EXHIBIT 10

(Part 2 of 3)

number of positive return observations in the portfolio is larger than that of negative ones in the first 15 months, during which period the returns are also significant. These results are robust to transaction costs.

If we divide the sample into two periods: 1) issues before the end of 2001 and 2) post-2001 issues, similar to the results of the equal money hedge position, we find that the delta-neutral portfolios are generally positive only in the earlier period. In addition, as shown in Exhibit 9, the standard deviation of the observations issued before 2001 is also higher (0.039 vs. 0.027), so the higher returns of the sample observations prior

EXHIBIT 8
Returns of Delta-Neutral Hedge from Issuance Date

Panel A. Complete Sample

Months	Returns	*t*-value	Positive	Negative	Total	Significance
1	1.07%	2.18	72	52	124	2
2	0.98%	1.53	64	58	122	0
3	2.83%	2.64	67	54	121	3
4	2.82%	3.16	73	47	120	3
5	3.43%	2.98	65	54	119	3
6	3.48%	3.08	61	55	116	3
7	4.48%	2.87	66	47	113	3
8	4.41%	2.99	68	42	110	3
9	3.43%	1.67	58	50	108	1
10	4.24%	1.61	58	48	106	0
11	7.25%	1.70	54	52	106	1
12	3.99%	2.10	52	50	102	2
13	4.98%	2.15	50	50	100	2
14	5.01%	2.28	47	50	97	2
15	6.49%	2.61	50	47	97	2
16	5.08%	1.88	44	51	95	1
17	4.43%	1.53	44	51	95	0
18	4.99%	1.44	36	58	94	0
19	5.82%	1.39	36	56	92	0
20	5.19%	1.26	32	59	91	0
21	6.69%	1.33	31	59	90	0
22	5.91%	1.05	31	57	88	0
23	1.86%	0.58	27	61	88	0
24	1.27%	0.42	27	59	86	0
25	0.90%	0.29	25	59	84	0
26	1.63%	0.43	25	58	83	0
27	1.57%	0.45	22	59	81	0
28	2.46%	0.65	25	56	81	0
29	1.32%	0.38	26	54	80	0
30	0.00%	0.00	26	53	79	0
31	−0.58%	−0.18	24	54	78	0
32	−0.22%	−0.06	20	56	76	0
33	−0.65%	−0.18	21	53	74	0
34	−1.28%	−0.33	19	54	73	0
35	0.83%	0.19	18	51	69	0
36	1.73%	0.37	19	44	63	0

EXHIBIT 8 *(continued)*

Panel B. Sample to End of 2001

Months	Returns	*t*-value	Positive	Negative	Total	Significance
1	1.77%	2.08	39	26	65	2
2	1.05%	0.98	26	39	65	0
3	3.84%	2.07	34	31	65	2
4	3.77%	2.60	39	26	65	2
5	4.99%	2.72	34	31	65	3
6	4.59%	2.66	34	31	65	3
7	6.00%	2.39	38	27	65	2
8	5.56%	2.50	42	22	64	2
9	4.44%	1.37	33	31	64	0
10	6.16%	1.49	35	29	64	0
11	10.79%	1.56	35	29	64	0
12	5.77%	2.19	34	29	63	2
13	7.52%	2.22	32	31	63	2
14	7.73%	2.47	32	31	63	2
15	10.06%	2.84	37	26	63	3
16	8.24%	2.07	30	31	61	2
17	7.23%	1.69	29	32	61	1
18	8.09%	1.59	25	36	61	0
19	9.45%	1.56	26	35	61	0
20	8.38%	1.39	22	38	60	0
21	10.34%	1.40	21	39	60	0
22	9.87%	1.20	23	36	59	0
23	3.82%	0.85	18	41	59	0
24	3.02%	0.72	20	37	57	0
25	2.62%	0.62	19	37	56	0
26	3.72%	0.71	18	38	56	0
27	3.13%	0.65	15	40	55	0
28	4.10%	0.78	18	37	55	0
29	1.50%	0.32	19	36	55	0
30	–0.32%	–0.07	19	35	54	0
31	–0.90%	–0.21	18	35	53	0
32	–0.55%	–0.12	14	37	51	0
33	–1.83%	–0.39	16	35	51	0
34	–3.09%	–0.63	15	36	51	0
35	–1.81%	–0.35	13	36	49	0
36	–1.80%	–0.33	14	33	47	0

to the end of 2001 may in part be due to incremental gamma effects. If we compare the returns of the delta-neutral portfolio in Exhibit 8 and the relative volatility in Panel B of Exhibit 5, we find that the volatility after issuance first goes down and then goes up until the fifth quarter; peak delta-neutral portfolio returns are observed over this same period. Furthermore, we note that the correlation coefficient of the quarterly volatility and the quarterly average portfolio return is as high as 71.36%.

