimizes the clearing firms' daily capital costs in the presence of price limits as follows:

$$\text{(P2)}\ \min \sum_{i\in\{\iota,\varsigma\}} (M_i + C_i)r,$$

with respect to M_ι, M_ς, C_ι, C_ς, L_ι, L_ς and θ_ι, θ_ς, subject to

5) $prob(R_t \geq L_\varsigma) + prob(R_t \leq -L_\iota) \leq \bar{\pi}$;

6) $\mathbb{E}[R_t | R_t \geq L_\varsigma, R_t > u_\varsigma] = \frac{1}{\theta_\varsigma}(M_\varsigma + C_\varsigma)$, for the upper limit;

7) $\mathbb{E}[-R_t | R_t \leq -L_\iota, R_t < -u_\iota] = \frac{1}{\theta_\iota}(M_\iota + C_\iota)$, for the lower limit;

8) $\mathbb{E}[R_t - M_\varsigma | R_t > M_\varsigma, R_t > u_\varsigma] \leq C_\varsigma$, for a short position;

9) $\mathbb{E}[(-R_t) - M_\iota | R_t < -M_\iota, R_t < -u_\iota] \leq C_\iota$, for a long position;

10) $u_i \leq L_i \leq M_i + C_i$;

11) $M_\varsigma \geq u_\varsigma$ and $M_\iota \geq u_\iota$;

12) $0 < \theta_i \leq 1$.

Note that this model is built on a distribution of unrestricted futures returns.[8] It is believed that possible losses indeed rest on uncensored futures prices, rather than those prices censored by price limits.

It is clear that the constraint 5) restricts the liquidity costs of two clearing firms through a range of price limits. The constraints 6) and 7) further specify the total collaterals required to cover the potential losses occurring next day. The loss is measured as an expectation (the left term in 6) or 7)), conditional on the upper (lower) price limit breach. However, this expectation may overestimate the required capital due to the truncation effect, as it is made under a distribution of unrestricted returns. So the expectation bias on the total collaterals is adjusted by a factor $1/\theta$ to ensure the self-enforcement of the futures contract, as shown the right term in 6) or 7). The variable θ, defined as a ratio of the conditional expectation under a distribution of truncated returns against the one under a distribution of unrestricted returns, is used to measure the magnitude of this overestimation (equivalently, the impact of price limits on the underlying price-generating process). If there is no overestimation (or less truncation effect), the value of θ is close to one. If this effect becomes much stronger, its value then tends to zero, as suggested in the constraint 12). Moreover, the constraints 8) and 9) establish the link between margin level and capital requirement, as done in Model $P1$. In order to seek prudential margins, however, truncation effect is not incorporated into

[8] For those censored futures price, Wang (1990) and Zakaria et al (2011) propose different approaches to derive the unbiased estimators for a tail distribution of unrestricted returns (see also Shanker and Balakrishnan (2005)).

these two constraints in that the underlying futures price process is less affected at the moment.

The constraint 10) requires that the optimal price limit for either trading position lies in the area indicated by the threshold u_ς or u_ι, and further should be less than total collaterals. To see this, we consider two cases. If price limits are set outside of the areas ($L < u$), they may hamper price discovery. Also, it is unlikely that a price limit is set at the level greater than total collaterals ($M + C < L \ll \infty$). Otherwise, the realized loss of a clearing firm would exceed the collateral deposited with the clearinghouse. This firm thus definitely has an incentive to renege. As a result, we impose the constraint 10) which corresponds to the case $u \leq L \leq M + C$. Moreover, the constraint 11) follows the same argument in Model $P1$.

Linking back to Model $P1$, Model $P2$ can be regarded as its extension in the sense that price limits are set as infinity in Model $P1$. In particular, Model $P2$ has a feasible solution with $\theta = 1$ and $L = M$ where M and C are the feasible solutions to Model $P1$. In order to show the existence of the solutions to Model $P2$, we establish the following result that identifies the optimal θ within our setup.

Proposition 2. *For a self-enforcing futures contract, the optimal θ^* caused by a price limit in Model $P2$ can be measured as the ratio of this limit against the expected loss, conditional on a price limit breach,*

$$(\theta_\iota^*, \theta_\varsigma^*) = (\frac{L_\iota}{\mathbb{E}[-R_t|R_t \leq -L_\iota]}, \frac{L_\varsigma}{\mathbb{E}[R_t|R_t \geq L_\varsigma]}) \tag{7}$$

for $0 < \theta_i^* \leq 1$ and $u_i \leq L_i$ where $i \in \{\iota, \varsigma\}$.

Proof See Appendix C.

3 Measurement of Conditional Expected Losses: Incorporating Risk Aversion

The solutions to both models proposed in Section 2 depend on the way we measure conditional expected losses. This manner may have informational content about the risk appetite of market participants. This section discusses the measurement of conditional expected losses. A new risk measure is proposed to incorporate clearing firms' risk-aversion into the models.

3.1 Expectations of Weighted Losses

In Section 2, it is impressed that the expected losses as the measure of risk, conditional on either margins being wiped out or price limits being breached, play a central role in seeking optimal solutions. To see this, take a short position for example and the proof in Lemma 1 (Appendix A) establishes that due to assumption $[A1]$ the following relation should hold:

$$\mathbb{E}[R|R > M] = \frac{1}{\alpha}\int_{1-\alpha}^{1} R_q dq, \tag{8}$$

where $R_q = \sup\{x : prob(R \leq x) \leq q\}$ and $prob(R > M) = \alpha \in (0, 1)$. Here R_q is exactly the 'q-quantile' of the distribution of R, and the right term in (8) is just the average of the worst $\alpha 100\%$ of losses.[9] Hence, the left term in (8) suggests that the conditional expected loss is measured by taking an average of quantiles in which tail quantiles (above $1 - \alpha$) have the same weight of $\frac{1}{\alpha}$ and zero otherwise.

Now recall the constraint 2) in Model $P1$. It suggests that the way of measuring expected losses has substantial impact on capital requirement and further on total collaterals. Actually, this measurement is done by assuming that clearing firms are risk-neutral, as the same weight in (8) is placed on all potential losses, regardless their amounts. In practice, however, this underlying assumption is relatively strong, as these clearing firms do have attitudes towards risk. They indeed are more concerned with higher trading losses. Under this circumstance, the measurement of expected losses shown in (8) may underestimate the amount of capital requirement and so the total collaterals required.

To accommodate the risk attitudes of clearing firms towards potential losses, we introduce a weighting function which allows those risk-averse firms to place more weights on high losses. Acerbi (2002) develops the theory of spectral risk measures (SRMs) in which a weighting function is called a 'risk aversion function' if it satisfies three conditions: a) non-negativity; b) normality (its norm is equal to 1); c) monotonicity. The third condition among these three, associated with the first one, is intended to reflect user's risk aversion

[9] Note that three risk measures that are widely used in the financial literature are involved in (8). The notation R_q defines a measure called Value-at-Risk (VaR) in Artzner et al (1999) and Cotter and Dowd (2006). Moreover, the left term in (8) defines the second measure called Tail Conditional Expectation (TCE) in Artzner et al (1999), while the right term defines the third measure called Expected Shortfall (ES) or Conditional Value-at-Risk (CVaR) in Acerbi and Tasche (2002). Acerbi and Tasche (2002) prove that the latter two measures under a continuous distribution are identical.

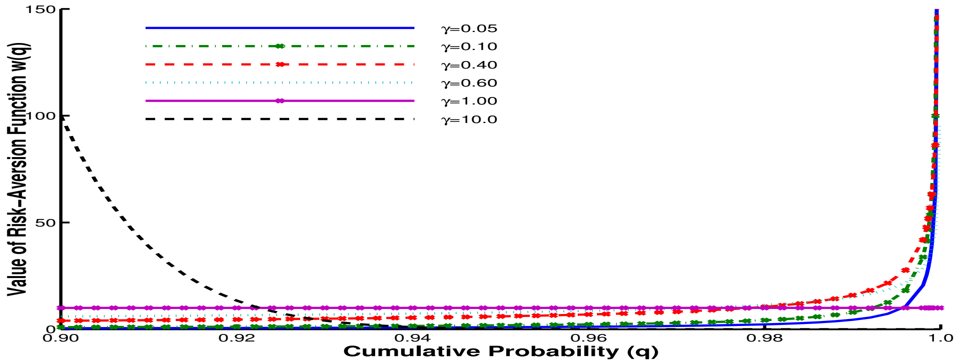

Figure 1: **A Risk-Aversion Function**. The risk-aversion function is given in (9). The probability α is set as 10%, e.g. $\alpha = 0.1$, and so the range of cumulative probabilities is from 0.90 to 1.0.

by requiring that those weights attached to higher losses should be no less than those weights attached to lower losses, while the second one is a normalization condition in a normed space.

