PCS Catastrophe Insurance Options
- A New Instrument for Managing Catastrophe Risk -

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Abstract

The present paper gives a risk theoretical analysis of the applications of PCS insurance option contracts to the risk management (control of the technical net value) of insurance companies. Fundamental institutional specifications of PCS Options are described and a quantitative analysis of basic PCS positions and hedging strategies are performend. Finally, the suitability of using PCS Options in the management of catastrophe risk is compared with traditional reinsurance programs.

Résumé

L'étude présente contient une analyse risque theorique de l'application de PCS contrats d'option sur l'assurance des risques de catastrophes dans le cadre de gestion du risque (contrôle valeur nette technique) des compagnies d'assurance. Les spécifications institutionelles des PCS Options sont descrites et une analyse quantitative des positions et stratégies de base des PCS contrats sur l'assurance des risques de catastrophes sont réalisées. Finalement, l'aptitude de PCS Options pour la gestion du risque de catastrophes par rapport aux programmes traditionelles de réassurance est discuté.

Keywords

PCS Options, catastrophe risk, risk management.

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1. Introduction

The property/casualty insurance industry is only recently aware of a magnitude of potential loss. When hurricane *Hugo* in 1989 and *Andrew* in 1992, which cost 4.2 billion USD resp. 16.5 billion USD, reached already a new dimension of claim settlement, some estimates predict that catastrophes occuring a major metropolitan area could cause claims anywhere from 50 billion USD to 100 billion USD. Obviously, this huge dimension of probably insured claims would not only affect the industry´s policyholders´ surplus but also the capacity of the whole market of direct and reinsurance (*Koegel* 1996).

On the other hand there is about 15 trillion USD in the private capital markets which could sustain those major catastrophical loss. For to transfer catastrophe risks from the insurance industry to those private capital markets in September 1995 the Chicago Board of Trade (CBOT®) launched a new class of catastrophe insurance options based on new indices provided by Property Claim Services, a division of American Insurance Services Group, Inc.[1]

In the second chapter of this paper some institutional basics for understanding the PCS™ Options are described. The third chapter deals with the fundamental trading and hedging strategies. In chapter four there is a comparative analysis about the suitability of traditional catastrophe reinsurance programs and the new PCS Options.

2. Institutional basics of PCS Options

A general reference for contract specifications, index valuation and CBOT trading facilities is *CBOT* (1995). The following remarks focus those items which are used in a specific risk theoretical based management analysis.

contract specification

PCS Options are exchange-traded and cash-based financial derivatives on *underlying* loss indices which have to be standardized in their objective, regional and temporal dimension. PCS indices are daily estimated and published. They reflect the dollar cumulative amounts of catastrophe claims in a specified US region and time. By PCS definition, a catastrophe means an event that leads to more than 5 million USD of insured property damages and affects a significant number of insurance companies and policy holders. The PCS loss indices track insured loss estimates identified by PCS for the following *regions* and states (see table 1):

National	Regional	State
(all 50 states plus Washington D.C.)	Easter Northeastern (including Washington D.C.) Southeastern Midwestern Western	Florida Texas California

