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Centralized Clearing for Over-the-Counter Derivatives

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Abstract

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1. Introduction

Over the course of the most recent financial crisis, the government, lacking regulatory mechanisms to deal with firms whose failure could trigger the failure of other firms through the over-the-counter (OTC) derivatives market, was forced to manage the systemic risk posed by large financial institutions on an *ad hoc* and *ex post* basis. To prevent cascading defaults, the government facilitated the sale of some large financial institutions (e.g. Bear Stearns), allowed others to declare bankruptcy (e.g., Lehman Brothers), and injected capital into many through the Troubled Asset Relief Program (TARP) (e.g., Bank of America). Even the treatment of firms that struggled after receiving payments through TARP was unpredictable; Citigroup and AIG received additional support through direct public investment while CIT received no further assistance beyond the initial support of $2.33 billion. The *ad hoc* nature of this process is unlikely to have been the most economically efficient choice except in the sense that urgency required action. These events have demonstrated the need to develop a clear regulatory framework to efficiently manage systemic risk whether posed by the OTC market or otherwise.

In August, 2008, Federal Reserve Chairman Ben Bernanke, speaking of the government bailouts in response to the financial crisis, warned that, "If no countervailing actions are taken, what would be perceived as an implicit expansion of the safety net could exacerbate the problem of 'too big to fail,' possibly resulting in excessive risk-taking and yet greater systemic risk in the future" (Bernanke, 2008). Bernanke's call for "countervailing actions" in the financial system is an explicit recognition that new public policy tools are needed to manage the underlying causes of systemic risk. Though many in the public sector are devising regulations to manage systemic risks, the focus of these activities is largely on regulation of the operational management of financial

intermediaries, rather than on developing policy instruments to directly manage the potential for propagation of default risk in the economy.[1]

In this paper we propose that systemic default risk be managed directly through the creation of a central counterparty clearing house (CCP). A CCP for OTC derivatives can be designed to decrease systemic risk by eliminating default risk between the counterparties to an OTC contract and by moderating the financial incentives to accumulate "excessive risk" in OTC markets.[2] The lack of such a CCP for OTC derivatives, particularly CDS's, has been labeled as a significant factor in the current financial crisis (Acharya, et al., 2009) and the OTC derivatives market, given its growth in recent years (Figure 1), will likely pose a larger threat to future systemic stability without a CCP.

Political leaders from around the world voiced their support for establishing an OTC derivative CCP in the initial meetings of the G-20 in London and Washington. President George W. Bush said in November, 2008, following the G-20 summit,

> How do we establish good regulatory structure without destroying the incentive to innovate, without destroying the marketplace? We agree that we need to improve our regulations and to ensure that markets, firms, and financial products are subject to proper regulation and oversight. For example, credit default swaps—financial products that ensure against potential losses—should be processed through centralized clearinghouses. (Bush, 2008)

The Executive Branch's current proposal (Treasury, 2009) for financial regulatory reform expands on this commitment, focusing on promoting the public good by managing the

[1] For example, in May, 2009, Federal Depository Insurance Corporation (FDIC) chairman Sheila Bair suggested that OTC risks could be reduced by requiring "derivative counterparties keep some 'skin in the game'" by taking a 20 percent haircut of the secured claim for firms with derivatives claims against a defaulting firm if the FDIC's resolution fund suffers a loss.

[2] This idea is not new: in 2004, Tim Geithner, then president of the Federal Reserve Bank of New York, warned the Federal Open Market Committee that the $5 trillion credit-default swap (CDS) market needed a CCP to control risk. At the time the idea of a CCP lacked support from the financial sector and derivatives continued to be traded without centralized clearing.

systemic risk posed by OTC derivatives and promoting transparency in the OTC market. This proposal calls for clearing "standardized OTC derivative transactions" and increasing "regulatory capital requirements" on non-standardized derivatives[3], though it contains no detailed plans for accomplishing these objectives. If this proposal is accepted by Congress, it is unclear how regulatory capital requirements will be set.

Though European regulators have expressed a similar desire to reform the OTC derivatives market, there have been no concrete white papers or proposals to implement centralized clearing or to establish "sufficient" capital requirements for all OTC transactions. This lack of official proposals, and abundance of *ad hoc* solutions, has resulted in confused "rules of the game" and thus increased uncertainty and risk aversion related to the OTC market.[4] Systemic risk remains opaque and regulators lack the necessary instruments to manage that risk.

The heart of the dilemma faced by policy makers in reforming the derivatives market is its size and complexity. As of June 2008, the notional value of all outstanding OTC financial contracts was in excess of $680 trillion, according to the Bank for International Settlements (2008) (Figure 1). In contrast, the value of all cleared derivatives traded by private regulated exchanges was below $20 trillion in notional value. Given the limitless variation among derivatives (i.e., underlying assets, terms and conditions, etc.) establishing capital requirements and clearing for this market has long been technologically infeasible. Only recently have technology and financial theory reached the point that centralized clearing for both vanilla and complex derivatives is possible.

The government cannot rely on the private sector alone to clear OTC derivatives, and must take an active role in creating and managing a CCP. Government backing is an essential ingredient, since it is the guarantor of last resort. Compensation to the government for providing such insurance, should be explicitly recognized by forming a

[3] Here we draw the usual distinction between standardized, or vanilla, OTC derivatives that have fixed terms and conditions and custom, or complex, OTC derivatives that have variable terms and conditions

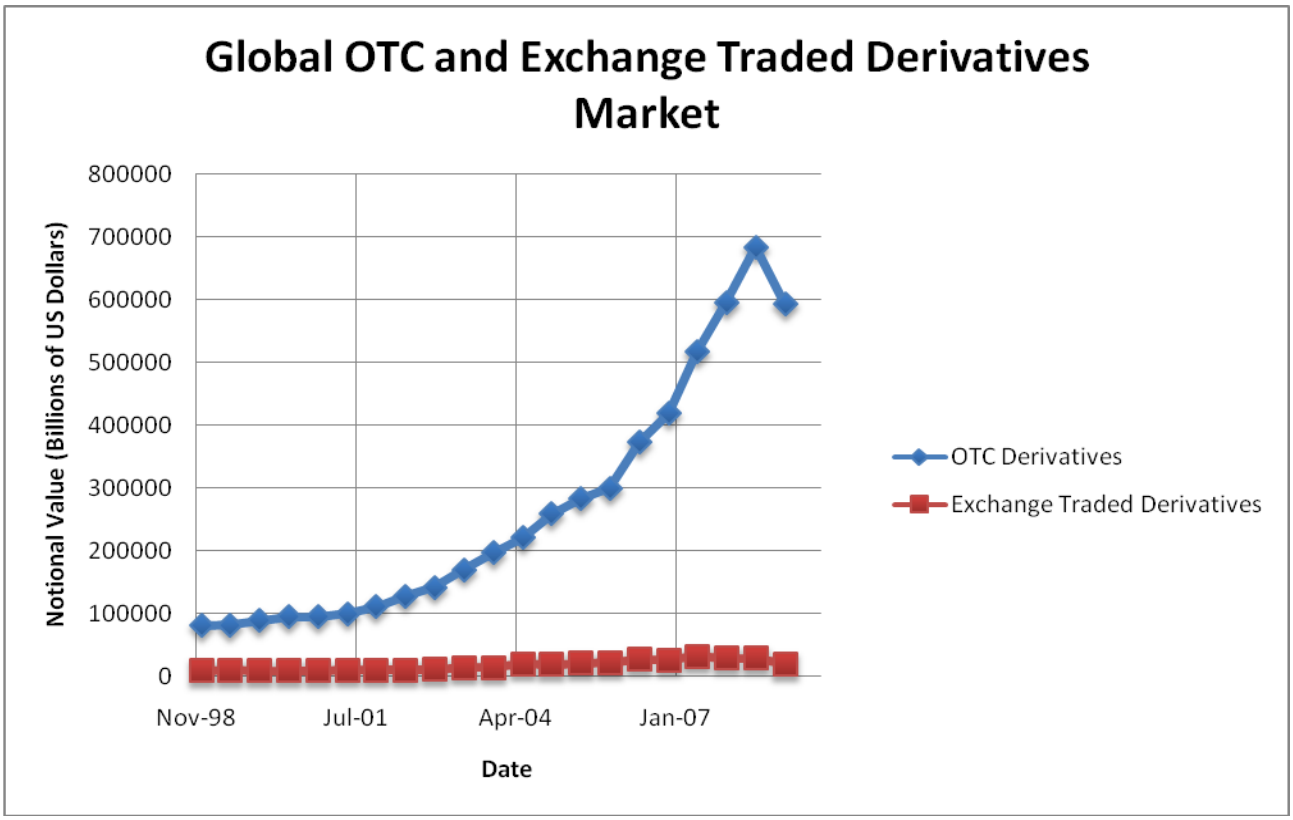
[4] Not only are the "rules of the game" unclear to market participants but also to the government regulators. For rescues of institutions deemed "too big to fail" the lack of government regulation "disclosure is striking" (WSJ, 2009).

public-private partnership. A partnership would allow the government to create a regulatory framework for managing systemic risk *ex ante* and would provide policy tools to manage that risk.[5] Since no central bank has sufficient capital to guarantee the OTC market during a systemic crisis,[6] policy makers responsible for the CCP would be given tools to discourage excessive risk taking on the part of the counterparties over the entire business cycle. The idea that central banks can exercise their lender-of-last-resort obligations *ad hoc* at the last minute is surely inadequate, resulting in an unacceptable risk of a collapse in the financial system.[7]

[5] While most economists analyze systemic risk as only a risk to be limited, in fact, there are times when private parties under invest in the face of systemic risk. During the financial crisis of late 2008, a defining aspect of the crisis was the unwillingness of any private party to invest in risky assets. The only alternative available to the government was direct investment. Our proposal, however, would conceptually allow the government to subsidize the clearing cost of OTC contracts and thus could be used both to reduce and/or to increase the incentive of private parties to invest in risky assets.

[6] Although the market value of the OTC contracts is much less than the notional value, in a cascading default crisis the guarantor could be obligated to pay the notional amounts.

[7] We view the fractional reserve financial system under such a scenario as being incapable of a fast restart, unlike physical production systems.



source: Bank for International Settlements, 2008.

Figure 1: 10-Year Growth of the Global OTC Market and Exchange Traded Derivatives Market

We advance a proposal to (1) centrally clear both standardized and complex derivatives with real-time permissioning and clearing, (2) explicitly recognize the public-private partnership structure needed to effectively manage systemic risk, (3) provide an analytical framework for centralized clearing of all OTC contracts using 2-part pricing to overcome the misalignment of public/private incentives, and (4) incorporate government policy instruments to allow the public sector to be compensated for controlling systemic risk over the business cycle. Instead of imposing excessive capital requirements suggested by government proposals, which would increase the cost of capital of trading such instruments, driving out the "good" with the "bad", our proposed framework will design a clearing solution that can accommodate all derivatives. This would allow traders

to benefit from the "good" complex contracts, and, with centralized clearing, limit the damage from the "bad" complex contracts.

2. Private Sector Clearing Initiatives

There many private sector initiatives to clear OTC derivatives and we will review the leading US and European efforts: IntercontinentalExchange (ICE), Chicago Mercantile Exchange (CME), Eurex, and Euronext. These financial institutions began clearing OTC derivatives in response to pressure from both the public and private sectors following the most recent financial crisis. The CCPs have recently opened and begun clearing a small set of OTC contracts that will slowly expand as the CCPs develop methods to standardize contracts and establish efficient margin requirements hoping to create sufficient liquidity.

2.1 Clearing in the US

IntercontinentalExchange Inc, through ICE US Trust, which is regulated by the Federal Reserve and the New York State Banking Department, has cleared over $1.3 trillion in North American CDS indexes since opening on March 9, 2009, making it the largest clearer of OTC derivatives. Currently, ICE US Trust only clears a small number of CDS indexes. Though there are plans to include more indexes and single name CDS contracts, the CCP has not announced any plans to clear bespoke OTC products[8] that lack liquidity. ICE began clearing European CDS in late July, 2009 and is also the leading clearer of European CDS. The clearing members are Bank of America/Merrill Lynch, Barclays Capital, Citi, Credit Suisse, Deutsche Bank, Goldman Sachs, JP Morgan Chase, Morgan Stanley and UBS.

ICE's largest US competitor, the Chicago Mercantile Exchange (CME) group, is a partnership between the largest US futures market and Citadel Investment Group. Though CME group has regulatory approval, its clearing and trading platform for CDS has not begun operations. The CCP plans to use Citadel's trading platform with a central order

[8] Bespoke is a term referring to OTC contracts that are customized to a buyer's specification. They may include contractual terms that reference standardized exchange-traded contracts or may be tailored to other indexes. They may include equity, debt, commodity or credit terms. Increasingly, volatility and correlation products are also available.

book for highly liquid issues. Though the CME-Citadel CCP's $7 billion fund is the largest CCP default pool, it would be insufficient to cover defaults by large financial institutions.