In Exhibit 10, we compare returns under different rebalancing strategies, including daily rebalancing, as

EXHIBIT 8 *(continued)*

Panel C. Post-2001 Sample

Months	Returns	*t*-value	Positive	Negative	Total	Significance
1	0.29%	0.71	32	27	59	0
2	0.88%	1.43	38	19	57	0
3	1.66%	1.98	33	23	56	1
4	1.69%	1.87	33	22	55	1
5	1.56%	1.29	31	23	54	0
6	2.07%	1.57	27	24	51	0
7	2.42%	1.78	28	20	48	1
8	2.80%	1.70	26	20	46	1
9	1.96%	1.09	25	19	44	0
10	1.32%	0.66	23	19	42	0
11	1.93%	0.87	19	23	42	0
12	1.12%	0.45	18	21	39	0
13	0.66%	0.29	18	19	37	0
14	–0.01%	–0.01	15	19	34	0
15	–0.09%	–0.04	13	21	34	0
16	–0.58%	–0.27	14	20	34	0
17	–0.60%	–0.25	15	19	34	0
18	–0.72%	–0.26	11	22	33	0
19	–1.29%	–0.42	10	21	31	0
20	–0.96%	–0.32	10	21	31	0
21	–0.57%	–0.19	10	20	30	0
22	–2.13%	–0.73	8	21	29	0
23	–2.15%	–0.71	9	20	29	0
24	–2.17%	–0.67	7	22	29	0
25	–2.58%	–0.73	6	22	28	0
26	–2.74%	–0.73	7	20	27	0
27	–1.76%	–0.44	7	19	26	0
28	–1.03%	–0.25	7	19	26	0
29	0.87%	0.20	7	18	25	0
30	0.60%	0.14	7	18	25	0
31	0.00%	0.00	6	19	25	0
32	0.40%	0.08	6	19	25	0
33	1.89%	0.35	5	18	23	0
34	2.80%	0.46	5	17	22	0
35	7.20%	0.98	5	15	20	0
36	11.98%	1.33	5	11	16	0

Note: Each day the portfolio is rebalanced based on the previous day's delta. The portfolio consists of long CBs and short share positions. Panel A includes all the observations in the sample; Panels B and C show issuances up to end of 2001 and post-2001 respectively. The last column provides the significance levels of the returns; 1, 2, and 3 indicate significance at the 10%, 5%, and 1% levels, respectively.

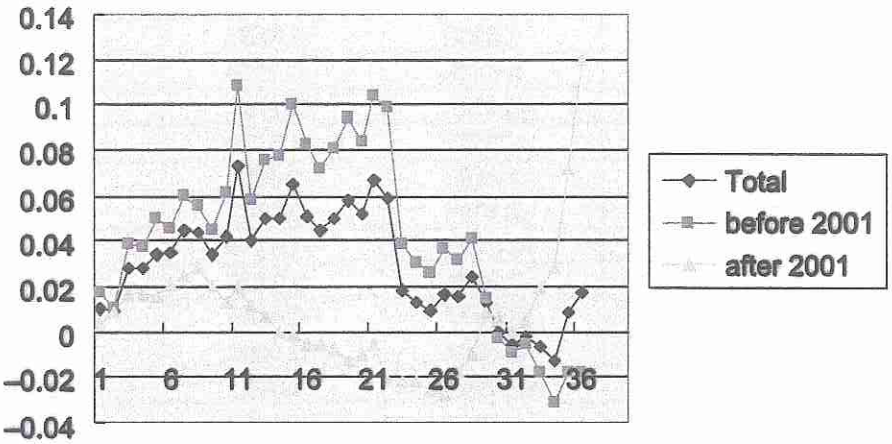
well as rebalancing only when delta changes no less than a delta change tolerance of 0.02, 0.04, 0.1, 0.2, and 0.3, respectively. For sample observations prior to the end of 2001, as the delta change tolerance increases from 0.02 to 0.3, average portfolio returns increase from 1.29% to 7.05%.