Table 1: Regions and states of PCS Indices

The *loss period* is the time during which a catastrophic event occures. Most of these indices refer to loss periods as the calendar quarters. The march contract refers the first quarter, the june- the second, september- the third and december contracts the fourth quarter. Only the Western index and the California index refer to the whole calendar year (annual contracts). PCS provides loss estimates as catastrophes occur. The last day of the loss period is the last day of the concerned quarter or year. The *development period* is the time after the loss period. During the development period PCS estimates and reestimates for catastrophes that occured during the loss period. The users of PCS Options can choose a six-month or a twelve-month development period. The index value at maturity of the chosen development period is used for cash settlement purposes (see figure 1). The settlement value represents the sum of the then-current PCS loss estimates over the loss and development period, even though PCS loss estimates may continue to change.
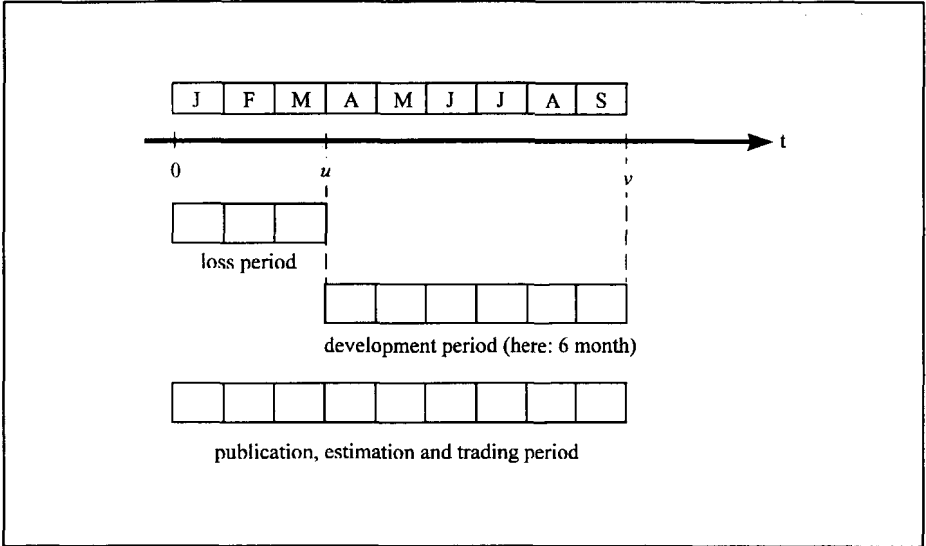
Figure 1: The time structure of PCS Options

index valuation, premium quotation and tick size

Due to the difficulties in option trading on the estimated dollar amounts, the CBOT has created a reflecting pricing index. The valuation principle shows, that each PCS Index represents the sum of then-current PCS estimates for defined insured losses divided by 100 million USD and rounded to the first decimal point. For example, if loss estimates of the first quarter 1996 is at april 17 USD 1.195.000.000, the corresponding loss index notes 12.0 points. Each index point equals 200 USD cash value.

To limit the amount of losses that can be included under a PCS contract which means to improve the flexibility of PCS contracts as a risk management instrument, PCS Options are available both as *small cap* (aggregate insured industry losses from 0 USD to 20 billion USD which means an index value from 0 to 200 points) and *large cap* (aggregate insured industry losses from 20 billion USD to 50 billion USD which means an index value from 200.1 to

500 points). The strike or exercise values are listed in integral multiples of five points (5 to 195 for small caps, 200 to 495 for large caps).

PCS Index Value	Industry Loss Equivalent
0.1	10 Mio. USD
1.0	100 Mio. USD
20.0	2.000 Mio. USD
100.0	10.000 Mio. USD
250.0	25.000 Mio. USD
500.0	50.000 Mio. USD

Table 2:   Index Value and Loss Equivalent

The PCS Options can be traded as calls, puts or *spreads*, where the latter can be interpreted as the simultaneous purchase and sale of two or more option contracts. Option spreads are the mostly preferred type of PCS contracts because they are - in opinion of the CBOT - very close to traditional XL-reinsurance. The PCS Contract premiums are quoted in points and tenths of a point and each point equals 200 USD.

loss estimating by PCS

The daily PCS insured loss estimates are based on both the expected dollar loss and the projected number of claims to be filed. It is intended to estimate the total industry net insurance payment for personal and commercial property lines. PCS uses a combination of different methods for estimation catastrophe damage. First of all, PCS takes a confidental general survey of almost 70% (based on written premium) of the whole US insurance industry (agents, companies and adjusters) by composing the reported individual losses and claim estimates. Second, PCS relies on its National Insurance Risk Profile (NIRP), where in more than 3.100 counties potential risk affectness of objects like buildings or vehicules are carefully regarded.

some basic trading facilities at the CBOT

PCS Options are european style, which means that an exercise is possible only at maturity. At this time all positions in-the-money will be equalized automatically. For example, the holder of an option call (put) receives a cash payment equal to the positive (negative) difference between the PCS index value at maturity and the exercise price. Without regar-

ding the settlement date, all PCS Options can be traded all over the trading period (loss period and development period, see figure 1).

The clearing process at the CBOT is organized and ensured by a clearing house which is named BOTCC™ (Board of Trade Clearing Corporation). Beside the CBOT itself the BOTCC is a seperate entity that works as a third-party guarantor to every option contract as well as it takes an integral part in market transactions: Customers place orders through their brockarage firm. The broker which should be a clearing member of the BOTCC fills orders through the open outcry system on the CBOT trading floor and transmits trade information to the BOTCC. After that the BOTCC matches the trade informations, guarantees performance and requires to settle gain or loss from the transactions.