2.2 Clearing in Europe

In February, 2009 Europe's largest financial institutions agreed to clear most European CDS in Europe, to avoid increased regulation by the European Central Commission. The three largest exchanges serving this market are Eurex, Euronext, and ICE. Eurex, the derivatives arm of Deutsche Börse, is the world's largest options and futures exchange. Eurex Credit Clear, the institution's CDS CCP, cleared $35 million in CDS trades on its first day of operation, July 30, 2009. Eurex Credit Clear opened with 18 market participants and, to increase usage among large financial institutions, will sell as much as 90 percent of Eurex Credit Clear to banks. Eurex's clearing is limited to a several CDS indices and 17 single name CDS from the utility sector. Both ICE and Eurex are working to expand operations and capture the European CDS market

The derivatives clearing operation of Euronext, the first CCP to offer clearing services for CDS in Europe, began operating in December 2008. Despite its early entry, Euronext was unable to find any customers for their clearing services. After six months of operation without clearing any trades this CCP was put under review, seriously questioning its continued pursuit of the OTC clearing opportunity.

Though each of these financial institutions has developed a platform that will efficiently facilitate transactions for standardized OTC contracts with liquid markets, the CCP proposals are not designed to provide complete public transparency or systemic risk management for the OTC market. These CCPs lack sufficient incentives to invest optimally in transparency and systemic risk management because the benefits of managing systemic risk generated cannot be appropriated by private CCPs. By only clearing standardized, liquid contracts (i.e., CDS indices and interest rate swaps), the public will only have information on those segments of the OTC market, and the OTC market for complex, custom derivatives would remain opaque. The private CCPs also

lack the capitalization necessary to remain solvent in the face of a financial crisis with cascading defaults in the OTC markets. Without adequate capitalization, the CCPs cannot economically manage systemic risk and will be forced to rely on government assistance in the event of a systemic crisis. As a result, institutions such as CME have become another potential source of systemic risk, particularly given the rapid consolidation that has taken place over the course of the last decade.[9]

3. The Need for a Public Private Partnership Exchange

To correct the weaknesses of the private clearing initiatives, it is essential to understand the externalities associated with transparency, systemic risk management, and the facilitation of trades. Transparency is a public good, both non-rival and non-excludable, the benefits of which cannot be entirely captured by a private CCP. The CCP's management of systemic risk is an impure good. [10] Systemic risk management is non-excludable because the contracts of all systemically important firms that default must be underwritten, either by the CCP or the government, but is rival because each defaulting firm requires a separate incremental investment. Indeed, the seeds of the recent financial crisis lies in the exploitation of some large financial firms that they were "too big to fail", i.e. they could not be excluded by the government from its implicit guarantee as lender of last resort. Like transparency, the benefits of systemic risk management cannot be fully captured by a private CCP. The pure facilitation of liquid standardized trades is a private good, both rival and excludable.

Unable to capture the positive externalities associated with clearing, private CCPs under invest in the public and impure goods. Rather than creating transparency by using a platform that could clear all OTC derivatives, private initiatives restrict their efforts to clearing the profitable standardized contracts.[11] The default pools are also inadequately

[9] The systemic risk posed by consolidating clearing operations is discussed in Jones (2009).
[10] Impure goods are goods that are either nonrival or nonexcludable but not both (if both, then the good is a public good). Impure goods lie on the spectrum between public and private goods.
[11] Private CCPs have an additional disincentive to produce the socially optimal level of the public good. The largest customers of the CCPs, financial institutions, have benefited from opaque pricing when writing OTC derivatives. These institutions stand to lose their informational advantage, and the associated profits, in the OTC market from transparent derivatives prices.

funded, providing an insufficient safeguard against systemic risk. Simply creating a CCP does not guarantee transparency or systemic risk management, because the level of production for each of these goods is separately determined by the CCP and each requires a unique costly investment. The government must work in partnership with the private firm to ensure adequate investment is made to achieve the government's goals of providing transparency, ensuring sufficient capital requirements, and managing systemic risk.

3.1 Public-Private Partnership and the Assignment of Control

A public-private-partnership (PPP) can be formed to manage an OTC derivatives CCP to ensure the optimal level of the public, private, and impure goods are produced. A PPP could provide adequate capitalization and ensure transparency while maintaining incentives to facilitate trades through the assignment of control rights. The PPP literature has shown that ownership should be determined by the type of good produced and in the case of impure goods, joint management by the public and private sectors can be optimal (Grossman and Hart, 1986; Besley and Ghatak , 2001; Francesconi and Muthoo, 2006). Joint ownership, which is determined by the contractual assignment of control rights, can provide both sectors incentives to invest their resources and each sufficient control to ensure socially optimal levels of production (Appendix 1).

A public-private OTC clearing partnership is inevitable, given the systemic importance of an OTC clearing and recent public sector support for failing financial institutions to prevent cascading defaults. If, during a financial crisis, a CCP becomes insolvent, the government will be expected to act as lender of last resort. In the academic literature, models of private OTC clearing implicitly assume the government would bailout a CCP to prevent widespread default, though there is no formal public involvement or any compensation for the public sector to provide such services (Jones and Perignon, 2009).

If the partnership is explicitly recognized *ex ante* by forming a public-private CCP, the government can manage system risk over the business cycle by choosing to be compensated for the services it provides to stem systemic risk. If the partnership is

designed *ex post*, the implicit insurance provided by the public sector will only be compensated on an *ad hoc* basis. But, the point of *ex ante* management is to moderate the forces that lead to excess in advance rather than *ex post.* Beyond compensating the government and strengthening their control over systemic risk, the creation of an explicit partnership clarifies the "rules of the game" for derivatives markets and reduces uncertainty over the government's role during a financial crisis.

An additional feature of the public-private partnership we propose concerns the matter of which contracts should be traded on an exchange. The initial set of formerly OTC contracts private CCPs will clear, a small set of CDS indexes, do not go far enough to ensure a sufficiently large set of contracts.[12] Because information on the non-cleared contracts is not published, the public does not see signals from mark to market price changes in OTC contracts. The public partner could achieve transparency by inclusion of the remaining OTC contracts that would provide a market test for mark to model assets (e.g., mortgage-backed securities) that cannot be accurately priced in the current market because critical forward markets do no exist (e.g. there is no forward market for foreclosure rates). Obviously an issue arises regarding trading volume because the private partner will have no interest in listing contracts for which there is inadequate liquidity.

In general, regulations should foster low transaction costs in order to enhance the potential for liquidity in the OTC markets. In the OTC marketplace, transaction costs include negotiating costs, risk-sharing costs, technology costs, collateral costs, clearing/guarantor costs, and enforcement costs. One reason that many OTC markets have low liquidity has historically been high transaction costs. However, over the last decade, technology costs have been driven dramatically lower by the advance of electronic communication networks. This has helped fuel the growth in the OTC markets. Enforcement costs (e.g. legal impediments, bankruptcy rules, etc.) have also become lower over time. Our proposal would continue this trend by lowering the cost of clearing and guarantee services which are currently inefficiently set. Any proposed rules requiring the majority of the OTC market to be conducted using only standardized contracts would

[12] We determine sufficiency in the sense that traded contracts "span" the market. Span means that all meaningful mark-to-market valuations can be performed as an interpolation.

have the adverse consequences of increasing transaction costs and reducing liquidity for customized, non-standardized contracts.[13]

4. Microstructure of Implementing a Public-Private Clearing Partnership Exchange

To bring transparency and systemic risk management to the OTC market, a CCP must have a transaction platform to clear all economically material OTC derivatives, not just standardized, liquid contracts. The double-sided auction platform, with a per-transaction clearing fee, used by private CCPs cannot profitably clear customized derivatives or contracts with low liquidity. To profitably clear standardized as well as complex OTC derivatives, a request for quotation (RFQ) process with two-part pricing for clearing could be used. An RFQ platform allows for unlimited customization by transactors and the two-part clearing price would be used to compensate the CCP for bearing the additional risk associated with clearing illiquid contracts.

4.1 Request-for-Quote Transaction Platform

An RFQ platform allows the market, not the CCP, to determine the set of OTC contracts that will be traded and cleared. The transaction process begins on an RFQ trading platform when a subscriber creates and posts the terms to a derivative contract. For example, if a subscriber chooses to create a calendar spread on an RFQ platform, they determine the underlying, strike price, class, quantity, and buy and sell expiration dates (Figure 2). Once posted, respondents offer quotes and sizes for the contract (Figure 3), which are aggregated and disseminated to all subscribers. Because the information processors for exchange traded options (i.e., Options Clearing Corporation and Options Price Reporting Authority) take complex option structures as individual legs for clearing and reporting purposes, after a contract is agreed on at its net debit/credit price, users can

[13] These potential adverse consequences are embedded in the testimony of the Secretary of the Treasury, Timothy Geithner, who stated:

> "We also will require that regulators carefully police any attempts by market participants to use spurious customization to avoid central clearing and exchanges. In addition, we will raise capital and margin requirements for counterparties to all customized and non-centrally cleared OTC derivatives. Given their higher levels of risk, capital requirements for derivative contracts that are not centrally cleared must be set substantially above those for contracts that are centrally cleared." (Geithner, 2009)

negotiate the actual leg prices prior to final trade acceptance (Figure 4). At the end of a short RFQ period, subscribers can "Post to Block" for an RFQ they generated and move the request into the Block Trade facility to meet a second, pre-defined party and affect a cross between the best bid and offer prices[14] at the end of the associated RFQ period (Figure 5). While the parties finalize the terms of a contract, the CCP evaluates the contract's risk (Section 4.2) and sets the clearing fees (Section 4.3).

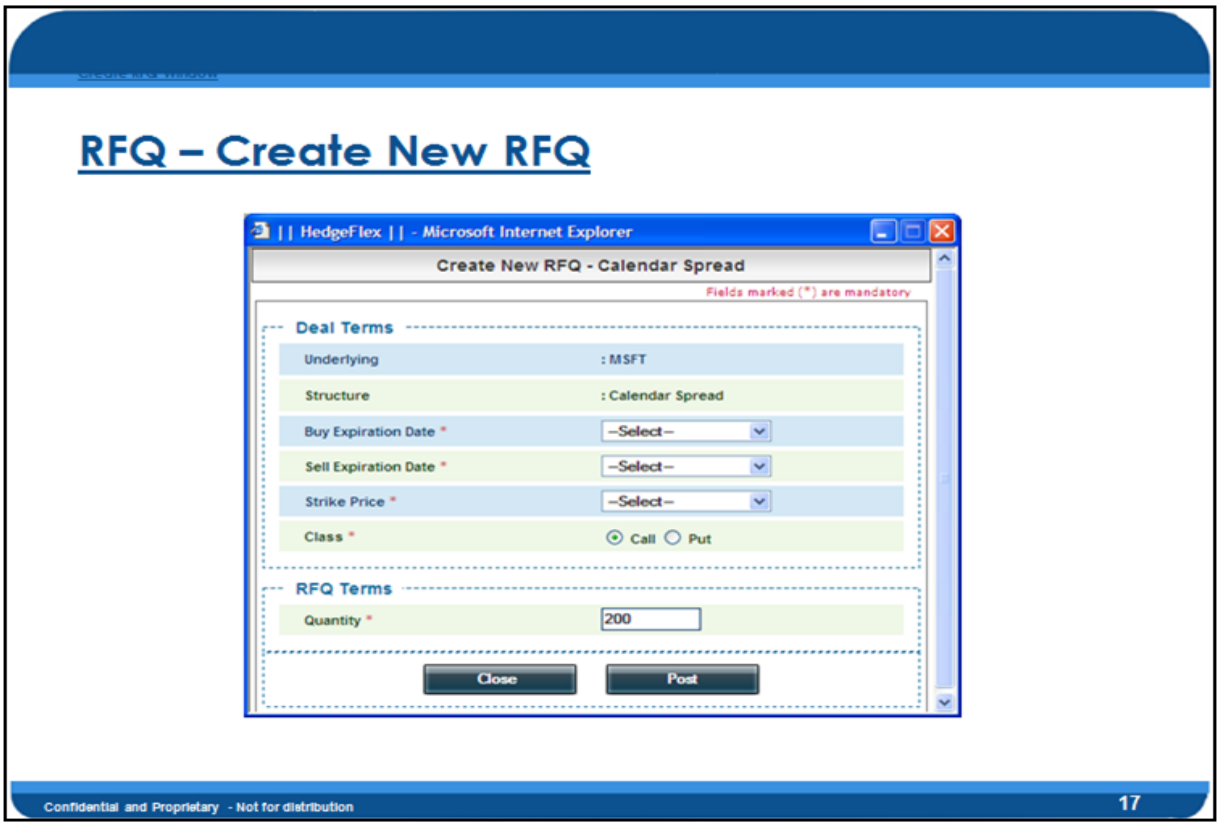


Figure 2: Creating a RFQ

[14] Best bid and offer prices are the best available ask prices, when buying contracts, and the best available bid prices, when selling contracts.