Since the risk aversion function in Acerbi (2002) is a user-defined weighting function over the full range of cumulative probabilities, a SRM defines a class of quantile-based risk measures each of which is determined by its own well-specified weighting function. In order to incorporate user's risk aversion into the measurement of potential losses, we employ a weighting function $w(q)$ depending on a cumulative probability $q \in [1-\alpha, 1]$ as follows:

$$w(q) = \frac{\gamma}{\alpha^{\gamma}}(1-q)^{\gamma-1}, \text{for } \gamma > 0, \tag{9}$$

where the parameter γ is used to specify a clearing firm's risk attitude so that we may have the following expression that is similar to the left term in (8):

$$\int_{1-\alpha}^{1} \frac{\gamma}{\alpha^{\gamma}}(1-q)^{\gamma-1} R_q dq = \frac{1}{\alpha}\int_{1-\alpha}^{1} [\alpha w(q)] R_q dq. \tag{10}$$

Linking back to the left term in (8), the right term in (10) shows that conditional on the margin being depleted the expected loss is measured by assigning each tail quantile q above $1-\alpha$ a weight of $w(q)$ and zero otherwise. Figure 1 illustrates the weighting function in (9) with the different coefficients of risk attitude. Note that the weight function in (8) can be viewed as a special case of the function in (10), i.e., $\gamma = 1$. This suggests that clearing firms are risk-averse if $\gamma \in (0, 1)$, risk-neutral if $\gamma = 1$, and risk-loving if $\gamma > 1$, which is exactly the message conveyed in Figure 1.[10] In particular, this weighting

[10]Note that the parameter γ is not qualified to measure the magnitude of clearing firms' risk aversion, as the weighting function in (9) is not a monotonic function with respect to γ.

function with $\gamma \in (0, 1)$ satisfies three conditions stated in Acerbi (2002), and thus can be regarded as a qualified risk-aversion function. We therefore restrict our attention to the case of $\gamma \in (0, 1)$ hereafter unless specified otherwise.

Dowd et al (2008) suggest that a large set of utility functions in the financial literature ensures the availability of a range of weighting functions. The weighting function in (9) is attached to those power-form utility functions.[11] Since these functions usually involve a parameter as a measure of investor risk aversion, however, it must be clear that this parameter is different from the one specified in (9). The former measures the magnitude of risk aversion of clearing firms, while the latter measures their risk attitudes, which further requires the establishment of a link between them. The motivations of using such a weighting function stem from the reason that the power-form utility functions may capture better the risky behavior of real-world agents towards wealth (see Dowd et al (2008)) and thus be regarded as appropriate candidates for financial applications (see Rosenberg and Engle (2002)).

In order to incorporate the expression in (10) into the two models in Section 2, we further convert the integration of all weighted losses in the right term into an expectation. Under the assumption of the continuity of the return distribution (assumption $[A1]$), the right term in (10) may be rewritten in the form of conditional expectation as follows:

$$\frac{1}{\alpha}\int_{1-\alpha}^{1}[\alpha w(q)]R_q dq = \mathbb{E}[\alpha w(q(R))R | R > M], \tag{11}$$

where $prob(R > M) = \alpha$ and the function $q(R)$ is a map from the sample space of R to a real value range between 0 and 1, and the function $w(q)$ is given in (9). In particular, if the weight is set as 1 (i.e., $\alpha w(q) \equiv 1$), we acquire the left term in (8). In this way, we then accommodate the investor's risk attitude in the measurement of expected losses.

[11] Widely used utility functions are the simple single parameter constant absolute risk aversion (CARA) exponential form or the constant relative risk aversion (CRRA) power (or log) form. By following an exponential utility function, Cotter and Dowd (2006) employ another well-specified weighting function $w(q)$:

$$w(q) = \frac{\gamma e^{-\gamma(1-q)}}{1-e^{-\gamma}}, \text{for } \gamma > 0 \text{ and } q \in [0, 1],$$

where γ measures user's risk aversion. This function can also be used in our analysis, but it requires computational efforts. This can be done by applying the algorithms provided by Miranda and Facler (2002).

3.2 Margin, Capital Requirement and Price Limits under SRMs

After proposing a risk-aversion function in (9), we establish the expectation of weighted losses in (11) so that the risk attitudes of clearing firms are incorporated into conditional expected losses under SRMs, and further can be accommodated in the two models proposed in Section 2. Now we are motivated to search for optimal margin, capital requirement and price limits under SRMs. More specifically, the constraint on an upper margin (see the constraint 2) in Model $P1$) may be replaced as follows:

$$\mathbb{E}[\alpha w(q(R_t))(R_t - M)|R_t > M, R_t > u] \leq C, \text{ for a short position,} \tag{12}$$

for $prob(R_t > M_\varsigma) = \alpha$, and the constraint on a lower margin can be replaced similarly. Moreover, the constraint on an upper price limit (see the constraint 6) in Model $P2$) may be replaced as follows:

$$\mathbb{E}[\beta w(q(R_t))R_t|R_t \geq L, R_t > u] = \frac{1}{\theta}(M + C), \text{ for the upper limit,} \tag{13}$$

for $prob(R_t \geq L) = \beta$, and the constraint on a lower limit can also be replaced similarly.

Within the context of setting prudential margin levels, however, the risk-aversion function is not applied to the constraints 8) and 9) in Model $P2$ to avoid extremely low margin levels. There are two reasons. First, these constraints just suggest a way to link initial margin with capital requirement, while the total collaterals required are determined by the constraints 6) and 7). So the incorporation of a risk-aversion function in the constraints 8) and 9) cannot change the amount of total collaterals that is intended to be minimized. But this way may imply that for the function in (9) with $\gamma \in (0, 1)$, clearing firms put more weights on high losses and then increase the expectation of weighted losses, which raises capital requirement but lowers margin. This function could lead to very low initial margins, which is inconsistent with the market margin setting practice. Second, those risk-averse clearing firms do have incentives to renege when a price limit is breached, but they definitely have less incentive to renege when initial margin is exhausted due to the availability of capital requirement.

In order to solve both Model $P1$ and $P2$ in the case where clearing firms' risk attitudes are captured by a risk-aversion function in (9), we then establish the following results:

Proposition 3. *Suppose the exceeding returns follow a distribution $G^u_{\xi,\sigma}$ in (3).*

i) Given a weighting function in (9) with $\gamma \in (0,1)$, the expectation of weighted losses, conditional on the margin being depleted, can be expressed as follows:

$$\mathbb{E}[\alpha w(q(R_t))R_t|R_t > M] = \begin{cases} M + \frac{\sigma}{\gamma-\xi}(\frac{\alpha}{prob(R_t>u)})^{-\xi}, & \text{for } \xi \neq 0 \text{ and } \gamma - \xi > 0, \\ +\infty, & \text{for } \xi \neq 0 \text{ and } \gamma - \xi \leq 0, \\ M + \frac{\sigma}{\gamma}, & \text{for } \xi = 0, \end{cases} \tag{14}$$

where both α and M are specified in the first statement in Proposition 1.

ii) Moreover, conditional on a price limit being breached, the optimal θ^* caused by this limit in Model $P2$ is determined in a similar way in Proposition 2:

$$(\theta^*_\iota, \theta^*_\varsigma) = (\frac{L_\iota}{\mathbb{E}[\beta_\iota w(q(R_t))(-R_t)|R_t \leq -L_\iota]}, \frac{L_\varsigma}{\mathbb{E}[\beta_\varsigma w(q(R_t))R_t|R_t \geq L_\varsigma]}) \tag{15}$$

for $0 < \theta^*_i \leq 1$, $u_i \leq L_i$ and $prob(|R_t| \geq L_i) = \beta_i$ where $i \in \{\iota, \varsigma\}$.

Proof See Appendix D.

The first result shows the analytical solution to the conditional expectation of losses under SRMs. More importantly, this result indicates that there exist certain circumstances (e.g., $0 < \gamma \leq \xi$) where the distribution of the underlying futures returns presents fat tails ($\xi > 0$), while clearing firms are sensitive to their fatness (e.g., $0 < \gamma < 1$). Under such circumstances, price limits would be the only instrument for clearinghouses to stabilize markets due to extremely large expected losses unless clearing firms' risk aversion is relieved (e.g., $\gamma > \xi$). In other scenarios, expected losses tend to be finite so that both initial margin and capital requirement can be regarded as available candidates for default risk mitigation. Furthermore, the second result states that the magnitude of truncation effect under SRMs is similarly determined, as suggested in Proposition 2.

4 Model Implementation

This section presents the implementation of the models proposed in Section 2 that are built upon the generalized Pareto distribution (GPD). Both the selection of the threshold (u) and the estimation of the GPD parameters (ξ and σ) together with their robustness tests are discussed in detail in Appendix E. We restrict our attention to the case of $\xi \neq 0$.

The model implementation is presented for those risk-neutral clearing firms with $\gamma = 1$ and for those risk-averse firms with $\gamma \in (0, 1)$, respectively.