The margin account system at the CBOT does not much differ from those of other futures exchanges. Beneath the margin system the BOTCC disposes over additional ressources, such as a reserve capital amount of currently more than 140 million USD and 300 million USD committed credit facilities available to provide temporary liquidity.

3. Fundamental trading and hedging strategies on PCS Options

3.1. Analysis of the basic positions: PCS call long and PCS call option spread long

For to understand how PCS Options work and which benefits they might give to an insurance company managing catastrophe risks one should look in a first step at the fundamental position of a PCS long call. The analysis is on the analogy of the risk theoretical remarks of *Albrecht/König* 1995 in the context of CAT derivatives. It seems to be sufficient to limit the considerations to the positions PCS call long position and the PCS call option spread long, for some more alternatives see *Schradin/Timpel* 1996.

Let $L(u;v;t)$ denote the estimated industry loss amount with loss period $[0,u]$ and development period $[u, v]$ at time t, measured in USD, then we have the corresponding PCS index

value $\quad L^*(u;v;t) = \left[\dfrac{L(u;v;t)}{10\ \text{Mio.}} + 0,5\right]\dfrac{1}{10}$, [2]measured in index points. The exercise

price X of the option is measured in index points as well as the option premium $C(s)$ payed at the purchasingtime s. $NV^l(t)$ denotes the USD amount of the net value of the PCS Option long position at time t.

In the case of a large cap contract the gross value of the PCS long call with loss period [0, u] and exercise price X at maturity v is given by

$$C(u;v) = 200 \min\left\{\max\left\{0;\ L^*(u;v) - X\right\};\ 500 - X\right\} \tag{1}$$

$$= 200 \min\left\{\max\left\{0;\ \left[\dfrac{L(u;v)}{10\ \text{Mio.}} + 0,5\right]\dfrac{1}{10} - X\right\};\ 500 - X\right\} .$$

Regarding the paid option premium at time s we find the corresponding net value as

$$NV^l(v) = 200\left[\min\left\{\max\left\{0;\ L^*(u;v) - X\right\};\ 500-X\right\} - C(s)\right] \tag{2}$$

$$= 200\left[\min\left\{\max\left\{0;\ \left[\dfrac{L(u;v)}{10\ \text{Mio.}} +0,5\right]\dfrac{1}{10} -X\right\};\ 500-X\right\} - C(s)\right] .$$

The net value position of a seller of PCS call options at maturity is complementary

$$NV^x(v) = C(s) - C(v).$$

Figure 2 shows the possible option values at maturity.

As already mentioned in the second chapter, the main trading activities on PCS Options do happen as option spreads, exactly as call option spreads (*COS*). A *COS* can be explained as a combination of a call long position and a call short position where the exercise price of the long position X is lower than the exercise price Y of the short position. The structure of a *COS* long is quite similar to the structure of the PCS long call, the only difference is the
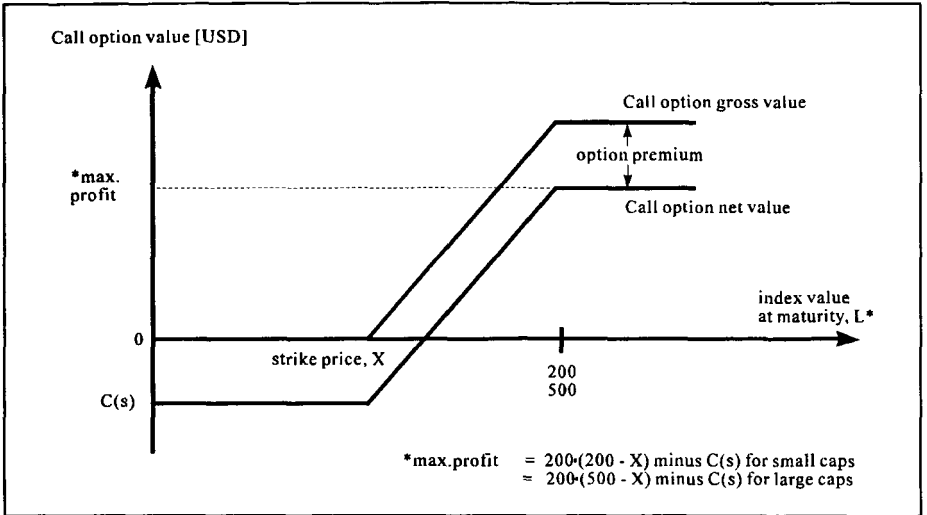
Figure 2: PCS long call option value at maturity [USD]