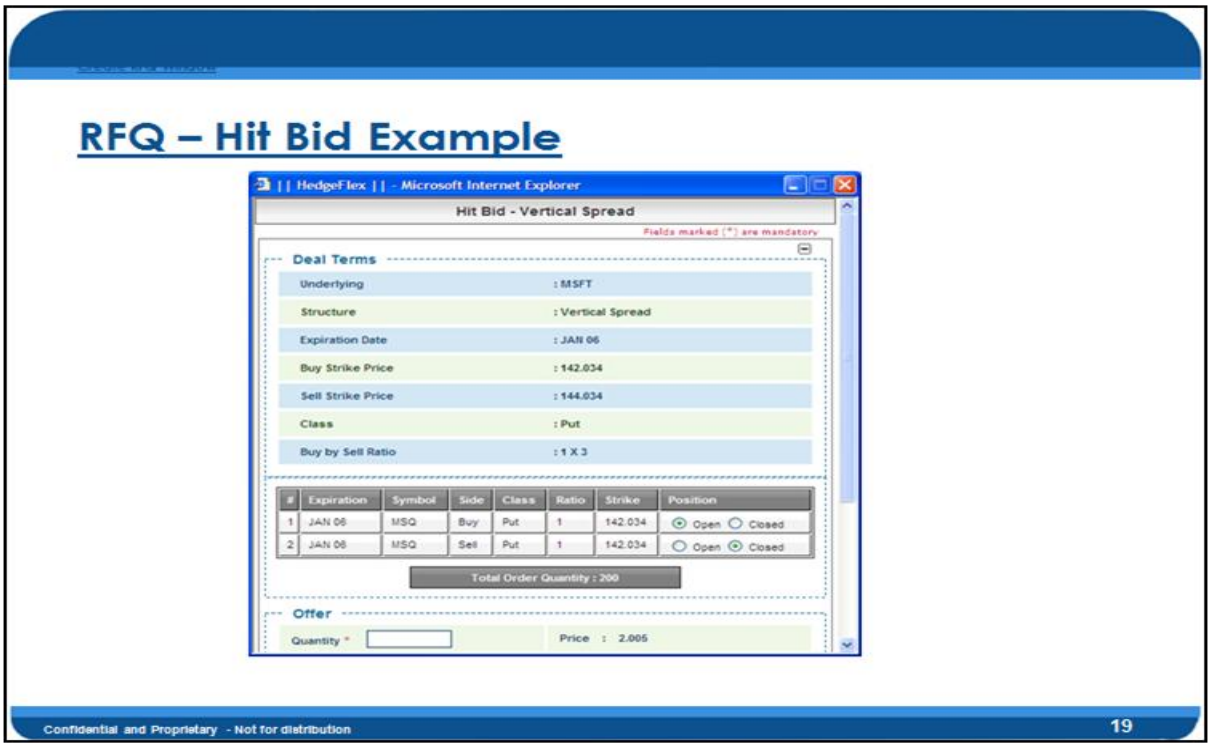


Figure 3: Bid and Negotiate

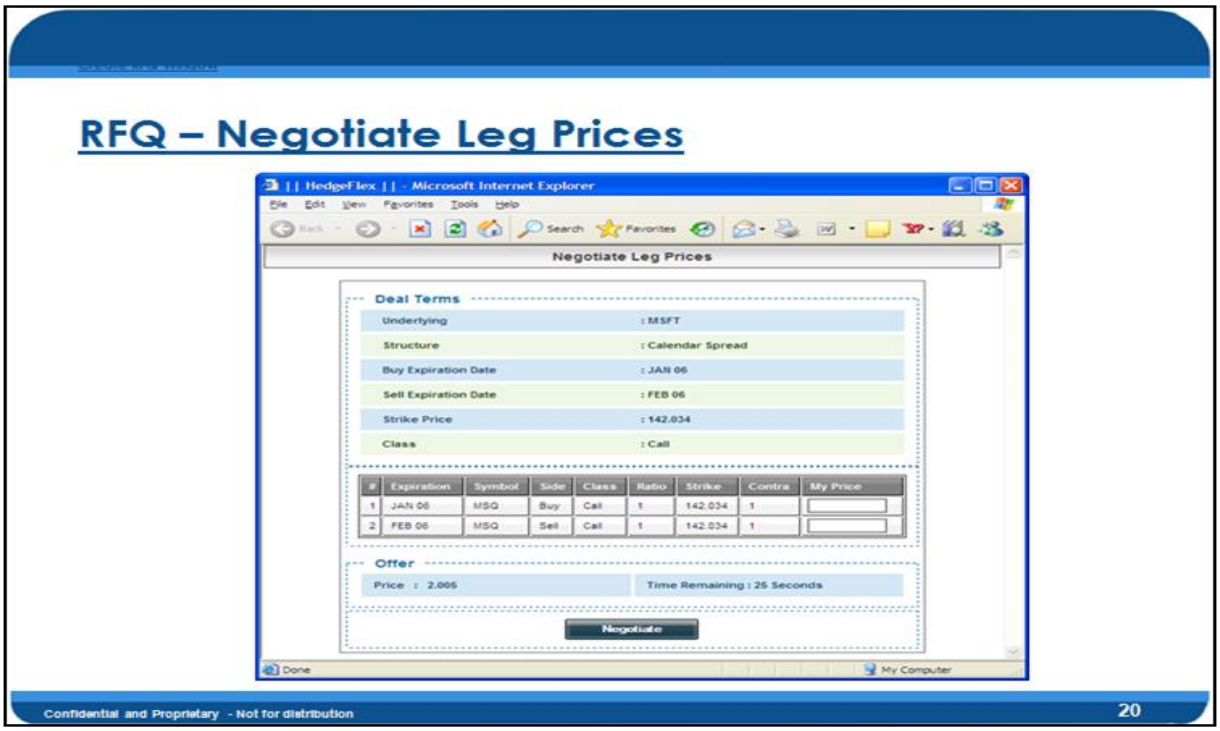


Figure 4: Negotiating Leg Prices

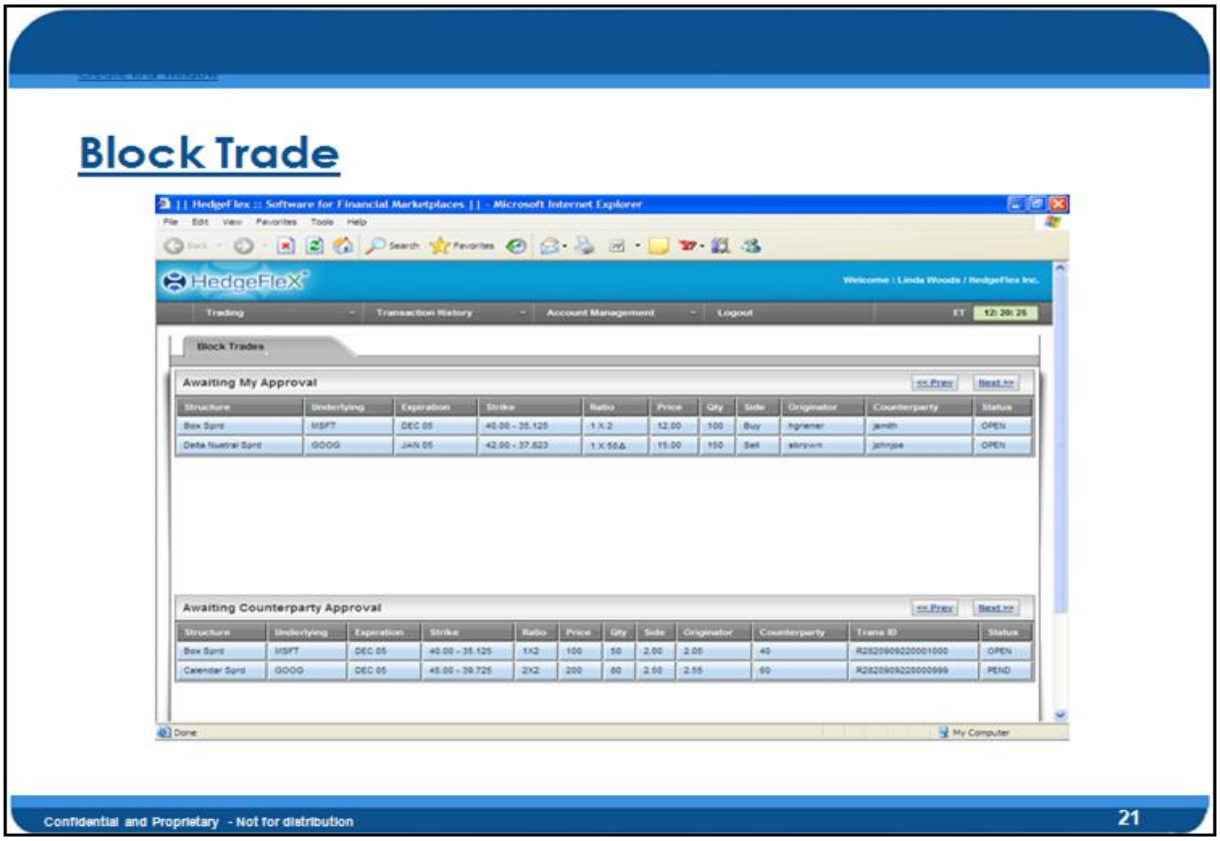


Figure 5: Block Trading on an RFQ Platform

An RFQ platform would promote transparency and systemic risk management by increasing information in the OTC market and allowing all OTC contracts to be traded and cleared. Multi-party negotiations disseminate offer data to all market participants, reducing the informational asymmetry in the OTC market by allowing all traders, not just large financial institutions, to follow derivatives pricing and purchasing trends. This aggregation and dissemination would put all market participants on equal footing, preventing large financial institutions from secretly buying and selling large positions in the OTC market (although anonymity would be preserved). And because an RFQ platform could facilitate trading for any OTC derivative, provided the counterparties will pay for the associated risk, the government could require all economically material derivatives to be cleared, removing counterparty risk from the OTC market. This would

clarify the vague requirement, found in current government proposals, to ***increase*** capital requirements for uncleared complex, non-standardized derivatives.

4.2 Centralized Clearing and Active Permissioning

From a risk management perspective, an essential difference between standardized and complex contracts is the ability to readily determine financial risk. The financial risk of a standardized position can be readily determined because the terms of the standard contract are known in advance, often with well specified underlyings. Most derivative exchanges are designed to efficiently handle large contract volumes of standardized contracts, for which financial risks are readily determined thus enabling contract execution without the need for real-time pre-trade clearing. Usually, various risk analysis methodologies are conducted to set a margin or collateral requirement on a per-contract basis for contracts whose specifications are fixed (e.g. as to the underlying, delivery quantity, delivery date, conditionalities, etc.). Margin requirements per contract can then be calculated and applied on a periodic basis and implemented post-execution. This is true in both the classic case of per-contract margining as well as portfolio margining which is determined by the overall risk of an entire portfolio of positions. The essential technology for clearing standardized contracts is pre-computing margin per contract and allowing execution of standardized contracts so long as the readily determined margin is posted by the transactor. For such contracts, clearing is little more than an arithmetic sum of positions, margins, and any net available funds.

The case of clearing complex contracts and positions has posed serious challenges for many decades for two principal reasons. First, complex contracts can embody a range from almost unlimited financial risk (e.g. correlated portfolio of short options) or in other situations little if any financial risk (i.e. fully hedged). This challenge is heightened by the introduction of innovative financial products with embedded lookback, volatility, multiple leg composite options, and correlation options which are inherently challenging to evaluate. For complex contracts or positions, pre-determining constant margins per-contract will typically result in margins that are either too high or too low since the financial risk of a position can readily change based on multiple underlying asset values

between the time of pre-computation and contract execution.[15] Second, the speed of evaluating complex portfolios taxes modern technological limits and will always be at the edge of technological feasibility. To be sure, there is a tradeoff between simplicity (speed) and accuracy in the assessment of complex portfolios although advancing technology enables increasingly rapid evaluations with increasing accuracy (Faden and Rausser, 1976; Sastri, et al., 1997). Typically, this challenge has been managed by computing the financial position risk of a complex portfolio on a daily or intraday basis, but still post-execution of any new positions.[16] The importance of speed grows ever more important as the speed of trading and market price movement increases. A single announcement by the Federal Reserve Chairman can move interest rates by a material amount in moments, and implicitly move hundreds of billions of mark-to-market valuation among accounts of financial market participants.

Even with the technological advances, pre-trade permissioning and novation guarantees of complex positions based on the *ex ante* evaluation of financial risk have proven elusive. To be useful, pre-trade permissioning must occur within a very short period of time to avoid impeding the flow of executions. Modern OTC trading can negotiate complex contracts with large shifts in financial risk within moments. This risk transfer process is an important feature of the modern financial system that allows efficient pricing of financial contracts.[17] It is obvious that an important feature of pre-trade clearing technology for OTC contracts is the rapid evaluation of financial risk within a period sufficiently short to avoid impeding contract negotiations. Sufficiently short implies sub-second evaluation of portfolios that can embody tens or hundreds of thousands of individual complex contracts.