In order to implement Model $P1$, we first introduce two variables as follows:

$$x_\varsigma \triangleq prob(R_t \leq M_\varsigma) = 1 - prob(R_t > u_\varsigma)prob(R_t > M_\varsigma | R_t > u_\varsigma);$$
$$x_\iota \triangleq prob(-R_t \leq M_\iota) = 1 - prob(-R_t > u_\iota)prob(-R_t > M_\iota | -R_t > u_\iota),$$

for $M_\varsigma \geq u_\varsigma$ and $M_\iota \geq u_\iota$. These two variables are used to restate the first constraint in Model $P1$. Proposition 1 has established all required results to translate this theoretical model into a computational program. Model $P1$ can be rewritten under two GPDs that are specified by the relevant parameters (e.g., u, σ and ξ) as follows:

$$\text{(P1}') \ \min \sum_{i \in \{\iota, \varsigma\}} (M_i + C_i)r,$$

with respect to x_ι, x_ς, M_ι, M_ς, C_ι and C_ς, subject to

$$1') \ (1 - x_\iota) + (1 - x_\varsigma) \leq \pi, \text{for } 0 < x_i < 1 \text{ and } 1 - x_i \leq \pi;$$
$$2') \ M_i = u_i + \frac{\sigma_i}{\xi_i}\{[\frac{N}{N_i^u}(1 - x_i)]^{-\xi_i} - 1\}, \text{ for a long (short) position;}$$
$$3') \ \frac{\xi_i}{1 - \xi_i}M_i + \frac{\sigma_i - u_i\xi_i}{1 - \xi_i} \leq C_i, \text{ for a long (short) position;}$$
$$4') \ M_\varsigma \geq u_\varsigma > 0 \text{ and } M_\iota \geq u_\iota > 0,$$

where N is the total number of observations and N_i^u is the number of exceedances above the threshold u_i and $prob(|R_t| > u)$ is approximated by N^u/N. All other notions are aforementioned in Section 2. As discussed in Section 2.2, this program has a solution.

Unlike Model $P1$ which imposes the restriction on margin levels in the form of a confidence level, Model $P2$ restricts the liquidity cost that two clearing firms have to bear. In order to implement Model $P2$, we further introduce another two variables in a similar way:

$$y_\varsigma \triangleq prob(R_t < L_\varsigma) = 1 - prob(R_t > u_\varsigma)prob(R_t \geq L_\varsigma | R_t > u_\varsigma);$$
$$y_\iota \triangleq prob(-R_t < L_\iota) = 1 - prob(-R_t > u_\iota)prob(-R_t \geq L_\iota | -R_t > u_\iota),$$

for $L_\varsigma \geq u_\varsigma$ and $L_\iota \geq u_\iota$. These two variables are then used to restate the constraint 5). Following the results in Proposition 2, we may rewrite Model $P2$ as follows:

$$\text{(P2}') \ \min \sum_{i \in \{\iota, \varsigma\}} (M_i + C_i)r,$$

with respect to y_ι, y_ς, M_ι, M_ς, C_ι, C_ς, L_ι, L_ς, θ_ι and θ_ς, subject to

$$5')\ (1-y_\iota)+(1-y_\varsigma)\leq\bar{\pi}, \text{for } 0<y_i<1 \text{ and } 1-y_i\leq\bar{\pi};$$

$$6')\ L_i=u_i+\frac{\sigma_i}{\xi_i}\{[\frac{N}{N_i^u}(1-y_i)]^{-\xi_i}-1\},\ \text{for a long (short) position;}$$

$$7')\ \frac{1}{1-\xi_i}L_i+\frac{\sigma_i-u_i\xi_i}{1-\xi_i}=\frac{1}{\theta_i}(M_i+C_i),\ \text{for a long (short) position;}$$

$$8')\ \frac{\xi_i}{1-\xi_i}M_i+\frac{\sigma_i-u_i\xi_i}{1-\xi_i}\leq C_i,\ \text{for a long (short) position;}$$

$$9')\ u_i\leq L_i\leq M_i+C_i,\ \text{for a long (short) position;}$$

$$10')\ M_i\geq u_i>0 \text{ and } M_\iota\geq u_\iota>0;$$

$$11')\ 0<\theta_i\leq 1.$$

As discussed in Section 2.3, this program also has a solution, given the initial values of u, σ, ξ and $\bar{\pi}$.

Both Model P1$'$ and P2$'$ are solved within MATLAB environment. Following the notation above, we now turn to implement both models for those risk-averse clearing firms. As discussed in Section 3.1, we restrict our attention to the case of $\gamma\in(0,1)$ and $\gamma>\xi$. Given the risk-aversion function in (9), we apply the first statement in Proposition 3, and revise the implementation of Model $P1$ under a SRM by only replacing the constraint 3$'$):

$$3'')\ \frac{\sigma_i}{\gamma-\xi_i}[\frac{N}{N_i^u}(1-x_i)]^{-\xi_i}\leq C_i,\ \text{for a long (short) position,}$$

while the other constraints are unchanged. Since this new constraint imposes restriction only on capital requirement, Model $P1$ still has a solution. Similarly, the implementation of Model $P2$ is revised so that only the constraint 7$'$) is replaced by the following form:

$$7'')\ L_i+\frac{\sigma_i}{\gamma-\xi_i}[\frac{N}{N_i^u}(1-y_i)]^{-\xi_i}=\frac{1}{\theta_i}(M_i+C_i),\ \text{for a long (short) position,}$$

while the other constraints are unchanged. This new constraint restricts the total collaterals $(M+C)$ in that the value of θ is determined by a price limit according to Proposition 3.

5 Empirical Analysis and Results

This section describes the data, reports the GPD estimators and analyses the empirical results regarding the performance of risk management instruments.

5.1 Sample Construction and Parameter Estimators

The data set consists of daily closing prices of the CBOE volatility index futures (VX) contracts from March 26, 2004 to August 14, 2012. VX contracts have expirations in each month over the year. For any given trading day, there are several contracts with different expirations traded simultaneously and the near contract is usually the most heavily traded one until the day prior to expiry date. We create a single time series of futures prices by splicing data from successive contracts in two steps. In the first step, a set of the most heavily traded VX contracts is selected. The second step involves rolling over futures contracts. On each rollover date, there is often a discrete jump in prices because of the change in maturity. After calibrating the GPD models to the VX time series, we do check whether a jump on the rollover date leads to an extreme (for technical reasons). It is found that extreme observations selected from the time series using the above methods are rarely associated with price changes at rollover dates, for example, only 4 out of 112 extreme observations are from rollover dates over the subsample from March 26, 2004 to August 26, 2008. Furthermore, we argue that margin committees or brokers are concerned with actual price changes observed in futures markets, including those maturing contracts that are the most heavily traded contracts until expiry, hence the original return observations are used in our research. In this way, a time series of VX contract prices over eight years is constructed. The daily returns, defined as $R_t = 100{*}\ln(\frac{P_t}{P_{t-1}})$, where P_t is the closing price of a VX contract at time t, are calculated from the continuous rolling prices. Returns on rollover dates, however, are calculated as the log difference between two consecutive daily prices from the same contract. The descriptive statistics are reported on the left panel in Figure 2, suggesting that i) this sample does not follow a normal distribution and ii) the fatter right tail indicates that the market fear (measured by the VIX) is stronger during the 2008 financial crisis.

Since all futures contracts, including VX contracts, are daily settled, it would make sense to re-estimate the daily margin requirement each day which incorporates the most updated information. In total we estimate daily margin requirement of 1000 business days (from August 27, 2008 to August 14, 2012). Since we are interested in observing the performance of our margin setting during the 2008 financial crisis, 27 August 2008 is the first day for which we estimate the margin requirement and it is estimated using data from the sample covering the period from 26 March 2004, when the VX contracts are

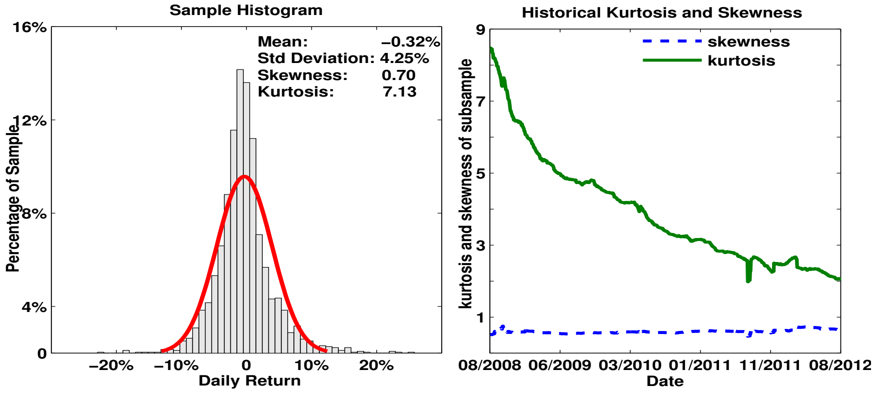

Figure 2: **Sample Statistics**. The left panel reports the descriptive statistics of the VX data from March 26, 2004 to August 14, 2012. The 1000 subsmaples are then constructed so that each subsample has 1113 returns. The solid (dashed) line on the right panel presents the historical kurtosis (skewness) of all these subsamples from August 27, 2008 towards August 14, 2012.

first introduced, until 26 August 2008, which also ensures that the sample size (with 1112 daily observations) is large enough for GPD estimation (see McNeil and Frey (2000)). Meanwhile, to make sure each daily margin requirement is estimated with adequate information but at the same time to avoid the impact of outdated data, we maintain the same sample size for all margin estimations by rolling over on a daily basis. That is, for each day 1112 daily log returns in the past four years are used to estimate that day's margin requirement. The right panel in Figure 2 reports that the historical kurtosis and skewness for the consecutive 1000 samples, indicating that the return distributions have fat tails and asymmetric characters.