insurers possibility to determine the higher exercise price and by the way, to reach a individual risk transfer or layer. The net premium of a buyer of a *COS* contract at time s is right the difference between the paid (long) premium and the earned (short) premium

$$\Delta C_{X,Y}(s) = C_X(s) - C_Y(s).$$

The net value of a *COS* long position then is

$$NV^{cos}(v) = 200 \left[\min \left\{ \max \left\{ 0; L^*(u;v) - X \right\}; Y-X \right\} - \Delta C_{X,Y}(s) \right], \qquad (3)$$

which can be written as

$$NV^{cos}(v) = 200 \begin{cases} -\Delta C_{X,Y}(s) & , \ L^*(u,v) \le X \\ L^*(u,v) - X - \Delta C_{X,Y}(s) & , \ X < L^*(u,v) \le Y \qquad (4) \\ Y - X - \Delta C_{X,Y}(s) & , \ L^*(u,v) > Y \ . \end{cases}$$

The net value of the *COS* long position at time v is negative in the size of the net payed spread premium, when the index value ist smaller or equal to the lower exercise price X. In

the second case, where the index value is higher than X but lower than Y, the *COS* buyers´ net value of the contract improves by the difference between index value and X. The net value of the position reaches its maximum for equality of index value and higher exercise price. In this third case, the net value is determined by the spread between Y and X reduced by the invested net premium amount.

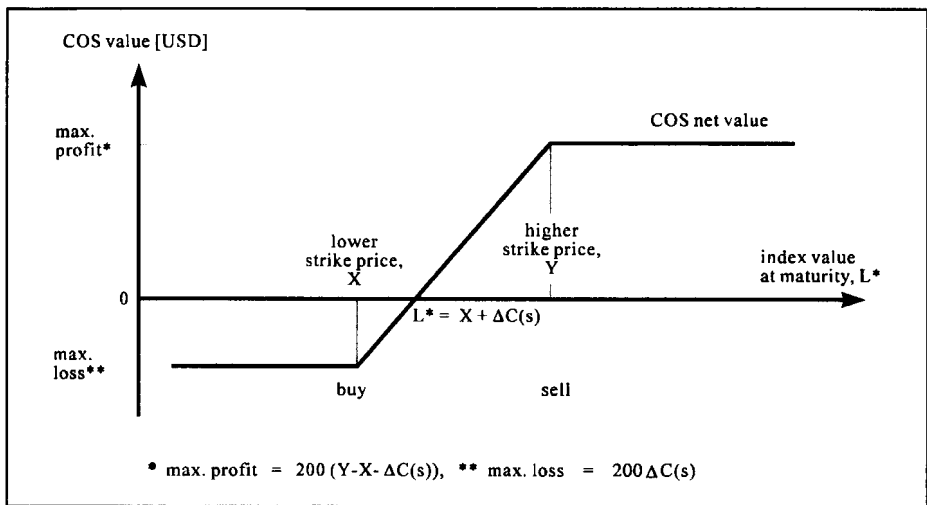Figure 3 illustrates the net value of a *COS* long position at maturity time v.

Figure 3: *COS* long net value at maturity [USD]

3.2. Quantitative analysis of the hedging strategie with call option spreads

3.2.1 The position of a (direct) insurance company

Looking at hedging strategies it is remarkable, that the original position of the insurance company is a *short position* (claims are paid) and the relevant hedge position therefore has to be a *long hedge*, i.e. the company has to *buy* PCS contracts, here *COS* long. In extension of the notation above we define with *Schradin/Timpel* 1996:

SB	$:=$	insurers retention [USD],
D	$:=$	"insured" layer, which has to be transferred to the PCS market [USD]
X	$:=$	exercise price long position, [indexpoints]
Y	$:=$	exercise price short position, [indexpoints]
α	$:=$	market share of the insurance company (% of written premiums)
k	$:=$	appropriate number of contracts
γ	$:=$	cross hedge ratio (individual anticipated losses of the insurer in relation to the anticipated losses of the whole market in %)
$\pi(u)$	$:=$	premium income of the regarded insurance company for risk taking the loss period [0, u]
$S(u, v)$	$:=$	claims of the regarded insurance company incurred in the loss period [0, u] and reported until maturity v,
$TNV(u;v;v)$	$:=$	technical net value of the regarded insurance company refering to [0, u] at maturity v