Achieving sub-second evaluation of the value at risk for a large portfolio of complex contracts requires selecting a combination of speed and accuracy. The most accurate

[15] Moreover, a transactor will often want to maximize its capital efficiency by seeking out a position for which any fixed margin policy is underpriced. Thus, a third-party guarantor faces the risk of adverse selection.

[16] A daily time scale in most cases permits advanced Monte Carlo modeling of even the most complex positions and advancing technology can accomplish the evaluation more quickly.

[17] In this context, efficiency is measured in terms of transaction overhead cost of contract executions.

evaluation methods involve Monte Carlo simulation methods that assess the value and financial risk of a position over time for potentially millions of scenarios for hundreds of thousands of contracts. Even with advanced pre-computation "tricks" and parallel computation technology, simulation methods cannot be inserted into the execution process without an unacceptable delay in the negotiation process. Yet, Monte Carlo methods are the only accurate method of assessing financial risk in markets characterized by irregular probability distributions, rapidly changing volatility and correlation matrices, and highly non-linear payoff functions.

Sub-second evaluation of risk for very large portfolios can be achieved using analytic value at risk methods. Analytic methods are amendable to very rapid calculations and analytic approximations are available for almost all elemental derivatives[18]. Portfolios of hundreds thousands of non-linear contracts, can be evaluated in sub-second time intervals. Even for aggressive trading behavior, which could involve complex contracts with hundreds of billions in notional value trading within seconds of major events, can in principle be monitored in real time on a pre-execution basis without impeding the flow of negotiations in the OTC market.

Employing only analytic VaR methods moves too far in direction of speed, sacrificing accuracy, particularly for positions involving lookback options, volatility contracts, and correlation contracts and for markets characterized by irregular probability distributions. It is only possible to achieve both speed and accuracy in evaluating financial risk by combining analytic and Monte Carlo simulation methodologies (see Appendix 2).[19] The essential insight is to use analytic methods as an extrapolation function that is calibrated to the Monte Carlo simulations. It is common to use extrapolation methods involving splines (Miranda and Fackler, 2004), which are readily implemented. Their principle detraction is that they are chosen for analytic convenience rather than for any particular relevance they have for evaluating financial risk. In contrast, analytic methods developed

[18] By elemental we mean the irreducible lowest decomposable element of a complex contract.
[19] Patent application Balson, et. al, 2003.

in financial applications have a theoretical foundation based on limiting assumptions such as the analytic form of the distribution of price changes.[20]

It is possible to relax any restrictions on mathematical form of the distribution of price changes by treating the analytic expression as an extrapolation function with appropriate modification enabling it to be periodically calibrated to the results of Monte Carlo simulations. The method of accomplishing this integration is explained in Balson, et al (2003). The level of accuracy is largely a function of how often the Monte Carlo simulation methods are updated.[21]

4.3 Two-Part Pricing for Clearing

The advent of pre-execution clearing opens an array of possibilities for both private and public novation or government guarantees. The most efficient is a two-part pricing scheme based on Ramsey (1927), where clearing customers pay an up-front price that covers origination and a variable fee in which retained risk is priced in proportion to the market value of the daily risk. Two-part pricing, which allows collateral or margins to be tailored to market conditions, is more efficient than a one part price with, or without, variable collateral requirements, under a variety of assumptions because it allows for a risk sharing equilibrium.

A pricing structure based on a per-transaction fee and margin requirement will not allow for efficient risk sharing in the presence of market risk that varies over time. Optimal risk sharing results from financial risk being shared by all parties to a contract, but margin requirements allocate all financial risk to the trading party, with no risk sharing. Consider a derivative contract among $i = 1, \dots, n$ parties where party i has a risk-averse utility function u_i and initial wealth w_i (Pratt and Zeckhauser, 1988). Suppose this contract has market risk $\tilde{z}$ that must be borne by some subset of the parties to the contract. Wilson

[20] E.g. standard option theory imposes an assumption of log-normal price changes

[21] No matter how quickly technology advances, Monte Carlo simulation methods will always be slower than analytic methods. For example, in a future world where OTC contract negotiations occur in milliseconds due to advances in automated trading, scenario evaluations using the same underlying technology would be minutes, while analytic VaR methods could keep pace with the evolving trading platforms in terms of execution performance.

(1968) has shown that the efficient allocation of risk, $\tilde{z}$, requires $\tilde{z}$ be divided into shares, $\tilde{z}_i$, that maximize $\sum_i \lambda_i E u_i(w_i + \tilde{z}_i)$ for some $\lambda_i \geq 0$, subject to $\sum_i \tilde{z}_i$. At the solution, for each $\tilde{z}$, the values of $\lambda_i u_i'(w_i + \tilde{z}_i)$ are the same for all i. Thus the values of $u_i{}'(w_i + \tilde{z}_i)$ have the same proportions for all risks $\tilde{z}$; meaning $\frac{u_i'}{u_j'} = \frac{\lambda_j}{\lambda_i}$. The Pareto frontier can be generated by varying these proportions.

When risks are shared linearly or separately, as is the case with a per-transaction fee and collateral requirement, the most efficient allocation of risk will not be Pareto efficient. It is essential that each party's share of risk is allowed to vary non-linearly when allocating the risk associated with derivatives. For example, if a contract' underlying is a set of equities, efficiency could require that the i^{th} party's share of the appreciation of an equity also depends on the level of appreciation of all other equities, and that party's share of the k^{th} dollar of appreciation differ from that party's share of the first dollar. A two-part price with collateral requirements allows for Pareto optimal non-linear risk sharing (Wilson, 1968; Pratt and Zeckhauser, 1989; Allen and Gale, 1994).

Efficient pricing is essential to adequately produce both the public and impure goods, since constrained pricing for clearing services necessarily generates an equilibrium off the efficient frontier. Over, or under, pricing of clearing services would lead to a sub-optimal amount of risk being borne by the CCP and would distort the prices of OTC contracts. Moreover, current proposals for clearing OTC derivatives misprice their services by omitting a fee for systemic risk management.

Beyond facilitating the management of systemic risk and production of accurate price feeds, two-part pricing could provide compensation for both the public and private partners (see Appendix 3). Though per transaction fee pricing with margins compensates the CCP for origination, it does not compensate the government for the insurance it implicitly provides (Jones and Perignon, 2009). Systemic risk cannot be efficiently managed until the CCPs charge for the government's underwriting and the terms are established *ex ante*. In essence, due to systemic risk, we incorporate this impure good service provided by the government into the model.

The price of contract novation can be expressed as,[22]

$$Pr = a + b\ x(M, f, Z) \qquad (1)$$

Where *a* and *b* are parameters set by the CCP, *x* is a vector of the contract's financial risk, *f* is a vector of market price feeds, *Z* is a vector of contract positions, and *M* is the margin policy requirement.[23]

In a derivative exchange for standard contracts, the parameter *b* is set to zero as a matter of policy (since margin requirements, *M*, are set to reduce financial risk, *x*, to approximately zero). In this case, the parameter *a* is simply the standard clearing fee given a margin policy, *M*, that manages financial risk faced by the CCP. As noted above, setting *b* and *M* to eliminate financial risk is dominated by two-part pricing, a more efficient risk-sharing contract among private parties for most utility functions (Wilson, 1968). Note that the two-part pricing presumes that financial risk, *x*, can be evaluated on an *ex ante* basis so that an efficient clearing contract can be priced. In practical terms, an efficient Ramsey contract means that the novation guarantor is fully compensated on an *ex ante* basis for the financial risk it undertakes in guaranteeing a contract and the guaranteed party's capital is used efficiently.

An essential component of the financial risk of an OTC derivative is liquidity. Liquidity is important when a party to a contract defaults, and the CCP attempts to sell that position to a new party. Since standardized derivatives can be traded in liquid markets, the CCP is likely to quickly find a buyer, and transfer the risk. But for customized derivatives, with highly illiquid markets, the CCP may be unable to sell the position or capture meaningful recovery and be forced bear the position's risk for some duration of the contract. Customized contracts that are traded in illiquid markets pose a greater risk to the CCP,

[22] This non-uniform pricing schedule is based on a simple two-part tariff, $T(q) = a + bq$ (Tirole, 2004), composed of a fixed access fee, *a*, and a variable fee, *b*. Two-part pricing structures have been shown to be welfare maximizing a variety of contexts (Schamalensee, 1981; Goldman, et. al, 1984; Srinagesh, 1986). A comparison of the welfare effects of per transaction fee and two-part pricing is contained in Appendix 4.

[23] The exact functional form of *x*(*M*,*f*,*Z*) need not be specified here, except that it is a many-to-one map between the financial risk of individual markets and the financial risk of a complex position, and that the function is not guaranteed to have continuous moments. Indeed, for Regulation T margin requirements higher moments are non continuous in *Z*. i.e. the regulatory limitation on 50% leverage implies a discontinuity in the first derivative of x with respect to *Z*.

and thus would be charged a larger variable fee than standardized contracts to compensate the CCP.

The role of a public guarantor introduces a public policy dimension to performance guarantees for financial contracts. Historically, the role of policy by regulated exchanges has been limited to setting *M*. This is inefficient in a public setting, but for a different reason than its inefficiency in a private setting. The incremental inefficiency is, of course, due to systemic risk. To efficiently account for this guarantee provision, we can modify the Ramsey pricing model to introduce a public guarantee component:

$$Pr = a + b\,x(M,f,Z) + c(P)\,x(M,f,Z) \qquad (2)$$

Where $c(P)$ is a public charge for the implicit guarantee made by central banks as the lender of last resort, and *P* is the setting on current macroeconomic policy instruments. This component allows policy makers to incorporate financial reality into their macroeconomic policy instruments.

Introducing the parameter c raises both fair value and public policy issues. First, the nature of public policy in financial markets is not necessarily the same as the problem facing a private guarantor. A private guarantor faces the markets as they are, while a public novation guarantor seeks to modify perceived financial risks in order to promote economic growth. A private party must take perceived financial risks as a given for purposes of fair valuation, while the central bank or public partner can set macroeconomic policies with a view toward modifying perceived financial risks to achieve an alignment with long-term macroeconomic objectives (e.g. price stability, long-term growth).

In light of the uncertainties in setting macroeconomic policies, perceived financial risk among private parties given current macroeconomic policies should be expected to undershoot or overshoot (Dornbusch, 1976). In essence, in the process of providing novation for guarantees for financial contracts a counter cycle policy can be implemented where the public novation guarantor may set *c* high during periods of low perceived risk in order to dampen "over exuberance", but set *c* low or even negative during periods of

financial crisis. In setting novation guarantees for this one component, *c*, policy could achieve neutrality vis-à-vis public winners and losers in the market. The guarantee would apply uniformly rather than to market participants chosen on an *ad hoc* basis.

It is possible that the public partner's role in setting Ramsey pricing uniformly treats systemic risk across the business cycle, allowing the public guarantee to reinforce other macroeconomic policies. Though systemic risk is typically managed during a crisis, it could be managed across the business cycle; were it not for the "irrational exuberance" phase of the cycle, the depth of the crisis phase would likely be moderated. Two-part pricing allows the government to actively moderate the formation of asset price bubbles and limit the effects of the inevitable burst on the derivatives market.

When viewed as a potential component of macroeconomic policy, the question arises as to whether interest rate policies alone are sufficient. Increasingly, private financial parties are just as concerned about their economic capital as their cash capital. Economic capital recognizes that contracts which shift risk represent a form of capital. Recently, some financial institutions have begun to charge corporations an interest rate on debt that is a function of that firm's CDS price. This practice reflects the concept that an interest rate alone does not fully price the shifting risks inherent in some securities. It is likely that the trend in financial markets will be away from simple cash oriented securities and toward more complex securities that embed optionality shifting with mechanisms compensated by fixed or variable interest rates. Macroeconomic policies that cannot directly manage the shifting of financial risk may miss the most important components of systemic risk as well as the "exuberance" phase of the cycle.

4.4 Novation vs. Guarantees

In the microstructure for the proposed public-private CCP, a critical question arises in regard to whether novation or a third party guarantee for contracts are provided in case of default. Novation has become the financial guarantee of choice in regulated contract markets (Williams 2001). Novation means, literally, the remaking of the contract so that each original obligor (i.e., the parties to the derivatives contract) is entirely removed and

is directly replaced by novator (i.e., the CCP). Though each party is replaced in the remade contract by the CCP, the contract has the same terms and conditions as the original contract. At the time of settlement or default, all enforcement and collection actions are taken directly against the novator and there are no direct transfers between counterparties. Because the CCP becomes a direct counterparty to each side of the trade, once novation occurs, the credit worthiness of the original counterparties is irrelevant to each trader as the traders only have a contractual obligation to the CCP. Novation completely isolates each party from the effects of a default by its counterparty, and indeed the counterparties may be anonymous.

Unlike novation, a guarantee is a contingent, secondary form of obligation that supplements, but does not replace, the original obligor. A CCP that only provides a third-party guarantee is only involved if one or more parties default. In case of default, demand must be made on the original obligator first, and that obligator must fail to perform before the CCP can be obligated to fulfill the contract. The CCP would typically only partially fulfill the contract and a haircut would be expected to be applied to the payments to each counterparty. A guarantee does not isolate the parties from the effects of a default by a counterparty, but it does cap the losses of each party.