As mentioned in Section 2.1.2, for a stationary time series of returns, the extreme value of returns converges to a GPD, which can be straightly applied to the sample mentioned above.[12] For a subsample (a time series), we first apply the simulation method presented in Appendix E to determine the optimal threshold (u). As reported on the top panels in Figure 3, the optimal thresholds show steady upward trends due to both the rolling over effect of sampling and the increasing frequency of extreme price movements since the financial crisis in 2008. Both positive and negative extreme values are then fitted by the GPD models. The maximum likelihood estimates of the scale parameter (σ) and shape parameter (ξ) for both tails together with their 95% confidence intervals are also

[12]To estimate the distribution of return tails, McNeil and Frey (2000) consider a two stage approach. They fit the GARCH-type model to return data, and then use a GPD to model the tail of the innovation of the GARCH model, which can be guaranteed to be a strict white noise process.

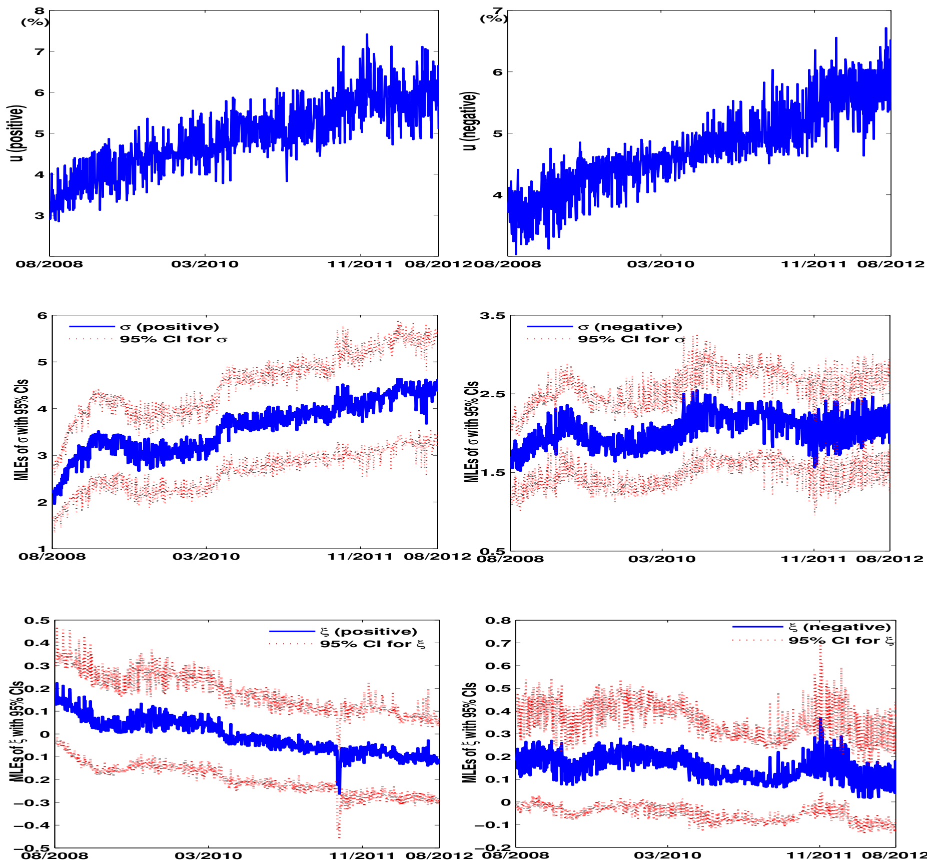

Figure 3: **Time Series of Parameter Estimators (u, σ and ξ).** All estimators from August 27, 2008 to August 14, 2012 are presented. The top panels report the optimal thresholds (us). The solid lines indicate the estimators of σ on the middle panels and of ξ on the bottom panels, while the dashed lines show their 95% confidence intervals. The first estimator of σ (ξ as well) is estimated using the tails of the subsample with 1112 returns from March 26, 2004 to August 27, 2008.

reported in Figure 3.[13] For the negative extreme returns on the left tail, the estimations for both σs and ξs (on the right-down panels) are stable across the 1000 subsamples. Most of the scale parameters (σs) are between 1.5 and 2.5 and all the shape parameters (ξs) keep positive between 0 and 0.4 for these 1000 subsamples.

However, the parameters for the positive extreme returns on the right tail (on the left-down panels) are more informative. It can be observed that an upward trend in σ is associated with the downward trend in ξ. The subsample scale parameters (σs) steadily increase from 2 to 3.5 from August 2008 to February 2009, keep stable till April 2010, and shift upward to 4.5 from July to August 2011. Compared to the left tail, the large

[13]The Cramer-von Mises statistic and the Anderson-Daring statistic are calculated and the results confirm that each series is from the GPD models with certain threshold values and the estimators of $\hat{\sigma}$ and $\hat{\xi}$.

and rising σs here indicate that investors' fear sentiment is persistently stronger during market downturn, supported by the left panel in Figure 2. In contrast, a different pattern can be observed for shape parameters (ξs). Most of the subsample shape parameters are positive (less than 0.2) till April 2010 while the rests are negative (above -0.15) with a dramatic drop (below -0.3) around from July to August 2011. In particular, the estimates of ξ are positive in the first 427 subsamples (until May 7, 2010), and then turn to negative, which is consistent with the pattern of the kurtosis reported in Figure 2. That is, there is a clear decreasing trend in kurtosis from 8.5 to 2 which indicates significantly heavy tails for the first half subsamples but relatively thinner ones for the second half. The increasing σs together with decreasing ξs need to be interpreted carefully. It suggests that when comparatively more large price changes are existent in a sample, the fatness of the distribution is weakened, which may lead to a small or even negative ξ, while return variation in tails is mostly measured by a scale parameter σ.

5.2 Optimal Margin and Capital Requirement in the Absence of Price Limits

The market initial margin requirements for VX contracts are acquired from the website of CBOE Futures Exchange (CFE), and their changes are announced through CFE Regulatory Circular. The CFE sets slightly higher initial margin for speculative customers than for hedgers. We restrict our attention to those margins for speculators who are the major liquidity providers and risk-takers in markets. The historical margin requirements on VX contracts for speculators are shown in the solid lines in Figure 4. These market initial margins increased twice in October 2008, once in May 2010 and four times consecutively from August 5 to September 23, 2011 due to the financial crisis in 2008 and the European sovereign debt crisis in 2010 which was further worsened in July 2011. Since the market margin is quoted in dollar value, both initial margin and capital requirement are estimated in percentage and converted into dollar value by following the way in Longin (1999).[14]

[14] The relationship between dollar value and percentage margin is described as follows: if the current futures contract value is 100, a dollar margin of 10 for a short (long) position corresponds to a percentage margin level of 9.53% ($= 100 * \ln(110/100)\%$) and 10.53% ($= (-100) * \ln(90/100)\%$) in absolute value.

5.2.1 Performance of Optimal Margin and Capital Requirement

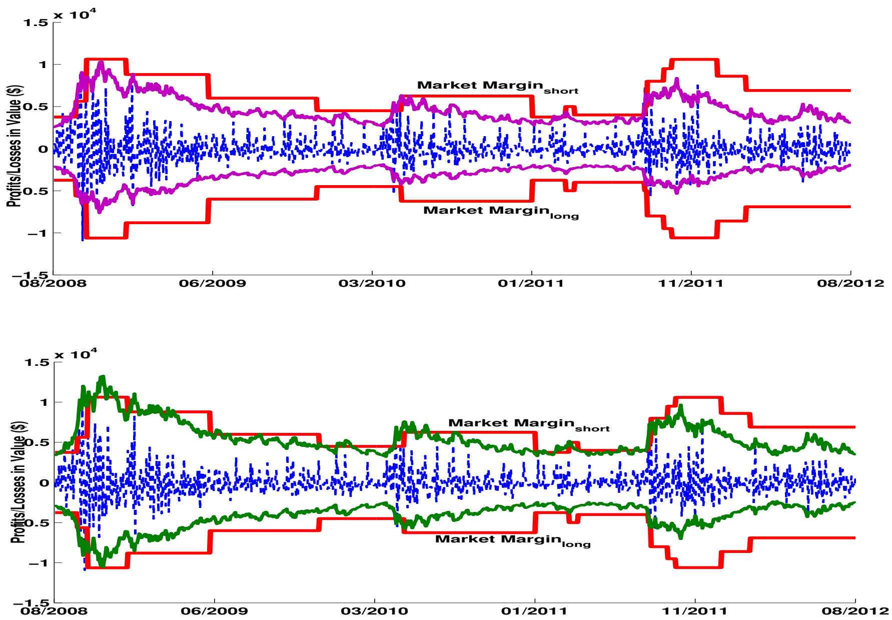

Figure 4: **Initial Margin (M) and Total Collaterals ($M+C$) for Risk Neutral Clearing Firms ($\gamma = 1.0$).** All the estimated margins and capital requirements are sought by solving Model $P1'$ (in Section 4) where the probability π is set as 1%, i.e., the confidence level equal to 99%, and a time series of the overnight US Dollar LIBOR interest rate from August 27, 2008 to August 14, 2012 is used. The solid lines show the daily margins (on the top panel) and the total collaterals (on the bottom panel), while the daily losses on a VX contract are indicated by the dotted line.