First of all we have to take into consideration, that the management of the insurance company refuses to use the PCS hedging opportunities. Regarding the catatrophe exposure of the company, the technical net value of the transferred risks during the loss period (payed premiums and reported claims) at time v is given by

$$TNV(u;v) \;=\; \pi(u) \,-\, S(u;v). \qquad\qquad (5)$$

If the insurance management decides at time s to buy a number of k PCS call option spreads (5) is going to change in

$$TNV(u;v) \;=\; \pi(u) - S(u;v) + k\; 200 \left[\Delta C_{X,Y}(u;v) \,-\, \Delta C_{X,Y}(s) \right] . \qquad (6)$$

Specifing the COS hedging strategie depends on the management decision about the position and size of the aimed layer. It is necessary to determine the adequate exercise prices X and Y as well as the number of contracts k. The lower exercise price X is a function of the desired retention SB, the cross hedge ratio γ and the market share of the company α and fixes the position of the layer as follows

$$X = \left[\frac{SB}{\alpha} \frac{1}{\gamma} 10^{-7} + 0,5 \right] \frac{1}{10} \; . \tag{7}$$

In addition, the higher exercise price Y of the COS depends on the of the extension of the liability D like

$$Y = \left[\frac{SB+D}{\alpha} \frac{1}{\gamma} 10^{-7} + 0,5 \right] \frac{1}{10} \; . \tag{8}$$

Finally, the adequate amount of COS contracts is

$$k = \left[\frac{D}{Y-X} \right] \frac{1}{200} \; . \tag{9}$$

Let´s assume that there is no cross hedge risk ($\gamma = 1$) what means, that the anticipated individual structure of losses for the regarded insurer is identical to the anticipated loss structure of the whole market (objective, region and time)[3]. The analysis ignores aswell the possibility of reestimating claim amounts after time v which does not affect the PCS index value but the real claim amount of the individual insurance company. Under these assumptions and in case of a 1:1 hedge, the companys´ claim variable can be substituted by

$$S(u;v) = \frac{D}{Y-X} L^{*}(u;v) \; . \tag{10}$$

With respect to (7) and (8) we can write (6) as

$$
\begin{aligned}
TNV(u;v) = {} & \pi(u) - S(u;v) \\
& + \left[\frac{D}{Y-X} \right] \left[\min\{\max\{0; L^{*}(u;v) - X\}; Y-X\} - \Delta C_{X,Y}(s) \right] \; .
\end{aligned}
\tag{11}
$$

Taking (10) we obtain

$$
TNV(u;v) \;=\; \begin{cases} \pi(u)-S(u;v) \;-\; \dfrac{D}{Y-X}\Delta C_{X,Y}(s) & , \quad L^{*}\leq X \leq Y \\[2ex] \pi(u)-\dfrac{D}{Y-X}X-\dfrac{D}{Y-X}\Delta C_{X,Y}(s) & , \quad X<L^{*}\leq Y \\[2ex] \pi(u)-\dfrac{D}{Y-X}\big[L^{*}-(Y-X)+\Delta C_{X,Y}(s)\big] & , \quad L^{*}>Y \end{cases} \quad (12)
$$

Once more the following figure 4 gives a visual imagination of the derived results from hedging with *COS* long.
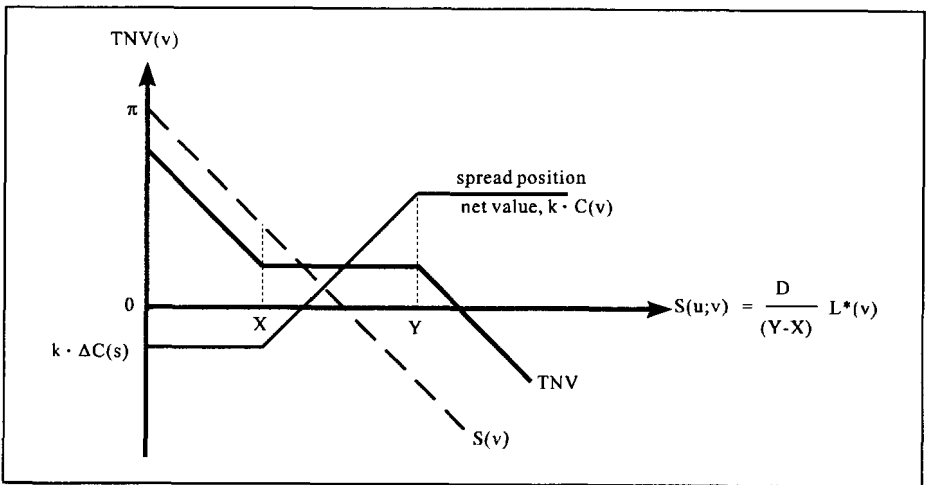