An additional difference between novation and guarantees is the level of anonymity among traders. Novation allows for complete anonymity between trading parties and permits the CCP to set universal standards for determining credit worthiness. Since guarantees place much of the burden of determining creditworthiness on the trading parties, there can be no anonymity. Anonymity combined with an elimination of counterparty credit risk between buyers and sellers is largely responsible for the rapid growth in the volume of standardized financial contracts over the past 30 years. This growth has produced substantial benefits to the economy by making prices of financial products public information.

The choice between novation and guarantee determines the degree of active involvement by the public sector. A CCP that selects novation for all OTC transactions would require regular, direct involvement of the public sector in active management of the partnership.

The partnership would determine the credit standards for participation in the OTC trades and the government would be compensated for all systemic risk insurance. If a CCP only provides guarantees for OTC derivatives the government would be involved when defaults exceed the CCP's capital.[24] Clearly, the PPP must make a determination of whether they will implement for the microstructure a novation or third-party guarantee process.

4.5 Exchange External Reporting

Periodic reporting for OTC derivatives is conducted today under the Basel framework, but is largely on an *ex post* basis and is self-reporting with regulatory oversight. In principal, the majority of such contracts could be subsumed in the electronic exchange we propose. This could be captured by an electronic submission that reports execution of contracts traded outside the exchange. Regulatory requirements would need to be developed that specify the types of firms subject to such reporting, the types of contracts requiring reporting, and the speed at which the reporting would be conducted. At a minimum, systemically large firms should report substantially all of their capital structure continuously so the public clearing component could be based on full knowledge of the financial risks.

A critical microstructure design issue is the determination of the price of risk, the second component of (1). The CCP will only have a lens on the portfolio of contracts held on the PPP exchange. If large offsetting positions are held off the exchange and unknown to the CCP, the price of risk will be distorted. For the systemic risk component, the third term of (3), the current treasury proposal suggests that at least large financial institutions should face mandatory requirements to report all OTC derivatives on a periodic basis (Treasury, 2009). Such external mandatory reporting will provide the CCP some visibility into the net notional exposure but will not allow mark-to-market measures of the price of risk for each of the counterparties or transactors.

[24] Jones and Perignon (2009) discuss the effects of a CCP that provides a guarantee with no explicit government involvement on systemic risk management.

An alternative microstructure is to also allow voluntary reporting for any transactor in addition to periodic reporting for the large, systemic risk sourced financial institutions. Clearly, as the price of risk for that portion of portfolio on the CCP platform for a particular counterparty begins to rise there will be incentives for that transactor to post additional collateral. This voluntary conduct will be in the self-interest of a transactor if their overall portfolio includes offsetting positions or hedged transactions. The posting of such exposures will lower the clearing fees, depending of course on the counterparty credit risk associated with any posted external transactions.

5. Conclusion

A crucial lesson from the current financial crisis is the need for regulatory certainty. Consider the case of Lehman Brothers: given the government intervention in the sale of Bear Stearns, most assumed the government would actively prevent bankruptcy by Lehman. The unexpected bankruptcy, with debts listed at $613 billion at time of filing, triggered a worldwide panic in equity markets and near catastrophic tightening of credit markets. When market participants are unable to anticipate the reaction of the government, the failure of a single firm can be amplified throughout the global economy, causing massive losses in the economy that exceed the value of the firm by orders of magnitude. Only when the "rules of the game" are known beforehand by all market participants can the effects of financial instability be dampened. The creation of a CCP is essential to establish *ex ante* the rules for the OTC derivatives markets.

A government-private partnership engaged in providing clearing services for OTC derivative markets is feasible and does not require a technology leap. We have argued here that one dimension of the technology leap is enabled by the technological innovation of real-time permissioning and novation or guaranteeing of OTC financial contracts. Equally necessary is the real-time monitoring by the centralized clearing organization during the negotiation of OTC financial contracts. This requires that all derivative

exchanges and dealer networks be integrated into a cohesive uniform communication and permissioning network using FIX software communication protocol routines[25].

Due to macroeconomic and psychological risk factors, there is likely to always be a cycle of perceived financial risk in most markets. In recent history we have witnessed extremely low levels of perceived risk (e.g. 2006) and extremely high levels of perceived risk (e.g. 2008/9). Public policy can counter that cycle and most governments and central banks proactively use a variety of financial tools to moderate excesses in both directions (e.g. monetary and fiscal policies).

The motivation for our proposed public-private partnership is no less than the survival of the financially interdependent world that has been created over the last twenty years. Increasingly sophisticated financial market participants have learned how to maximize the value they extract from the implicit guarantees provided by the world's central banks or "lenders of last resort". In the most recent financial crisis, exercising that guarantee has pressed the financial capacity of the global economy to an extreme not previously witnessed even in the Great Depression. The benefits of the past year's *ex post* and haphazard intervention have been concentrated among financial market participants who exploited the under priced guarantee creating a system that is fraught with moral hazard. The next cycle can only be more extreme as a consequence and a continued failure to allocate the costs and benefits of the implicit, *ad hoc* public guarantee could well continue to generate periodic catastrophic results.

It is our view that regulations that inhibit financial innovation are not the answer, whether those regulations restrict specific forms of contracts or restrict the allocation of economic rents among the producers of financial products (e.g. executive compensation and fee sharing). Such restrictions reduce economic efficiency and thus retard economic growth. Our proposal enables the public sector to be actively engaged in managing financial risk over the business cycle that is potentially uniform, agnostic to winners/losers, efficient, and mutually reinforcing with other macroeconomic policies.

[25] FIX stands for the Financial Information Exchange Protocol, which is an industry supported standard for electronic communication of information about financial contracts. It was first developed in 1992, is currently in Version 5.0, and is supported by most large participants in financial markets.

Appendix 1. Control Rights in a Public-Private Partnership

Our framework for assigning control rights in a PPP is sourced with the incomplete contracting literature (Hart and Moore 1988; Hart and Moore, 1999).[26] In this literature, a control right is the authority to make a decision with respect to both anticipated events and events that are not foreseen in the contract. The allocation of control rights can determine whether a partnership will operate efficiently.

In the case of a partnership that produces a pure private good (i.e., the facilitation of transactions), the partners have an incentive to underinvest because the benefits from their investment can be lost in *ex post* renegotiation (Grossman and Hart 1986). Grossman and Hart (1986) used a two-period model with two firms. In the first period, the firms create a contract that allocates control rights and each firm makes relationship-specific investments, (a_1, a_2). In the second period, each partner makes production decisions, (c_1, c_2), based on the control rights assigned in the contract, which determine the partnership value for partners 1 and 2, $B_1(a_1, c_1, c_2)$ and $B_2(a_2, c_1, c_2)$. Both the investments and the decisions are uncontractible in period 1, but once the decisions are made, each partner is presumed to have equivalent information about their values.

In the first period, the firms make the relationship-specific investments noncooperatively. After these investments are observed, the second period begins and the control rights, which were allocated by the first-period contract, are exercised. These decisions can be made noncooperatively or cooperatively, through costless renegotiation, because the choice of c becomes contractible in period 2. It is unlikely that the noncooperative

[26] A contract is incomplete in the sense that there is a set of events, that can influence the partnership, that have not been enumerated in the contract.

equilibrium decisions, $(\hat{c}_1, \hat{c}_2)$, will maximize the partnership's value, so the firms can benefit from renegotiation in period 2, after observing the investment decisions from period 1, which are chosen in anticipation of the renegotiation, and create a contract specifying the optimal c_1 and c_2. Grossman and Hart (1986) assumed the firms divide the surplus from the joint venture symmetrically. This outcome will generally be inefficient as both firms underinvest and do not maximize the *ex ante* value of the partnership.

If one firm's first-period investment has a larger effect on the partnership's value than the other firms, the contract should assign the firm with the more valuable investment full control over decision making in the second period.[27] Under this circumstance, the allocation of control in the first period provides the firm with the most valuable investment an incentive to invest optimally. When the firm whose investment has a larger impact on the partnership's value invests optimally, the partnership's value is maximized. Thus, underinvestment can be mitigated, in a joint venture that produces a private good, if the contract assigns agents control rights to assets on which their production is dependent. In a public-private CCP, this would mean the private partner, who has the resources and experience to make the most valuable investment, would be given the control rights over the facilitation of transactions.

Besley and Ghatak (2001) extended the incomplete contracting framework to a partnership that produces a public good. In their model, two agents, n and g, make relationship specific investments, a_n, a_g, that increase the nonrival and nonexcludable benefits generated by a project, $B(a_n, a_g)$. Each agent's valuation parameter, θ_i, determines his or her respective payoffs: g's payoff is $\theta_g B(a_n, a_g) - a_g$ and n's payoff is $\theta_n B(a_n, a_g) - a_n$. The first-best levels of investment, which maximize the joint payoff $(\theta_g + \theta_n)B(a_n, a_g) - a_g - a_n$, are generally not reached because the investments are not contractible and each agent will posses bargaining power once the investments are

[27] Under this circumstance, the allocation of control in the first period provides the firm with the most valuable investment an incentive to invest optimally. When the firm whose investment has a larger impact on the partnership's value invests optimally, the partnership's value is maximized. Thus underinvestment can be mitigated, in a joint venture that produces a private good, if the contract assigns agents control rights to assets on which their production is dependent.

sunk. If the parties engage in *ex post* Nash bargaining, with a symmetric split of the surplus, the *ex ante* investment decisions will not be optimal because the partners will receive only a fraction of the social benefit generated by their investment.

Besley and Ghatak (2001) demonstrated that the project's joint surplus will be maximized by allocating all control rights to the partner that assigns the highest monetary value to the project. The partner with the highest valuation has the incentive to invest optimally and this assignment of authority allows that partner to do so. Thus, when a public good is produced by a partnership, the agent's valuation of the output generated, and not the relative value of their investment, should determine the allocation of control rights. In a public-private CCP the public partner, who values transparency most, would be given control over the production of the public good.

Most of the control rights literature has focused on the optimal allocation of control rights when producing either a private good or a public good, and though we can glean useful lessons, it does not provide a complete framework to evaluate PPPs that produce impure goods such as systemic risk management. For such goods, Francesconi and Muthoo (2006) developed a framework for allocating control rights in PPPs. Initially, two agents, g and n, divide the control rights between themselves. The partner g holds a share $c \epsilon [0,1]$ of the control rights, and the remaining $(1-c)$ of the control rights are held by the partner n. After the control rights are allocated, g and n invest $a_g, a_n \geq 0$, respectively, in the project. Once the investments are made, the partners can make decisions either unilaterally or jointly through cooperative bargaining. If the partners do not cooperate, the project's value will be $B(c, a_g, a_n)$; if they cooperate, the value will be $b(c, a_g, a_n)$, where $b(c, a_g, a_n) > B(c, a_g, a_n)$. The noncooperative project value, $B(c, a_g, a_n)$, is assumed to be a linear function of control rights: $B(c, a_g, a_n) = cB^g(c, a_g, a_n) + (1-c)B^n(c, a_g, a_n)$, where $B^i(c, a_g, a_n)$ is the project's value for partner i when i has sole decision-making authority.

The players bargain over whether the decisions are to be made cooperatively or noncooperatively and what, if any, transfers there will be from g to n or n to g. If g and n cooperate, their payoffs are $\theta_g b(a_n, a_g) + t$ and $\theta_n b(a_n, a_g) - t$, respectively, where the valuation parameters, θ_n and θ_g, determine each partner's valuation of the project, and t is a monetary transfer from n to g, which can be positive or negative. But if the partners choose to make decisions noncooperatively, the payoffs are $\theta_g[cB^g(a_g, a_n) + (1-\alpha)(1-c)B^n(a_g, a_n)]$ and $\theta_n[(1-\alpha)cB^g(a_g, a_n) + (1-c)B^n(a_g, a_n)]$, respectively, where the impurity of the good produced by the project is measured by the parameter $\alpha \epsilon [0,1]$. The α parameter allows this framework to be extended to PPPs that produce any good on the spectrum between pure private goods and pure public goods.

If the partnership produces a pure private good $(\alpha = 1)$ or a pure public good $(\alpha = 0)$, the model yields the results from Grossman and Hart (1986), Hart and Moore (1990), or Besley and Ghatak (2001). However, if the PPP produces an impure good, $\alpha \epsilon (0,1)$ and each partner invests, one partner should have sole authority. The allocation of authority depends on the valuations and size of the investment. For a public-private CCP, optimal systemic risk management would result from assigning the public partner the control rights.