As mentioned in the literature, market margin is usually set to cover at least 99% of potential exposure to default risk. We thus set the overall probability of margin violation as $\pi = 1\%$. Figure 4 reports the estimated daily initial margin (M) and total collaterals ($M + C$) for risk-neutral clearing firms using the most up-to-date information. The top panel shows that the market margin is more expensive than the estimated margin in most cases. That is, the estimated margin for a short (long) position stays below the market margin in 99.5% (99.4%) of the sample time over four years. Even after accounting for capital requirement, the total collaterals are still lower than the market margin in 78.1% (96.7%) of the time. As a result, the cumulative capital saving of the estimated margin compared to the market margin is 30.06% for short positions and 51.81% for long positions over the sample period. After counting in capital requirement, however, the average capital saving decreases to 15.06% for short positions and 32.98% for long positions.

Moreover, Figure 5 plots the total collaterals for a short (long) position charged on the risk-averse clearing firms with $\gamma = 0.4$ against those risk-neutral firms ($\gamma = 1.0$) towards the price changes in VX contracts. This figure clearly illustrates that clearing firms' risk attitudes have a significant impact on total collaterals, particularly on capital requirement. On October 24, 2008 when the market margin reached the highest level of \$10,625 after the bankruptcy of Lehman Brothers, for example, the change in risk attitude from risk neutrality ($\gamma = 1.0$) to risk aversion ($\gamma = 0.4$) could lead to a substantial rise in the total collaterals by about 63% for a short position and by 102% for a long position.

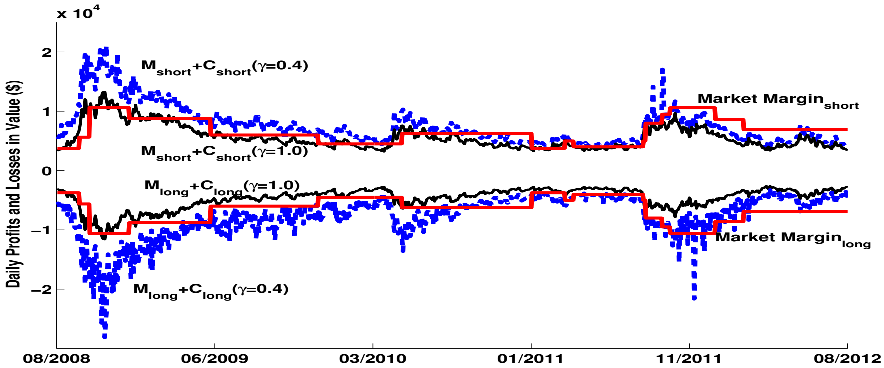

Figure 5: **Total Collaterals for Clearing Firms with Different Risk Attitudes**. The risk-aversion function is given in (9) with $\gamma = 0.4$ and $\gamma = 1.0$, and the probability π is set as 1%.

These increases are caused mainly by the manner that clearing firms form up their expectations about potential losses, because the risk-aversion function in (9) suggests that risk-averse firms would place heavy weights on high losses. Their risk attitudes thus result in the increase in capital requirement, but may have less impact on margin. Figure 5 reports that the estimated margin for a short (long) position on October 24, 2008 shifts up by just 5.1% (4.5%), while the capital requirement for either position doubles. Moreover, when clearing firms tend to be risk averse (e.g., $\gamma = 0.4$), the total collaterals for short (long) positions stay below the market margin in 32.5% (50.6%) of the sample time, compared to the percentage of 78.1% (96.7%) for those risk neutral firms (e.g., $\gamma = 1.0$) in Figure 4, suggesting that although the VX contracts may not always be self-enforcing, the risk attitudes among clearing firms have been indeed incorporated into the present margin setting system.

5.2.2 Probabilities of Margin Violation and Default

In this section, we assume the probabilities of default can be estimated by the probabilities of expected losses exceeding margin or total collaterals. They are calculated from the recorded violation events (daily losses exceed estimated initial margins or total collaterals) over 1000 business days, and are compared to the performance of the market margin. Table 1 reports the estimates of these probabilities with $\pi = 1\%$ (0.5%). When π decreases from 1% to 0.5%, the number of violation events tends to decrease by at least 50%. For $\pi = 0.5\%$, the estimated margins may lead to 1.4% margin violation that is very close to the one estimated from market margins (1.5%), suggesting the effectiveness of initial margin for managing default exposure in futures markets.

Variables	$\gamma = 1.0$		$\gamma = 0.8$		$\gamma = 0.4$	
Overall probability of margin violation in Model $P1'$ (π)	1.0%	0.5%	1.0%	0.5%	1.0%	0.5%
% of daily loss exceeding estimated margin M	2.7	1.4	2.7	1.4	2.4	1.2
% of daily loss exceeding total collaterals $M + C$	1.1	0.4	0.6	0.3	0.2	0.1
% of daily loss exceeding market margin	1.5					

Table 1: **Probabilities of Exceeding Margin and Total Collaterals.** The confidence level equals 99% (99.5%), e.g., $\pi = 1\%$ (0.5%). All the estimated margins and capital requirements are sought by solving Model $P1'$ (in Section 4). The percentage of daily loss exceeding margin (M) or total collaterals ($M + C$) is calculated by the sum of violation events divided by 1000 observations.

If clearing firms are risk-neutral ($\gamma = 1.0$), the total collaterals ($M+C$) are lower than the market margin in most cases (see the second panel in Figure 4), while the expected probabilities of default for both $\pi = 1.0\%$ and $\pi = 0.5\%$ are smaller than that estimated from market margin (see Table 1). More importantly, the funding constraints on clearing firms caused by high margins may be further relieved by capital requirement that is charged optionally. Note that in Table 1 there is no significant change in the default probability estimated from margin while clearing firms tend to be risk averse. However, the default probability estimated from total collaterals may reach the level of 0.2% (even 0.1%) when $\gamma = 0.4$ and $\pi = 1.0\%$ (0.5%). This small probability of default indicates that compared with initial margin, capital requirement may accommodate clearing firms' risk attitudes in an effective manner, and also substantially reduce the residual default probability.

5.3 Imposition and Effects of Price Limits

Although the CBOE does not impose price limits on VX contracts and so no price limit information is available on these contracts, the financial turmoil in 2008 highlights the value of this instrument. That is, when market liquidity is a major concern, it may further intensify clearing firms' risk aversion. Figure 5 demonstrates the substantial impact of clearing firms' risk attitudes on total collaterals, while Proposition 3 suggests that capital requirement could be extremely large (even be infinite) under certain circumstances where price limits may be an alternative instrument for clearinghouses to enhance market stability. Therefore, it is worthwhile to assess the truncation effect caused by price limits and understand the interaction amongst price limits, margin and capital requirement.[15]

5.3.1 Effects of Price Limit Rule

As discussed before, the truncation effect may result in the overestimation of potential exposure to default risk. In Model $P2$, a variable $\theta \in (0, 1]$ is introduced to measure the magnitude of this effect on the underlying price-generating process. The top panel in Figure 6 reports its dynamics for risk-neutral clearing firms when the price limits on VX contracts are imposed with a probability $\bar{\pi} = 1\%$. On average, the value of θ is around 0.77 on the left tail, and 0.82 on the right one during the sample period. These estimators imply that there exists a moderate truncation effect on the futures price-generating process if price limits are above the 99% quantile of the return distribution.

The bottom panel in Figure 6 reports the estimated margins (dashed lines) associated with those optimal θs (top panel). For comparison, this panel also reports those initial margins estimated by setting $\theta = 1$ (thick lines), representing no adjustment for truncation effect. In this case, it describes the special situation that the self-enforced futures contracts ensure that a clearing firm has sufficient total collaterals to cover potential losses when a price limit is breached. It suggests that price limits may reduce initial margins, yet dependent on the magnitude of truncation effect. That is, the average margin deposit is reduced by 39.93% for short positions and 32.43% for long positions, when the

[15] In contrast to our approach of assuming a price limit afterwards on a time series of price data originally without price limit, Shanker and Balakrishnan (2005) investigate price limit by filtering the price limit effect of a time series of price data originally with price limit. Both approaches have limitations in that it is a priori unclear how actual data with(without) price limits would look like.