Figure 4:   Net value of the hedging strategy *COS* long at maturity [USD]

The net value of the *COS* hedging strategy at time v shows a *perfect hedge* while the PCS index is higher than the lower exercise price X and lower than the higher exercise price Y. In this case, the gains of the *COS* position compensate the losses of the original risks and the aimed net value is stabilized and determined by the difference between the earned premium π and the sum of k-times the amount of the lower exercise price X and k-times the invested

COS premium. If the index value does not reach X, the hedging strategy reduces the original result of the non-hedged situation by the paid *COS* premium (parallel shift of the gross value). If the index value exceeds the higher exercise price Y, only a partial hedge can be realized, which is once again visualized with a parallel shift in amount of the difference of k-times the size of the layer (difference between the two exercise prices Y and X) and the paid *COS* premium.

3.2.2 The position of a reinsurance company

On the point of view of a reinsurance company and despite of the existence of cross hedge risks, there is an obviously interesting hedging possibility: Based on a the stop loss treaty case with priority M_1 and a limitation of the liability at M_2 a constellation is considered, that the reinsurer wants to hedge the final accumulated claim amount.

The technical position of the unhedged reinsurer is

$$
\begin{aligned}
TNV_{RV}(u;v) &= \pi_{RV}(u) - S_{RV}(u;v) \\
&= \pi_{RV}(u) - \min\left\{\max\{0;\ S(u;v) - M_1\};\ M_2 - M_1\right\}.
\end{aligned}
\tag{13}
$$

For to reduce the complexity of the following relations we substitute the institutional adjustments of PCS index valuation as described in chapter 2 by a variable h which is defined as

$$
h := \left[\frac{1}{\alpha} 10^{-7} + 0.5\right] \frac{1}{10}.
\tag{14}
$$

Then the suitable exercise prices are determined by

$$
X = h\, M_1
\tag{15}
$$

and

$$
Y = h\, M_2.
\tag{16}
$$

The adequate amount of *COS* contracts is

$$k = \left[\frac{M_2 - M_1}{Y - X}\right] \frac{1}{200} = \frac{1}{200\, h} \; . \tag{17}$$

If there is no cross hedge risk and a 1:1 hedge is aimed, the loss variable can be substituted by the index value with

$$S(u;v) = \frac{M_2 - M_1}{Y - X} L^*(u;v) = \frac{1}{h} L^*(u;v) \; . \tag{18}$$

In the constellation considered it is possible to establish a completely riskless position, i.e. the reinsurer is able to close completely his risk position based on a stop loss contract with limited layer like

$$TNV_{RV}(u;v) = \pi_{RV}(u) - \frac{1}{h} \Delta C_{X,Y}(s) \; , \qquad \forall \quad S(u;v) \; . \tag{19}$$

3.3 Using PCS Option Protection - Additional Remarks

In addition to those basic standardized protection strategies, there are a lot of more reasons to use PCS contracts for direct and reinsurance companies as described in *CBOT* 1995 and *Himick* 1995.

- For instance, if the traditional reinsurance market does not offer an adequate coverage, an insurance company that has written too much catastrophe risk in a special region of the US market could *fill the gap* and supplement traditional reinsurance with exchange traded PCS Options.

- PCS Options can be used to *rebalance the portfolio* which means the quantitative risk exposure of the insurer. If e.g., a company got too much catastrophe risk at the lower

layers, it could synthetically swap a lower layer of risk for a higher available at the CBOT or, as an alternative, it could sell PCS Options at higher risk layers.

- Finally, PCS contracts can be used to di*versify geographically*. If an insurers´ catastrophe exposure depends too much on a region or state in the US, the company improves the balance of its portfolio by bying or selling national, regional or state PCS Options.