Appendix 2: Analytical Integration with Monte Carlo Simulations

The Purpose of this appendix is to illustrate how conventional Value at risk (VaR) methodology can be combined with Monte Carlo simulation methodology to implement real-time OTC contract permissioning. As shown in the academic literature (Gregory and Reeves, 2008), Value at risk for a portfolio is a one-sided confidence interval on portfolio losses and may be defined mathematically as:

$$Pr[\Delta V_A(T^{Var}, \Delta\tilde{x}) \geq -VaR_A] = 1 - \alpha \qquad (3)$$

where *PR* denotes probability, T^{Var} is the risk horizon of interest, VaR_A is the value at risk for portfolio *A*, α is the level of confidence, $\tilde{x}$ is a vector of random state variables, $\Delta\tilde{x}$ denotes changes in the random state variables, V_A is the value of a portfolio of deal elements, ΔV_A denotes the change in the value of portfolio *A*, *A* is the portfolio of deal elements of interest, and a is a deal element in portfolio *A*.

This formulation is applicable to any portfolio, any set of state variables, and any process governing the stochastic evolution of the value of the portfolio. It is common in the literature to restrict the nature of deal elements in the portfolio, the nature of the state variables, and the nature of the stochastic price process that governs changes in the value of the portfolio in order to create tractable analytical structures. The portfolio may include deal elements that are securities, equities, bonds, options, futures, derivatives, or other assets. The state variables may be prices on deal elements, events that affect prices, external events, credit ratings, or other risk factors. The price process may be a named stochastic process or may have jumps, reversion, non-Markovian state evolution, stochastic volatility, discontinuities, or other features.

Equation (3) can be rewritten as

$$\int_{-\infty}^{VaR_A^*} \Pr[V_A(T^{Var}, \tilde{x})]\, d\tilde{x} = 1 - \alpha \qquad (4)$$

The symbol VaR_A^* denotes the result of calculating value at risk by using the most appropriate available methods and technology where computational speed is not required. To be explicit about the dependence of VaR_A^*, it may be written as $VaR_A^*(\Delta V_A(T^{Var}, \Delta\tilde{x}), \alpha)$ to emphasize that value at risk is taken with respect to a specific confidence level α, a specific time horizon T^{Var}, and a specific valuation methodology ΔV_A. VaR_A^* in practice is approximated using combinations of simulation, decision tree, historical, or parametric methods. For many portfolios of interest, accurate estimation of VaR_A^* requires very large Monte Carlo simulations, and when early exercise of options is considered a stochastic dynamic programming approach. Because evaluating ΔV_A is computationally expensive, parametric methods are often utilized to achieve approximate results more rapidly. In the literature, many of the practical applications for computing value at risk rely on parametric methods.

In one parametric method, the mathematical form of the distribution on V_A is restricted by assuming that V_A has derivatives with respect to each argument, that the state variables are the prices of the deal elements, and that the periodic changes in value of V_A with respect to each argument are jointly normally distributed with mean zero. This is called the delta-normal method, which will be denote by VaR'. The value of the contract, given the assumptions, will be called V_A'. The parametric approach assumes $V_A' \approx V_A$. VaR' can be expressed as,

$$VaR' = -\Theta_A T^{Var} + Z(\alpha)\sqrt{g^T \Sigma g} \qquad (5)$$

where g is a vector of $\frac{\delta V_A}{\delta \tilde{x}_i}$ for all x_i, g^T is the transpose of g, $Z(\alpha)$ is the α^{th} percentile of the standard unit normal distribution, Σ is the covariance matrix for the joint normal distribution on returns to $\tilde{x}$, and Θ_A is the derivative of V_A with respect to time $\frac{\delta V_A}{\delta T}$

Other preferred embodiments may utilize a more appropriate parametric method than presented in equation (5); however, the present invention will be explained with respect to (5) for purposes of clarity.

It is observed that there are many methods of computing value at risk, and among them are VaR_A^*, which is intended to produce an accurate estimate of value at risk, and VaR_A', which is intended to be computationally fast. Other parametric forms could be used. For example, in applications referred to as extreme value theory, the parametric VaR will use a formula that is only intended to approximate the tail of the distribution since that is the region of most interest.

The method applies this observation to insert control variables $\tilde{C}$ into the standard parametric VaR equations in a manner such that the parametric equations result in a closer approximation to VaR_A^*. The new estimate of value is called a risk position risk PR_A' to emphasize its modification from the standard form and may be written as:

$$VaR_A^*(T^{Var}, \Delta\tilde{x}, \alpha) \approx PR_A'(T^{Var}, \Delta\tilde{x}, \alpha, \tilde{C}) \tag{6}$$

and solved for the control variables $\tilde{C}$ that minimize the difference as in equation (5)

$$\tilde{C} = argmin_{\tilde{C}}\left\{\left|PR_A'\left(T^{Var}, \Delta\tilde{x}, \alpha, \tilde{C}\right) - VaR_A^*(T^{Var}, \Delta\tilde{x}, \alpha)\right|\right\} \tag{7}$$

or some other method may be used for choosing the control variables $\tilde{C}$. For example, a maximum likelihood estimate could be used, or changes could be minimized to the control variables over time.

To further illustrate the approach, equation (5) is modified with several sets of control variables C_1, C_2 and a vector $\tilde{C}$ that are multiplicative factors applied to $\Theta_A, Z(\alpha)$ and Σ to produce

$$PR_A' = -C_1\Theta_A T^{Var} + C_2 Z(\alpha)\sqrt{g^T \Sigma \tilde{c} g} \tag{8}$$

The purpose of these control variables is to adjust the result of the parametric estimate of value at risk so as to better approximate the result of VaR_A^*. Other parametric forms would have control variables appropriate to the particular parametric formulation. A specific embodiment uses a version of parametric value at risk will be referred to as PR_A^P. The control variables can be chosen with the viewpoint that VaR_A^* can generally be computed within a 24-hour period, while PR_A^P is generally constrained to tight time limits in order to support a rapid throughput of processing transactions. The calculation of PR_A^P is performed by the real-time position risk system, while calculation of VaR_A^* is performed by a simulation-based position risk supervision system. The essential feature of the combined systems is that PR_A^P is calculated in real time, while VaR_A^* is calculated periodically.

Appendix 3: The Value Proposition of Centralized Clearing

Consider novation of an OTC equity contract between two counterparties, *A* and *B*. Party *A* believes large value caps will outperform growth and enters a $100 million contract that is long the Dow Jones Industrial index (DJI), long the Standard and Poor 500 index (OEX), and short the NASDAQ 100 index (NDX). Party *B*, believing growth will outperform large value caps, enters a $100 million contract that is short DJI, short OEX, and long NDX. Both parties post collateral of $50 million reflecting a 2:1 leverage ratio, with the remainder being a loan against the position. The duration of the contract is two years. Novation is used to insulate both parties from counterparty credit risk, but not from market price exposure. Figure 6 shows the indexes variation over the period March 25, 2007 to March 24, 2008 expressed in terms of cumulative price change over the period (the charts show daily closing price for each trading period during this period).

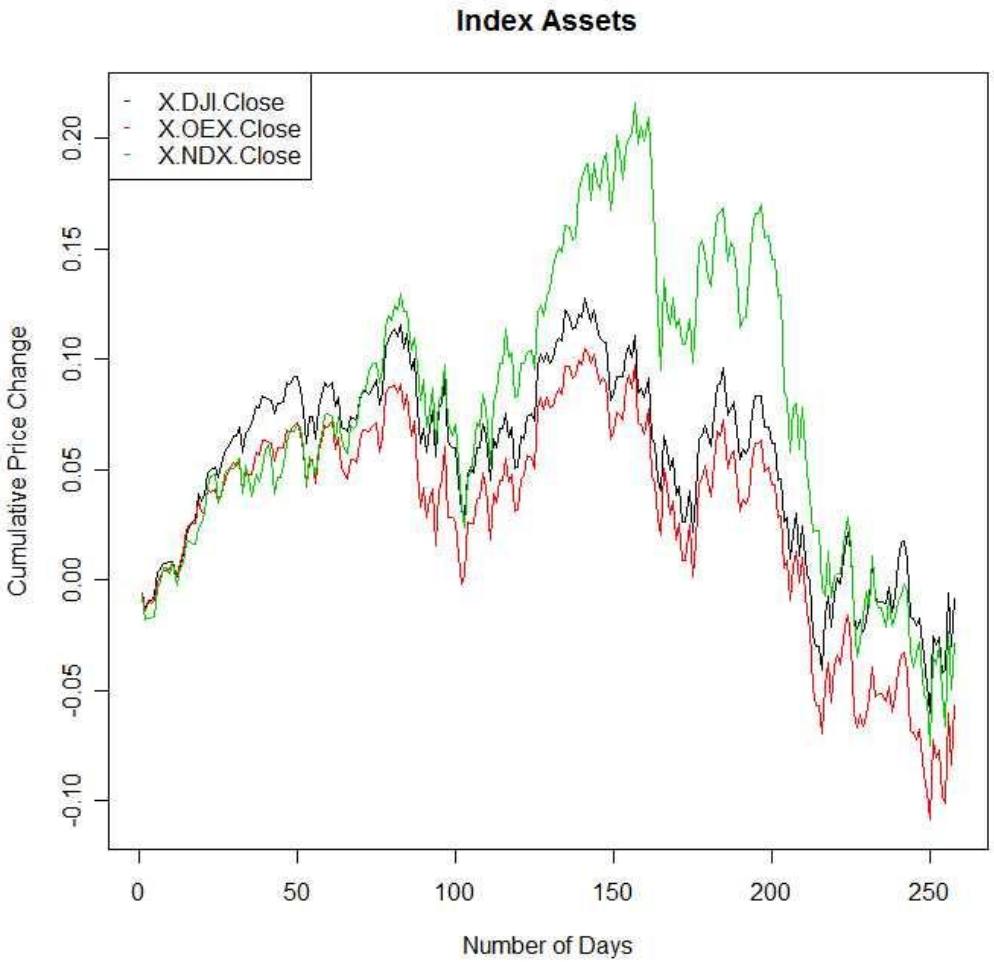


Figure 6: The DJI, OEX, and NDX Indices

A per-transaction fee pricing schedule with collateral requirements, which is used by all private CCPs, is very unlikely to efficiently price risk in this simple contract. The typical 2:1 leverage cap for equities will increase inefficiency by forcing unnecessary margin calls. Pricing novation with our proposed two-part price schedule to cover both origination and the variation in risk over time allows for efficient pricing of risk and for margin calls to be tailored to market conditions. A two-part pricing schedule adds value to the novation process and the clearing parties can be compensated accordingly.

The correlations between the underlying assets over the course of the contract, March 25, 2007 to March 24, 2008, are $\rho_{\mathrm{DJI,OEX}} = 0.986$, $\rho_{OEX,NDX} = 0.892$, $\rho_{\mathrm{DJI,NDX}} = 0.8751$

(Figure 7). Among the underlying indices, DJI was the least volatile, followed OEX and NDX (Figure 8). Given these correlations and volatility, the exponentially weighted daily volatility of each index grew dramatically over the course of the contract (Figure 9). The position value for Party A initially increased and then decreased (Figure 10) toward the end of the period. The variation in the position value was about +/- 10% over the period. The position risk for Party A, measured as the 99% 10-day VaR, grew approximately six-fold in response to the increasing daily volatility (Figure 11).

Figure 11 illustrates why a one part clearing fee is inefficient: a one-part fee must either compensate the clearing firm for the variation in risk over the life of the contract or require the posting of cash collateral as the position value and/or position risk varies. Pricing a potential six-fold change in risk upfront present insurmountable financial challenges, which is why no current CCP prices such a product. However, as the "lender of last resort" the government implicitly does guarantee at least some portion of such contracts at a price of zero. Rather than forcing liquidation or posting additional collateral, a two-part clearing fee raises the daily charge for risk as risk increases, as illustrated in Figure 12. It is true that by increasing the daily risk charge, the parties will likely find their position less attractive economically and may choose to hedge or liquidate. But that is an economic decisions and not a constrained decision.