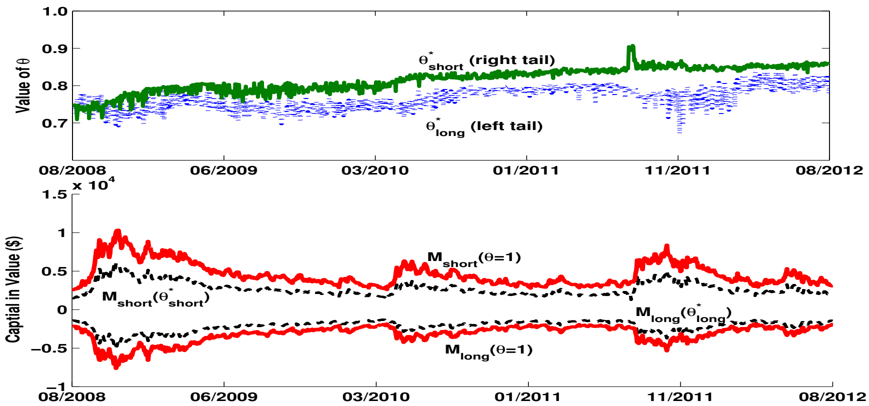

Figure 6: **Estimated Margin and Truncation Effect with Risk Neutrality**. The estimated margins are sought by solving Model $P2'$ (in Section 4) where the probability $\bar{\pi}$ is set as 1%. The top panel reports the optimal θs. The thick lines on the bottom panel present the estimated margins for $\theta = 1$, and the dashed lines indicate the estimated margins for $\theta \in (0, 1]$.

truncation effect is enforced (indicated by the decreasing value of θ). After accounting for capital requirement, price limits reduce the average total collaterals by 22.17% for short positions and 21.13% for long positions. These numbers indicate that price limits save the overall capital cost by reducing initial margin, although capital requirement may actually increase to make the futures contract self-enforcing.

5.3.2 Incorporation of Risk Attitudes among Clearing Firms

Figure 7 suggests that the truncation effect may be further reinforced when clearing firms change from risk neutrality ($\gamma = 1.0$) to risk aversion ($\gamma = 0.8$). For instance, the change of θ from 0.75 to 0.69 on the right tail of the return distribution on October 24, 2008 (when the market margin reached the highest level of $\$10,625$) indicates the intensified truncation effect of the upper price limit. The similar pattern can be observed on the left tail. Moreover, when price limits are set at above the 99% level, the values of θ on the right tail have a steady trend upward to 0.90, while the values of θ on the left tail tend to lie in the range between 0.55 and 0.85. This pattern implies that the lower limit has a persistent truncation effect on the underlying price process, which hampers price discovery, but the upper limit has relatively weak influence, which is consistent with the pattern of the right tail index ξ (tend to be negative after May 7, 2010) in Figure 3.

For those risk-neutral clearing firms, it has shown that price limits may decrease initial margin and increase capital requirement, but the total collaterals are reduced (see Figure 6). For those risk-averse firms, however, the effects of risk attitude on margin and capital

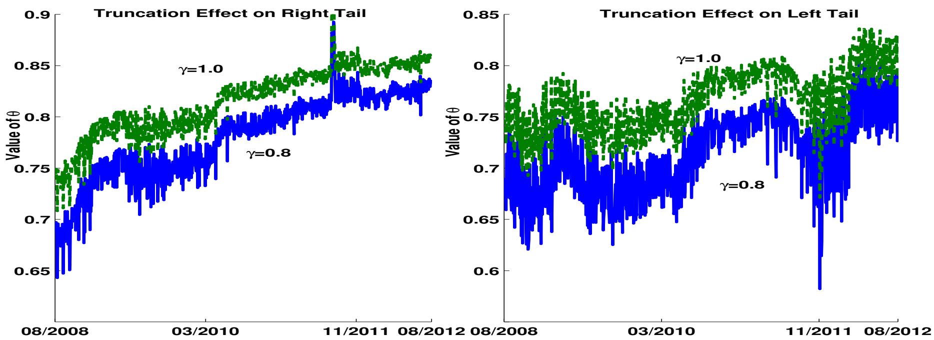

Figure 7: **Impact of Risk Aversion on Truncation Effect.** The probability of price limit being hit is bounded above by 1%, e.g. $\bar{\pi} = 1\%$. The dashed (solid) line presents the dynamics of θ with respect to $\gamma = 1.0$ (0.8) during the sample period.

requirement are mixed in the presence of price limits. As mentioned above, when the risk attitudes of clearing firms had changed from $\gamma = 1.0$ to $\gamma = 0.8$ on October 24, 2008, the truncation effects caused by price limits would be reinforced, as the value of θ declines from $\theta_\varsigma = 0.75$ to $\theta_\varsigma = 0.69$ on the right tail and from $\theta_\iota = 0.72$ to $\theta_\iota = 0.65$ on the left tail. The decreasing value of γ implies that those clearing firms may increase their expectations about potential losses, and so the capital requirement needs to be increased to mitigate default (see Figure 5), while the declining value of θ suggests that the demand for total collaterals is yet decreasing due to the truncation effect. As a result, for either $\gamma = 1.0$ or $\gamma = 0.8$, almost no impact is observed on both the initial margin and capital requirement (namely, $(M_\varsigma, C_\varsigma) = (7.99\%, 5.37\%)$ for a short position and $(M_\iota, C_\iota) = (7.26\%, 4.26\%)$ for a long position in terms of contract value). These results show that while risk aversion may increase initial margin and capital requirement, the imposition of price limits (and accordingly the truncation effect) may offset the effect caused by risk attitude shift, hence the demand for collaterals needs not to be increased. This observation spotlights the value of price limits as a cost-saving instrument to enhance market stability.

5.3.3 Probabilities of Margin Violation and Price Limit Breach

Table 2 reports the performance of initial margin and price limit in two probability scenarios (e.g., $\bar{\pi} = 1\%$ and 0.5%). In either scenario, the probability of default is expected to be zero, provided that the total collaterals are sufficient to offset expected losses, conditional on a price limit being breached. For each value of γ, we report the performance of margin and price limits for both optimal θs and a fixed $\theta(=1)$. Both panels show that the probability of price limit being breached in each scenario is relatively stable across different γs, but is almost halved if $\bar{\pi}$ decreases from 1% to 0.5%. This striking change implies that the ambiguity effect (unobservable future price changes caused by price limits, as discussed in Section 2.3) is weakened to a large extent.

Variables	$\gamma = 1.0$		$\gamma = 0.8$		$\gamma = 0.4$	
	$\theta^* \in (0, 1)$	$\theta = 1$	$\theta^* \in (0, 1)$	$\theta = 1$	$\theta^* \in (0, 1)$	$\theta = 1$
Panel I: overall probability of daily loss hitting price limits in Model $P2'$ ($\bar{\pi} = 1.0\%$)						
% of daily loss hitting price limit L	2.8	2.7	2.8	2.7	2.8	2.4
% of daily loss exceeding margin M	10.4	7.8	10.4	5.7	10.4	2.9
Panel II: overall probability of daily loss hitting price limits in Model $P2'$ ($\bar{\pi} = 0.5\%$)						
% of daily loss hitting price limit L	1.4	1.4	1.4	1.4	1.4	1.2
% of daily loss exceeding margin M	8.0	5.5	8.0	3.6	8.0	3.0
% of daily loss exceeding market margin		1.5				

Table 2: **Probabilities of Exceeding Margin and Hitting Price Limit.** Price limits are set at $\bar{\pi} = 1\%$ (0.5%). All the margins and price limits are sought by solving Model $P2'$ (in Section 4). The percentage of daily loss exceeding margin (M) or hitting price limit (L) is calculated by the total violation events divided by 1000 observations.

Table 2 suggests that for each fixed γ, initial margins decrease substantially in the presence of strong truncation effects, indicated by increasing margin violation rates over 1000 business days when θs decrease from one. However, for a fixed $\theta = 1$, indicating weak truncation effect, initial margins increase when clearing firms tend to be risk averse (γ becomes smaller), which can be seen from the decreasing margin violation percentage. For each optimal $\theta < 1$, indicating strong truncation effects, the identical margin violation rates across different γs in both scenarios can be observed in Table 2, which provides support to the preceding discussion about the offset effect caused by price limits and risk aversion on initial margin. Overall, the results suggest that when the truncation effect is relatively weak, the shift in risk attitudes among clearing firms may have significant impact on initial margin.

5.4 Further Discussion

It seems that for VX contracts initial margin is an effective instrument to prevent potential reneging in most cases, as suggested by the market margin violation rate of 1.5% in the sample. To approach this rate, a high confidence level of 99.5% is required (see Table

1). In the context where clearing firms show heterogeneous risk attitudes, however, the margin instrument is less efficient to dynamically incorporate clearing firms' sentiments towards market conditions (e.g., large price volatility). Their sentiments certainly possess significant informational content to indicate market trends (e.g., market liquidity), and cannot be covered by simply increasing the confidence level based on historical data. Moreover, the charge of high margin will lead to the concern about funding liquidity amongst clearing firms, as discussed by Brunnermeier and Pedersen (2009).