4. PCS Options and traditional catastrophe reinsurance programs

As already mentioned by *Albrecht/König/Schradin* 1994 in the context of CAT derivatives[4], the PCS Options lead as well to a transfer of catastrophe insurance risk based on the instruments of modern financial markets. To compare the new and traditional risk transfer concepts it seems suitable, to separate the market dimension and the technical dimension of the involved instruments.

Starting with the latter, it can be noticed, that in principle PCS contracts represent an alternative to traditional risk transfer approaches in the insurance industry. As showed in chapter 3, the financial consequences of PCS Options and PCS *COS* are quite similar to those of traditional non-proportional catastrophe (re-)insurance. The main differences between those synthetical (re)insurance instruments and the traditional concepts depend on their institutional specialities. The following table 3 shows meanful features and differences between PCS Option contracts and traditional catastrophe reinsurance programs focusing the aggregate claim amount.

features	risk management instrument	
	PCS Option spreads	traditional reinsurance program (i.e. stop loss reinsurance)
claim basis (loss definition)	PCS claim estimates	original claims (net losses)
type of covered claims	catastrophe claims defined by PCS	claims negotiated in the individual contract
covered lines	aggregate over all lines	aggregate or coverage per line as negotioted in the individual contract
insured perils	all-risk coverage	named perils (variable)
region	by PCS specific defined regions in the USA	specification all over the world as negotiated in the individueal contract (high diversification possibilities)
loss period	calendar quarters	as defined in the individual contract
development period	six or twelve month	as defined in the individual contract
standardizing degree (e.g. volume, time, region)	high	low (individual)
contract valuation	daily at the exchange market	according to the financial accounting system
pricing techniques	exchange-traded and cash-based premiums	actuarial approaches for risk premium calculation
payment characteristics	long Position/ ceding company	the market premium of the contract has to be paid at the purchasing time	the reinsurance premium has to be paid at the beginning of the contract, very often accountings for every calender quartal
	reinsurer/ short Position	daily contract valuation in addition with the margin system of the commodity exchange	depots, reinstatements, accountings for every calender quartal
security for the buyer of the coverage	guaranty of the CBOT resp. the BOTCC	quality and standing of the reinsurance partner
effectiveness of the coverage	typically higher cross hedge risks	completely oriented to the needs of the ceding company

Table 3:   PCS options and traditional reinsurance

The conclusion of those differences is, that PCS contracts will not substitute but supplement and extend the traditional catastrophe (re-)insurance programs.

The second item, which has to be reflected, is the stability and liquidity of the PCS markets. As one can see, the CBOT is very much engaged in improving the availability of informa-

tion about the PCS contracts and market constitutions. E.g. the new established quarterly "Review on the CBOT´s Cat Option Market" (see *CBOT* 1996) which includes not only some historical remarks about the market in 1995 but also names a number of INTERNET connections as there are "Using Cat Options" on *http://www.cbot.com/financ.htm#sub15*, "Current PCS Index Values" on *http://www.cbot.com/pcsondex.htm*) or "Weekly Market Updates" on *http://www.cbot.com/13pcs.htm*).

But all these activities of the responsible CBOT management do not lead to an answer to still existing fundamental market problems. Repeating the questions of *Albrecht/König/Schradin* 1994, until now there is neither an adequate arbitrage free pricing modell for PCS Options published[5] nor an convincing explanation given to the fundamental question about the reasons of the market participants on the short position.

5. Final remarks

The real advantages of PCS Options are, that they might open the private capital market for to sustain the traditional catastrophe (re-)insurance markets and that they might add flexibility to insurers´ and reinsurers´ risk management. But on the other hand, there are several critical aspects of the PCS market that may change this optimistic view, e.g. PCS contracts are less customized as traditional reinsurance programs are and the liquidity and stability of the PCS market are not yet really proved.

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Endnotes

1) As described and analyzed in the 4th and 5th AFIR colloquium there already exists a number of catastrophe insurance derivatives, the so called CAT Futures and CAT Options. The institutional and risk theoretical specifities of the CAT derivatives are discussed by *Smith/Pickles* (1994) and *Albrecht/König* (1995).

2) The notation [] means the *Gauss´* brace which leads to the index valuation principle (division by 100 million USD and rounded to the first decimal point).

3) Under the existance of cross hedge risks ($\gamma \neq 1$) the exercise prices X and Y and as a result the number of contracts k will have to be adjusted.

4) *Albrecht/König/Schradin* 1994, S. 669-672.

5) First steps are made by *Schradin/Timpel* 1996.