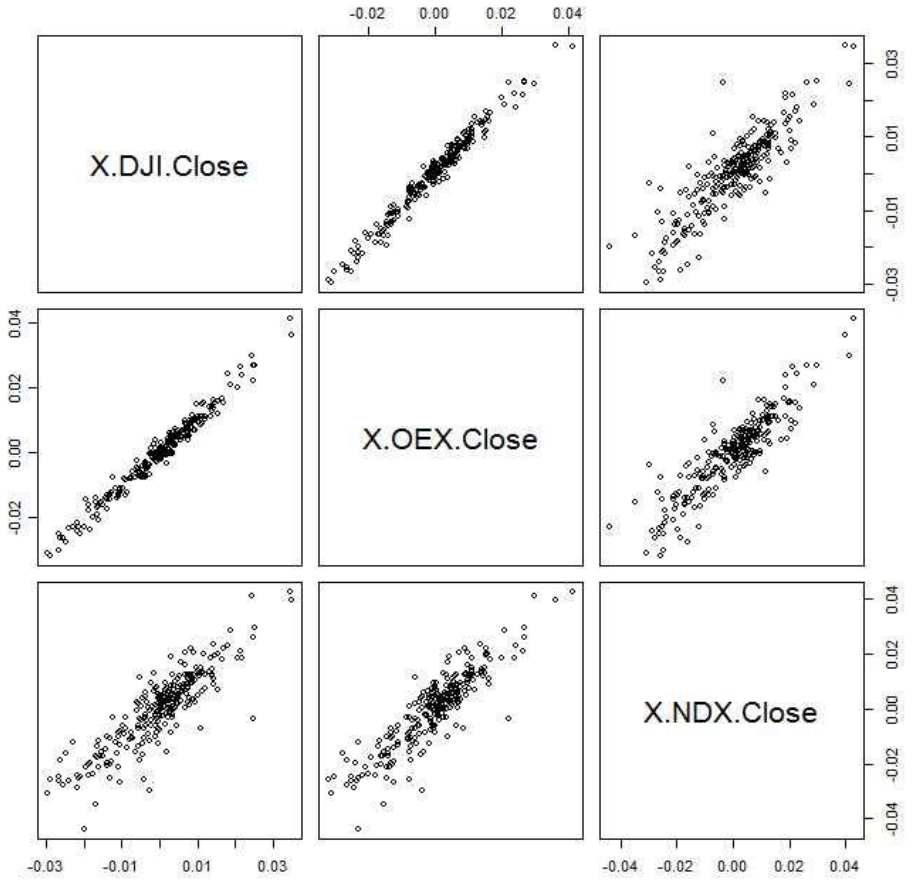


Figure 7: Correlations of Indices

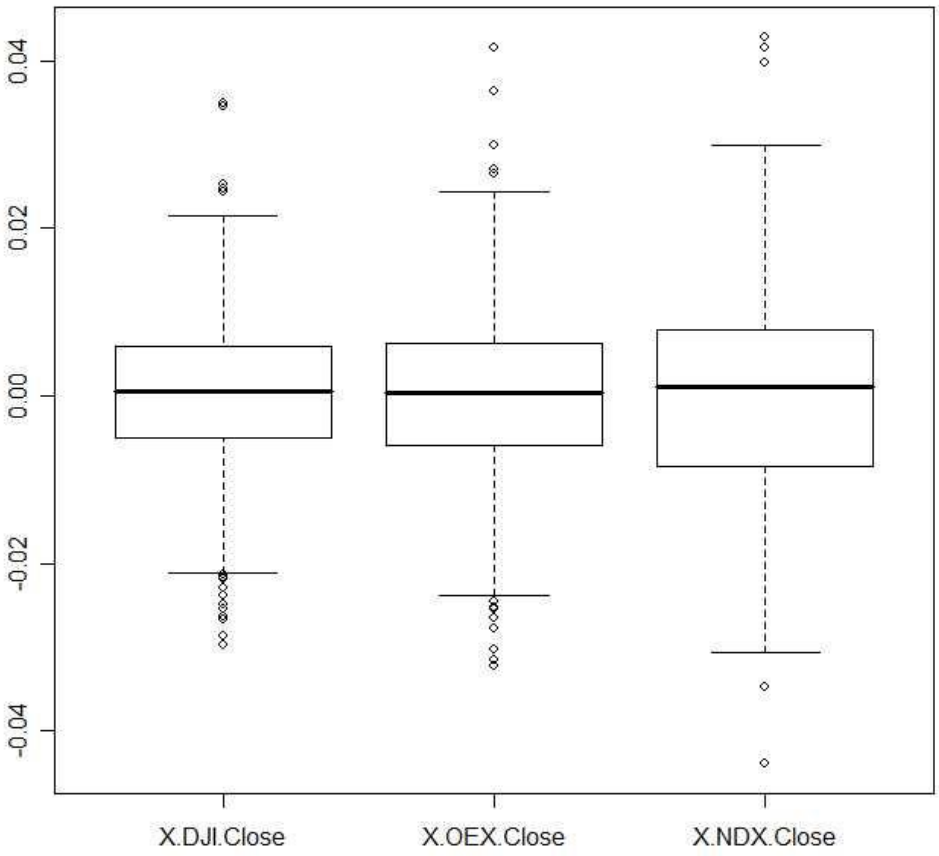


Figure 8: Comparison of Volatilities

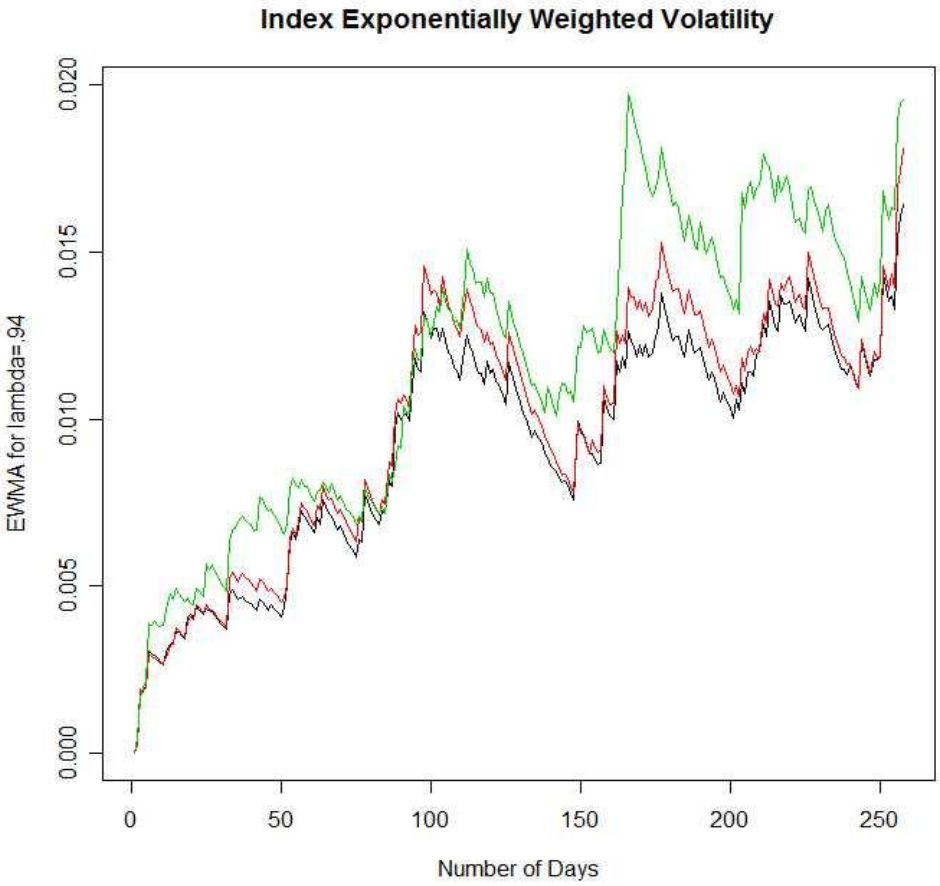


Figure 9: Exponentially Weighted Volatility of Indices

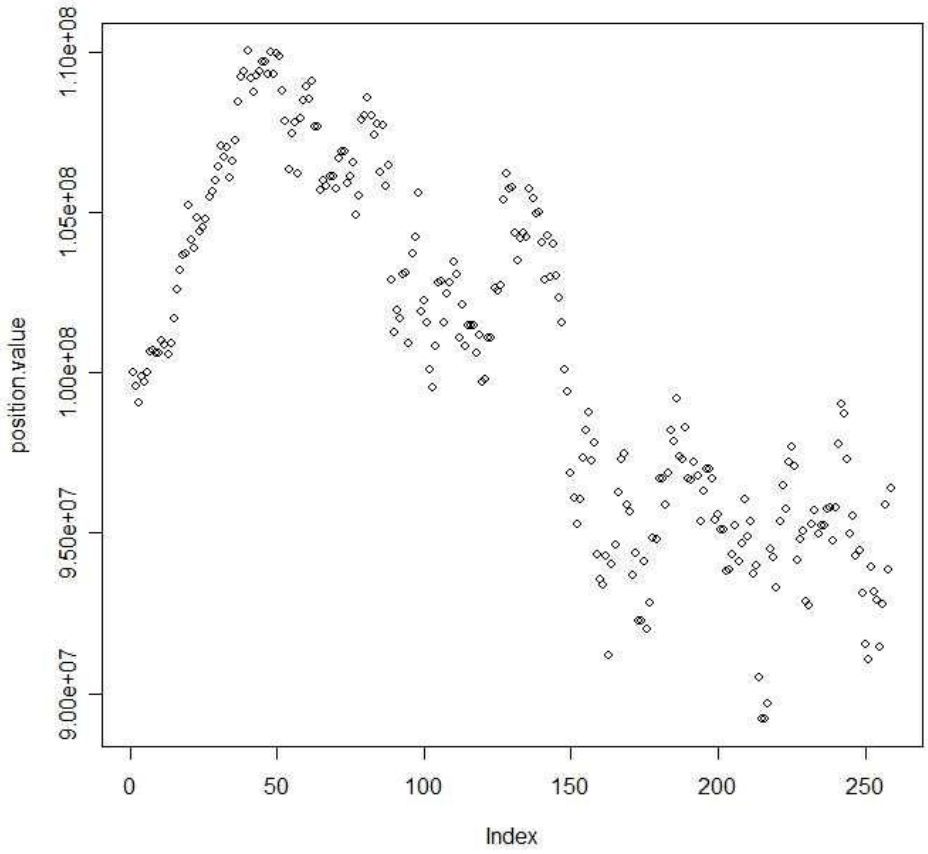


Figure 10: Position Value

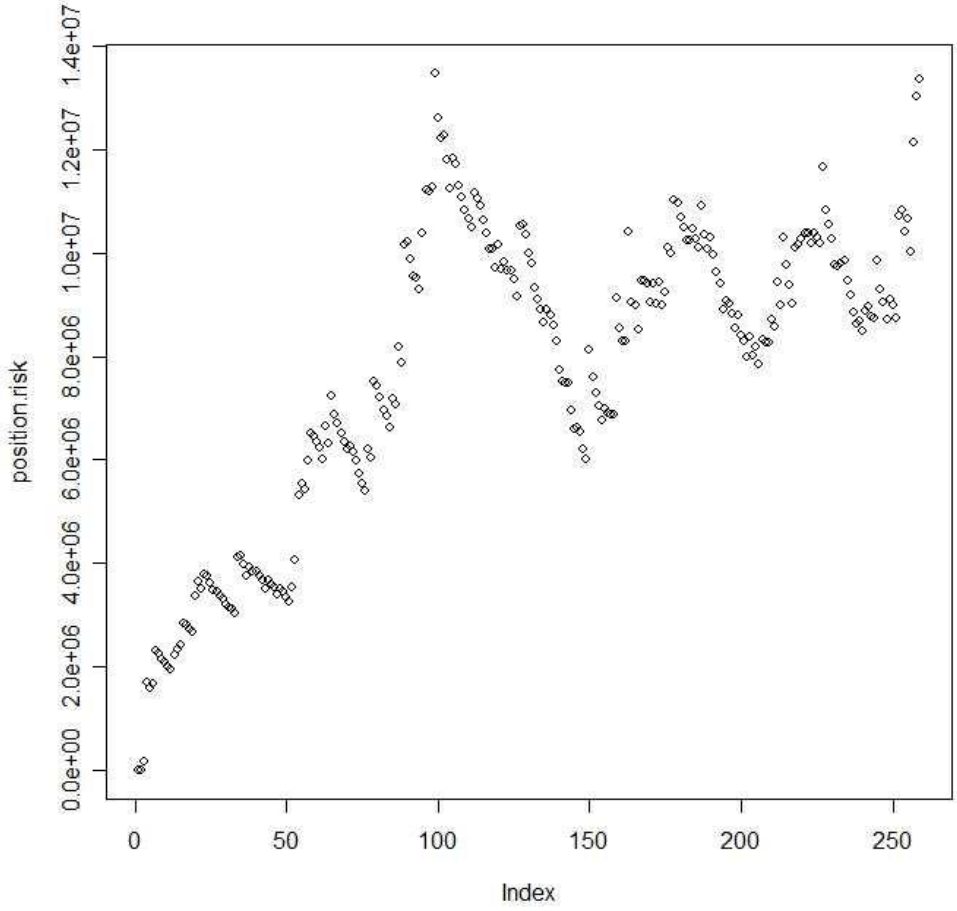


Figure 11: Position Risk

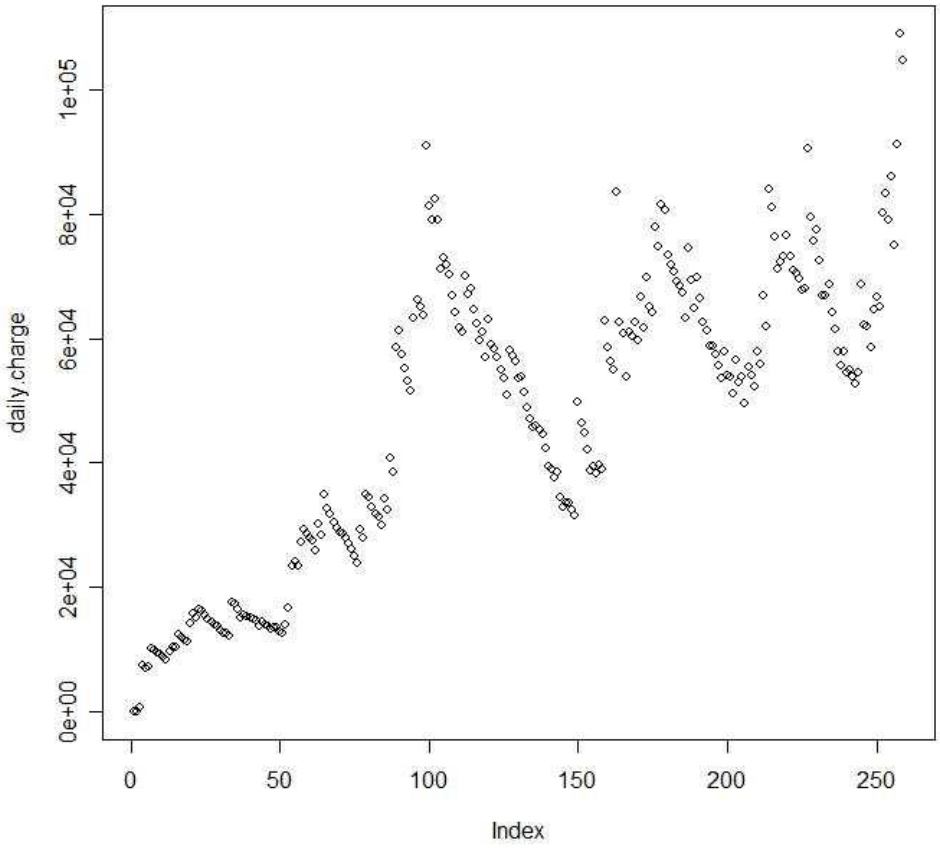


Figure 12: Daily Change in Risk

A two-part clearing fee is risk sensitive and applied to the value at risk for the clearing firm. The economic capital of Party A at any point in time is the value of its contract position less the 99% 10-day VaR less the loan. At the outset of this contact, Party A's economic capital would be about $48 million (i.e. $100 million less VaR of about $2 million less $50 million loan). At its lowest point, Party A's economic capital was about $28 million (i.e. $ 90 million less VaR of about $12 million less $50 million loan). In effect, that economic capital is the excess capital still protecting the guarantor. As that economic capital declines over the course of the contract, daily risk charges for novation in this example would have increased 10-fold. These daily risk charges compensate the clearing firm for the variation in risk while not requiring either a single up-front fee or a margin call. Figure 13 illustrates the changing relationship between the economic value

and the position risk, expressed as the ratio of economic capital to position risk for Party A. The variable clearing fee adjusts to compensate the CCP for this risk (Figure 14). Risk-based charges compensate for the increased market risk, while retaining positive control over risk exposure, in contrast to a fixed-fee structure (Figure 15) that does not respond to changes in risk.

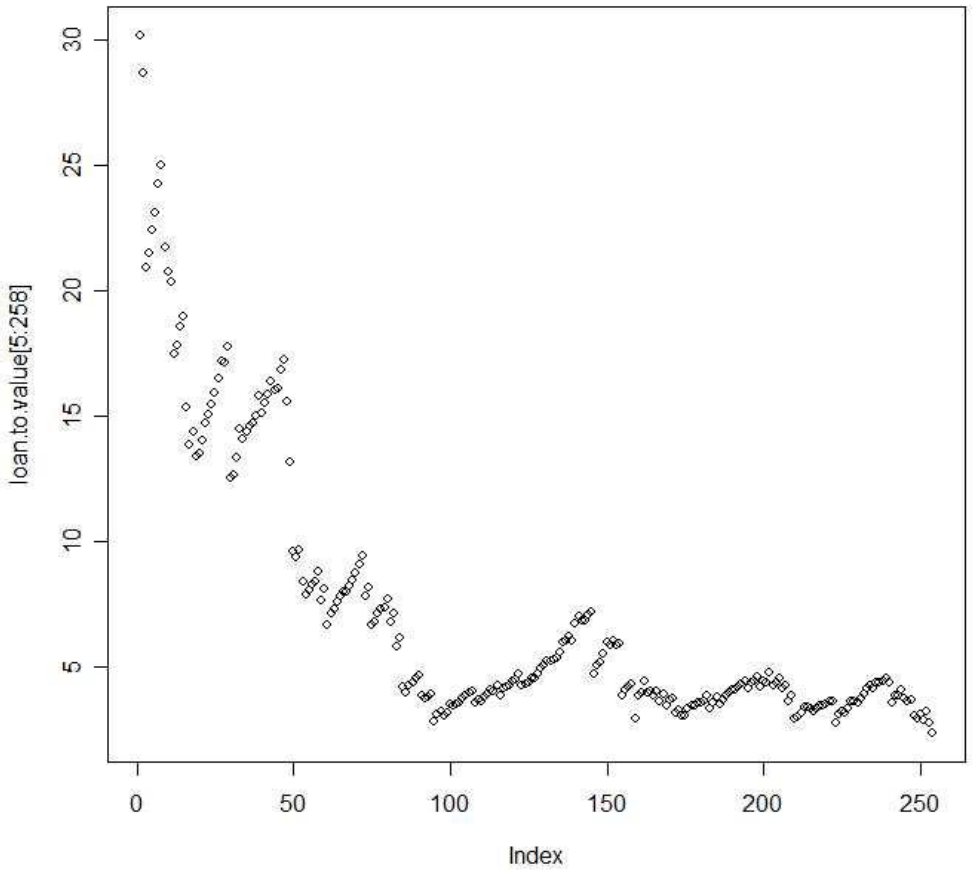


Figure 13: The Ratio of Economic Capital to VaR

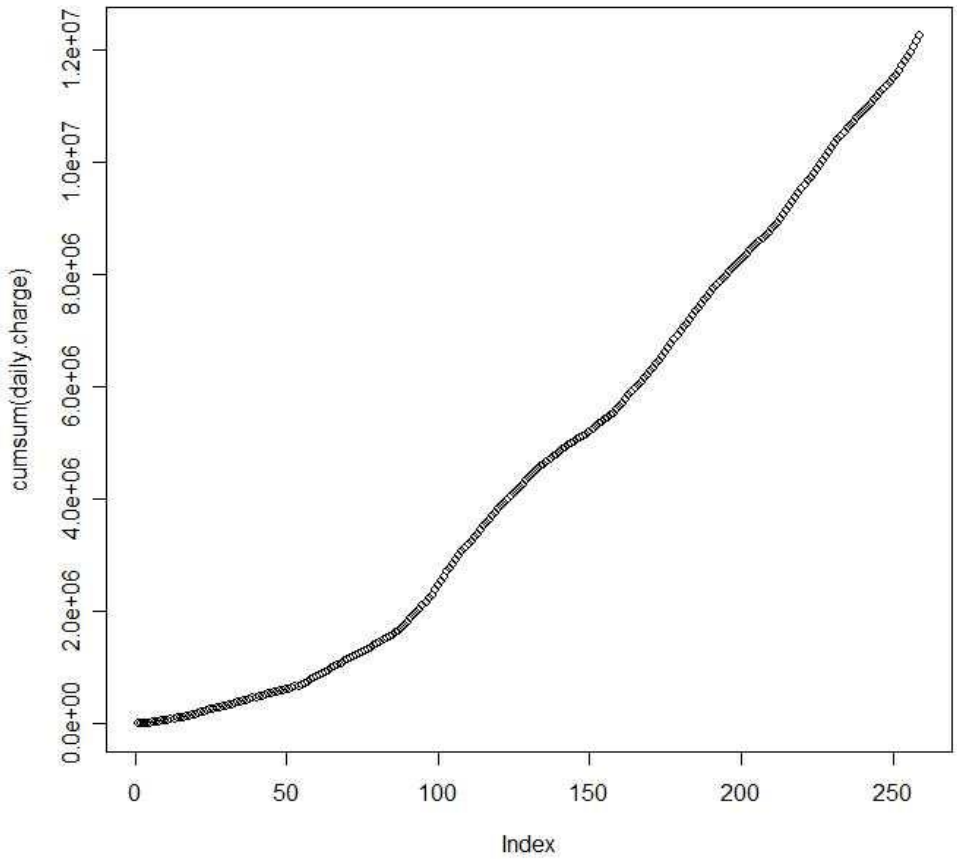