Alternatively, capital requirement as an additional fund contribution, which stems from the concept of self-enforcing contracts, may further mitigate residual default risk without requiring high margin deposits. It is set in such a way that clearing firms' risk attitudes are accommodated under two risk measures (e.g., ESs and SRMs). The results (see Table 1, Figure 4 and Figure 5) appear to suggest that capital requirement as an optional collateral deposit may help relieve the "margin spiral" effect by avoiding charging high margins. More importantly, this instrument may effectively accommodate the substantial shift in clearing firms' sentiments in extremely volatile markets. However, its effectiveness relies on not only the risk attitudes of clearing firms, but also the tail fatness of underlying futures price distribution, as shown in Proposition 3.

Furthermore, price limits are widely accepted as a partial substitute for initial margin to enhance market stability. Since in the real market there is no imposition of price limits on trading VX contracts, the empirical investigation conducted in previous sections suggests a new approach to understand the role of price limits. On the one hand, the empirical results (see Table 2 and Figure 6) suggest that price limits are helpful to reduce margins for both risk-neutral and risk-averse clearing firms (see Brennan (1986)), but the latter depends on the magnitude of truncation effect. More specifically, in the presence of strong truncation effect, the increase in margin violation indicates a decline in initial margins. But when truncation effect is relatively weak, the shift in clearing firms' risk attitudes (from risk neutrality to risk aversion) may drive up initial margins.

On the other hand, the changes in risk attitudes among clearing firms may result in the interaction effects among three market instruments. First of all, the empirical results show that the truncation effect may offset the influence of changes in clearing firms' risk attitudes on these instruments (refer to Figure 3). As a result, there is a limited impact on initial margin and capital requirement (see Figure 7), which indicates the ineffectiveness of these two market instruments in this situation and also highlights the value of price limits as a regulatory instrument. Yet, if the truncation effects are weak (e.g., $\theta = 1$), the shift from risk neutrality to risk aversion may substantially increase both initial margin and capital requirement, as reported in Table 2 and Figure 5. More importantly, there exist certain circumstances (e.g., $0 < \gamma \leq \xi$) where clearing firms are extremely sensitive to the tail fatness of the futures price distribution (e.g., $0 < \gamma < 1$ and $\xi > 0$), as suggested in Proposition 3. Under such circumstances, capital requirement would be less useful, while price limits, which may yield ambiguity effect and truncation effect, could be one alternative instrument to stabilize markets and mitigate default risk. This result provides a new explanation about the economic rationale underpinning price limits: they can be viewed as an alternative manner for clearinghouses to incorporate investors' risk aversion into the regulatory system particularly in financial turmoils in order to secure market stability.

6 Conclusions

Initial margin, capital requirement and price limits are widely used for the regulatory purposes in various futures markets across the world. In this way, clearinghouses may maintain market integrity and stability even in tough market situations. In order to strike a delicate balance between increasing futures price stability, not impairing price discovery, and facilitating futures growth, it is vital for clearinghouses to employ appropriate market instruments to improve the attractiveness of futures contracts and guarantee contract performance. This article proposes a theoretical framework to study the performance of margin, capital requirement and price limits and their interaction effects in the presence of clearing firms' risk preference. This framework is rooted in extreme value theory. By applying the concept of self-enforcing contract initiated by Brennan (1986), we incorporate clearing firms' risk attitudes into the framework so that the effects of three risk measures (e.g., VaRs, ESs and SRMs) on these market mechanisms have been investigated. In particular, the latter two risk measures present two ways to gauge potential losses in the form of capital requirement.

An empirical study has performed using the VX contract data. The results suggest that to catch up the performance of market margin, a high confidence level is required. In the absence of price limits, the shift in clearing firms' risk attitudes from risk-neutrality towards risk aversion may lead to a significant rise in capital requirement as long as initial margin is set. Although price limits may be helpful to reduce initial margins, the shift of risk attitudes may mitigate the truncation effect caused by price limits, and consequently result in a very limited impact on initial margin and capital requirement. Moreover, the numerical results on VX contracts imply that when clearing firms show extremely high risk aversion towards the tail fatness of the futures price distribution, price limits may be regarded as an alternative to stabilize markets. These results therefore lead to a number of implications for clearinghouse regulation. In future research, the correlation between the futures contract and other external information sources could be incorporated into the framework (see Poon et al (2004)).

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A Proof of Lemma 1

Lemma 1. *Let $H(R_t)$ be the cumulative function of return R at time t such that $H(R_t \leq x) = prob(R_t \leq x)$. Given assumption [A1], the following statements hold for the expectation of all the returns greater than M:*

i) $\mathbb{E}[R_t|R_t > M] = \frac{1}{\alpha}\int_{1-\alpha}^{1} x_q dq$;

ii) $\mathbb{E}[R_t|R_t > M] \geq M$;

iii) $\mathbb{E}[R_t|R_t > M]$ *is a decreasing function of* α,

where $\int_M^\infty dH(R_t) = prob(R_t > M) = \alpha$ *and* $x_q = H^{-1}(q)$.

Proof i) The expectation of return under the function H, conditional on the return greater than M, may be written as:

$$\mathbb{E}[R_t|R_t > M] = \frac{\int_M^\infty R_t dH(R_t)}{\int_M^\infty dH(R_t)} \tag{A.1}$$

Following assumption [$A1$], the continuity of the function H implies that the following relationship must hold

$$prob(R_t \leq x) = q \Rightarrow x_q = H^{-1}(q). \tag{A.2}$$

If $prob(R_t \leq M) = 1 - \alpha$, Equation (A.1) can be rewritten as

$$\mathbb{E}[R_t|R_t > M] = \frac{\int_M^\infty R_t dH(R_t)}{\int_M^\infty dH(R_t)} = \frac{\int_{1-\alpha}^{1} x_q dq}{\alpha}, \tag{A.3}$$

where $\int_M^\infty dH(R_t) = prob(R_t > M) = \alpha$ and x_q is the inverse of the function H in (A.2).

ii) We have

$$\mathbb{E}[R_t|R_t > M] - M = \frac{1}{\alpha}\int_{1-\alpha}^{1} x_q dq - x_{1-\alpha} = \frac{1}{\alpha}\int_{1-\alpha}^{1} (x_q - x_{1-\alpha})^+ dq \geq 0,$$

where $x_{1-\alpha} = H^{-1}(1-\alpha)$ and $x_q \geq x_{1-\alpha}$ for any $q \in [1-\alpha, 1]$, which implies $\mathbb{E}[R_t|R_t > M] \geq M$.

iii) We apply Leibniz' rule to the conditional expectation of return in i):

$$\begin{aligned} \frac{d}{d\alpha}(\mathbb{E}[R_t|R_t > M]) &= \frac{d}{d\alpha}\left(\frac{\int_{1-\alpha}^{1} x_q dq}{\alpha}\right) = -\frac{1}{\alpha^2}\int_{1-\alpha}^{1} x_q dq + \frac{1}{\alpha}x_{1-\alpha} \\ &= \left(-\frac{1}{\alpha}\right)\left(\frac{1}{\alpha}\int_{1-\alpha}^{1} x_q dq - x_{1-\alpha}\right) = \left(-\frac{1}{\alpha}\right)(\mathbb{E}[R_t|R_t > M] - M) \leq 0, \end{aligned} \tag{A.4}$$

where the second statement (ii) implies the inequality, which completes the proof. □

B Proof of Proposition 1

Proof From (3), a generalized Pareto distribution, $G^u_{\xi,\sigma}$, may be expressed as follows:

$$G^u_R(R_t > x) = \begin{cases} (1 + \xi\frac{x-u}{\sigma})_+^{-\frac{1}{\xi}}, & \text{if } \xi \neq 0, \\ exp(-\frac{x-u}{\sigma}), & \text{if } \xi = 0. \end{cases} \tag{B.1}$$

From (4), we further obtain the cumulative distribution of returns that are greater than the threshold u (namely, $R_t > u$) as follows:

$$\begin{aligned} prob(R_t \leq x) &= 1 - [1 - prob(R_t \leq u)][1 - G^u_R(R_t \leq x)] \\ &= 1 - prob(R_t > u)G^u(R_t > x). \end{aligned} \tag{B.2}$$

i) From $prob(R_t > M) = \alpha > 0$, we know that $prob(R_t \leq M) = 1 - \alpha$. Associated with Equation (B.1), Equation (B.2) then yields the following result:

$$M = prob^{-1}(1-\alpha) = \begin{cases} u + \frac{\sigma}{\xi}\{(\frac{\alpha}{prob(R_t>u)})^{-\xi} - 1\}, & \text{for } \xi \neq 0, \\ u - \sigma\ln(\frac{\alpha}{prob(R_t>u)}), & \text{for } \xi = 0, \end{cases} \tag{B.3}$$

for $M > u$.