Figure 14: Risk-based Clearing Fee

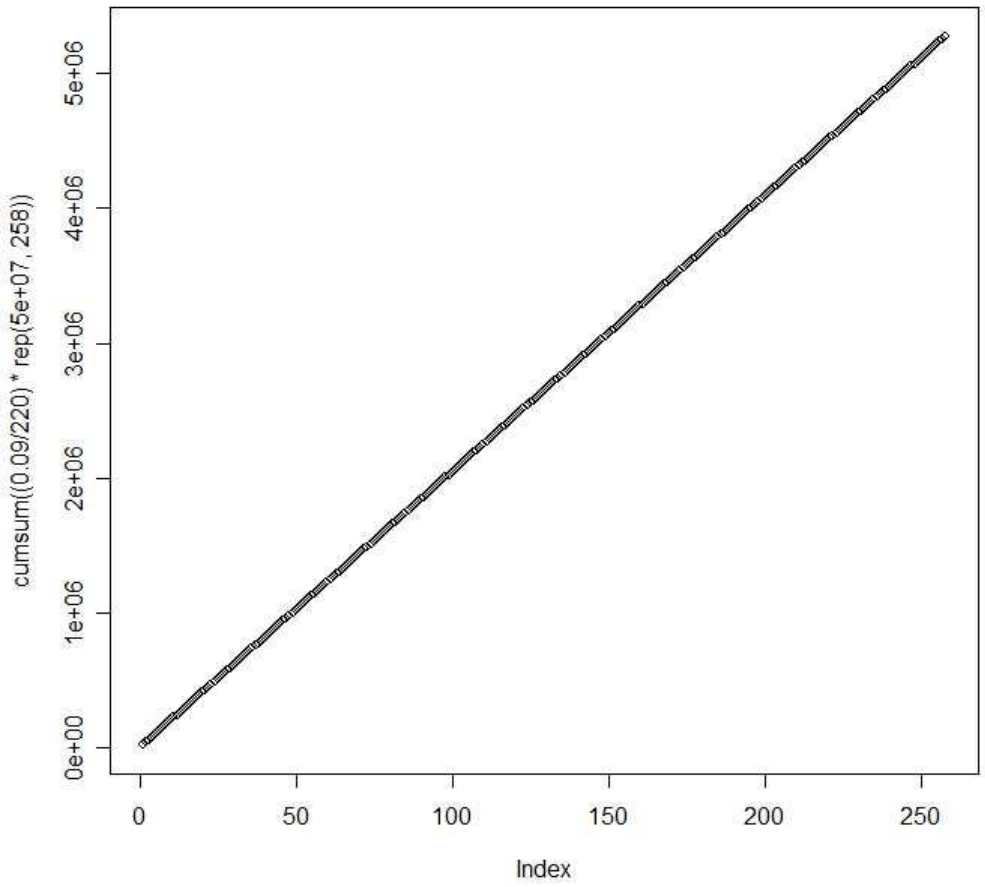


Figure 15: Benchmark

Appendix 4: Two-Part Pricing and Social Welfare

Consider the transactor surplus generated by the per-transaction fee and two-part pricing schedules (Dionne, 1991). In a per transaction fee pricing schedule, novation is priced competitively to just cover total losses, CX, where C is expected cost of default per contract and X is the total number of contracts cleared. The transactor surplus generated by clearing X_1 contracts is,

$$Fixed\ Fee\ Transactor\ Surplus = \int_0^{X_1} P(X)dX - CX_1 \qquad (9)$$

where X_1 is determined by the inverse demand function for clearing, $P(X)$.

In a two-part pricing structure, the CCP charges an up-front fee, *a*, and variable, risk based fee, *b*. The transactor surplus generated when X_0 contracts are cleared is

$$Two - Part\ Price\ Transactor\ Surplus = \int_0^{X_0} P(X)dX - bX_0 - a \qquad (10)$$

where X_0 is the welfare maximizing amount of clearing, given the inverse demand function, which is found by solving

$$\max_{X_0} \left[\int_0^{X_0} P(X)dX\right] - M - CX_0 \qquad (11)$$

where *M* is the cost of monitoring risk.

The CCP's profit

$$\Pi(X_0) = a + bX_0 - CX_0 - S \qquad (12)$$

The value of clearing to the transactor is maximized when the variable fee is equal to the marginal cost of risk, $P(X_0) = C = b$, if this cost of monitoring risk is low enough to allow for non-negative profits,

$$F \geq S \qquad (13)$$

The transactor will prefer two-part pricing if

$$\int_0^{X_0} P(X)dX - a - bX_0 \geq \int_0^{X_1} P(X)dX - CX_1. \qquad (14)$$

Combining (13) and (14) yields,

$$C(X_1 - X_0) \int_0^{X_1} P(X)dX \geq S \qquad (15)$$

which shows that two-part pricing is more efficient that per transaction fee pricing when the costs of monitoring risk are less than the reduction in default losses, since $X_1 > X_0$, minus the reduction in benefits from derivatives trading.

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