ii) By applying the results above, we obtain the expression for x_q in the second statement in Lemma 1 as follows:

$$x_q = prob^{-1}(q) = \begin{cases} u + \frac{\sigma}{\xi}\{(\frac{1-q}{prob(R_t>u)})^{-\xi} - 1\}, & \text{for } \xi \neq 0, \\ u - \sigma\ln(\frac{1-q}{prob(R_t>u)}), & \text{for } \xi = 0, \end{cases}$$

for $x > M > u$. Integrating the integrator in the first statement in Lemma 1 separately yields the result:

$$\mathbb{E}[R_t|R_t > M > u] = \begin{cases} \frac{M}{1-\xi} + \frac{\sigma-u\xi}{1-\xi}, & \text{for } \xi \neq 0, \\ M + \sigma, & \text{for } \xi = 0. \end{cases}$$

□

C Proof of Proposition 2

Proof The second statement in Lemma 1 implies that

$$\begin{aligned} L_\varsigma &\leq \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma]; \\ L_\iota &\leq \mathbb{E}[-R_t|R_t \leq -L_\iota < -u_\iota]. \end{aligned} \tag{C.1}$$

Now suppose both price limits are set. We focus only on a short position by looking into the condition 6) in Model $P2$:

$$\theta_\varsigma \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma] = M_\varsigma + C_\varsigma. \tag{C.2}$$

Then the term $\theta_\varsigma \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma]$ measures the expected loss with adjustment due to the truncation effect, conditional on the upper price limit being breached, while the variable θ is used to measure the magnitude of the truncation effect and lies in the range of $(0, 1]$. When θ approaches one, it means that the truncation effect is weakened. When θ is close to zero, this truncation effect then tends to be substantial.

To make the futures contract self-enforcing, it is required that this expected loss should be covered by the total collaterals in the margin and capital accounts so that the clearing firm has less incentive to renege when the upper price limit is breached. Given the ambiguity effect caused by price limits, on the other hand, it is required that the optimal θ should satisfy the following relation:

$$\theta^*_\varsigma \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma] = L_\varsigma. \tag{C.3}$$

To see it, consider two cases. If $\theta_\varsigma \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma] > L_\varsigma$, it means that the truncation effect can be enforced by deceasing the expected loss in (C.2) so that the total capital cost can be further reduced. If $\theta_\varsigma \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma] < L_\varsigma$, however, it means that the truncation effect is weakened too much (e.g. a trading interruption) so that the total collaterals (the left term in (C.2)) is insufficient to cover the realized loss when the futures price lies between the range of $(\theta_\varsigma \mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma], L_\varsigma)$, which does not make the underlying futures contract self-enforcing. As a result, the optimal θ must take the value as follows:

$$\theta^*_\varsigma = \frac{L_\varsigma}{\mathbb{E}[R_t|R_t \geq L_\varsigma > u_\varsigma]}.$$

The similar argument can be applied to a long position, which implies that the optimal θ in this case should take the following value:

$$\theta^*_\iota = \frac{L_\iota}{\mathbb{E}[-R_t|R_t \leq -L_\iota < -u_\iota]}, \tag{C.4}$$

for a lower price limit L_ι. □

D Proof of Proposition 3

Proof Following Lemma 1, the continuity of the futures price returns (assumption $[A1]$) implies that the conditional expectation of weighted losses can be written as follows:

$$\mathbb{E}[\alpha w(q(R_t))R_t|R_t > M] = \int_{1-\alpha}^{1} w_q R_q dq = \int_{1-\alpha}^{1} \frac{\gamma}{\alpha^\gamma}(1-q)^{\gamma-1}R_q dq, \tag{D.1}$$

where $q(R)$ is a map from the sample space of R to a real value range between 0 and 1, and $w(q)$ is given in (9) with $\gamma \in (0,1)$.

The first statement in Proposition 1 has established that the expression of R_q may have two forms:

$$R_q = \begin{cases} u + \frac{\sigma}{\xi}[(\frac{1-q}{prob(R_t>u)})^{-\xi} - 1], & \text{if } \xi \neq 0, \\ u - \sigma \ln(\frac{1-q}{prob(R_t>u)}), & \text{if } \xi = 0, \end{cases} \tag{D.2}$$

Inserting the first expression of R_q into the integration above yields the following results:

$$\mathbb{E}[\alpha w(q(R_t))R_t|R_t > M] = \begin{cases} M + \frac{\sigma}{\gamma-\xi}(\frac{\alpha}{prob(R_t>u)})^{-\xi}, & \text{for } \xi \neq 0 \text{ and } \gamma - \xi > 0, \\ +\infty, & \text{for } \xi \neq 0 \text{ and } \gamma - \xi \leq 0, \end{cases} \tag{D.3}$$

where $prob(R_t > M) = \alpha$ and $M = prob^{-1}(1-\alpha)$ (which is given in Proposition 1). Similarly, the integration with the second expression of R_q may lead to the result:

$$\mathbb{E}[\alpha w(q(R_t))R_t|R_t > M] = M + \frac{\sigma}{\gamma}, \text{ for } \xi = 0, \tag{D.4}$$

which proves the first part.

When price limits are imposed, it is easy to check the following inequality, conditional on the upper price limit being breached:

$$\int_{1-\beta}^{1} \frac{\gamma}{\beta^\gamma}(1-q)^{\gamma-1}(R_q - L)dq \geq 0, \tag{D.5}$$

due to $prob(R_t \geq L) = \beta$ and $prob(R_t \leq R_q) = q \geq 1 - \beta$, which further implies that

$$\mathbb{E}[\beta w(q(R_t))R_t|R_t \geq L] \geq L. \tag{D.6}$$

Following the same arguments in Proposition 2, the self-enforcing feature of a futures contract implies that when the information about the risk attitudes of clearing firms is incorporated into Model $P2$ the optimal θ^* may be determined in a similar way as follows:

$$(\theta_\iota^*, \theta_\varsigma^*) = (\frac{L_\iota}{\mathbb{E}[\beta_\iota w(q(R_t))(-R_t)|R_t \leq -L_\iota < -u_\iota]}, \frac{L_\varsigma}{\mathbb{E}[\beta_\varsigma w(q(R_t))R_t|R_t \geq L_\varsigma > u_\varsigma]}) \tag{D.7}$$

for $0 < \theta_i^* \leq 1$ and $prob(|R_t| \geq L_i) = \beta_i$ where $i \in \{\iota, \varsigma\}$. □

E Parameter Estimation

To estimate the shape parameter ξ and scale parameter σ of a GPD in (3), we employ the approach of maximum-likelihood estimation (MLE) among a number of available methods. Hosking and Wallis (1987) shows that for $\xi > -0.5$, which corresponds to heavy tails, maximum-likelihood estimates (MLEs) are asymptotically normally distributed with regularity conditions. In order to evaluate the MLE, a threshold u must be carefully specified, and its value should be large enough so that the GPD approximation is valid.

More specifically, we use a modified Monte Carlo simulation proposed by Longin and Solnik (2001) to obtain an optimal threshold by balancing the trade-off between bias and variance. The Student t-distribution with a degree of freedom k is used to run the simulation, where k must be chosen carefully to capture the fatness of return tails precisely. The lower the degree of freedom is, the fatter the tail distribution is. Huisman et al (1989) propose a bias-corrected tail index estimator ρ based on the Hill estimator in the form of $k = 1/\rho$. We use this estimator ρ to acquire an estimator for k from a series of actual return observations.

Once the degree of freedom of a Student t-distribution has been specified, we can run the simulation as follows. We first simulate S time series containing T return observations from the Student t-distribution with a degree of freedom k, for different numbers n of return exceedances, in our case, $S = 1000$ and $T = 1112$. For the range of n, we choose from $0.05 \times T$ to $0.15 \times T$, suggesting that a range of extreme observations from 56 ($= 0.05 \times T$) to 167 ($= 0.15 \times T$) is used in the estimation process. Since the parameter ξ characterizes the distribution tails, we follow the MSE (mean square error) criterion:

$$\text{MSE}((\tilde{\xi_s})_{s=1,\cdots,S}, \xi) = (\bar{\xi} - \xi)^2 + \frac{1}{S}\sum_{s=1}^{S}(\tilde{\xi}_s - \xi)^2, \tag{E.1}$$

where $\tilde{\xi_s}$ is the tail index estimate for the sth simulation, and $\bar{\xi}$ represents the mean of S simulated observations, while ξ is related to k by $\xi = 1/k$. Jansen and De Varies (1991) show that there is a U-shaped relation between $\text{MSE}((\tilde{\xi_s})_{s=1,S}, \xi)$ and n which explains the trade-off between bias and variance. The number of return exceedances which minimizes the MSE is selected and the corresponding optimal threshold u^* can be obtained.

After specifying the optimal threshold u^* is specified, we then estimate the parameters ξ and σ based on the small numbers of observations over threshold (so-called "peaks over threshold"). Hosking and Wallis (1987) find that the biases of parameter estimators are all positive but are generally not severe for samples over 100 based on simulation results. We further apply the analytic bias-correction procedure suggested by Giles, Feng and Godwin (2011) to our estimators, but there is no significant improvement in our MLE procedure.