The last two rows of Exhibit 10 show the effects of variations in leverage, defined as self-capital allocations for building a portfolio. Here the returns of the delta-neutral portfolio are calculated as the returns of the initial self-invested capital. With increased leverage, portfolios can earn higher (though riskier) returns. The last two rows in Exhibit 10 show the leverage effect when the leverage ratio is equal to two and three respectively.[11] We find that the absolute values of the highest and lowest returns are bigger, while the volatilities increase dramatically: from 0.0230 without leverage to 0.5607 with a leverage of 3.[12]

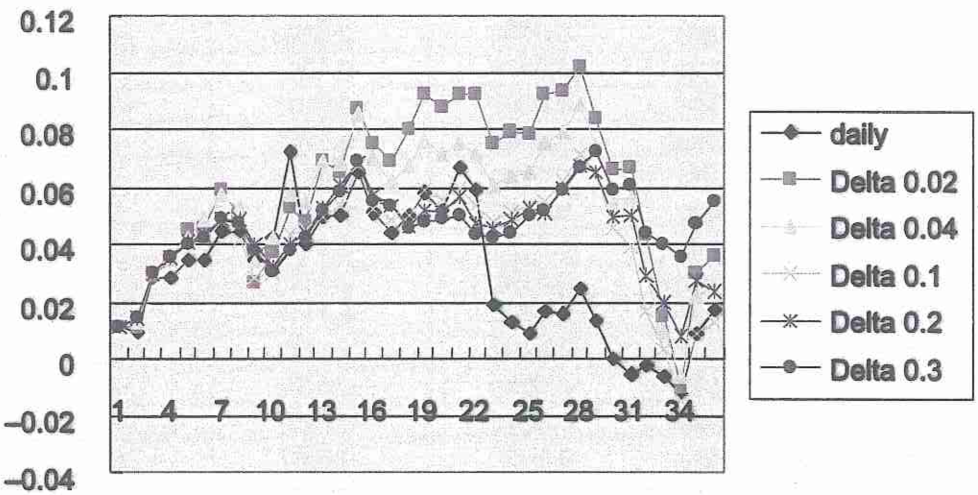
E X H I B I T 9

Average Month-End Returns of a Delta-Neutral Hedge from Issuance Date

Panel A. Daily Rebalancing Returns



Panel B. Returns Under a Different Rebalancing Policy



To identify the risk components of delta-neutral hedging strategies, we performed regressions of returns on the risk components used in Exhibits 3 and 6.[13] Equity risk, interest rate risk, and credit risk are all significant determinants of delta-neutral returns at the 1% level. Interest rate risk and credit risk have positive effects on the returns. However, unlike the pure CB or pure equity returns, equity risk has a negative impact, suggesting that delta-neutral CB portfolios may help investors smooth the equity portion of their wealth function.

GAMMA HEDGE

As discussed above, volatility is the most important factor that captures the returns of a delta-neutral portfolio. Hence, it seems most appropriate to investigate the returns of a gamma hedging strategy. The CB gamma is defined as the rate of change of the delta with respect

EXHIBIT 10

Returns of Delta-Neutral Hedge with Different Inputs from Issuance Date

Rebalancing Policy		Total	Before 2001	After 2001
Daily Rebalance	Mean	0.0299	0.0437	0.0074
	Std	0.0230	0.0388	0.0274
	Max	0.0725	0.1079	0.1198
	Min	−0.0128	−0.0309	−0.0274
Rebalance if Delta Change ≥ 0.02	Mean	0.0587	0.0129	−0.0061
	Std	0.0285	0.0520	0.0348
	Max	0.1019	0.1698	0.0832
	Min	−0.0103	−0.0010	−0.0688
Rebalance if Delta Change ≥ 0.04	Mean	0.0526	0.0129	−0.0205
	Std	0.0237	0.0443	0.0331
	Max	0.0884	0.1496	0.0624
	Min	−0.0066	0.0001	−0.0719
Rebalance if Delta Change ≥ 0.1	Mean	0.0409	0.0679	−0.0111
	Std	0.0198	0.0184	0.0130
	Max	0.0710	0.1236	0.0316
	Min	−0.0145	−0.0075	−0.0605
Rebalance if Delta Change ≥ 0.2	Mean	0.0436	0.0650	0.0045
	Std	0.0153	0.0154	0.0131
	Max	0.0685	0.1081	0.0881
	Min	0.0080	−0.0001	−0.0381
Rebalance if Delta Change ≥ 0.3	Mean	0.0463	0.0705	0.0007
	Std	0.0130	0.0115	0.0126
	Max	0.0723	0.1106	0.0740
	Min	0.0111	0.0164	−0.0421
Daily Rebalance Leverage = 2	Mean	0.3593	0.5113	0.0552
	Std	0.2670	0.4113	0.1078
	Max	0.8903	1.3077	0.4805
	Min	0.0016	−0.0170	−0.1063
Daily Rebalance Leverage = 3	Mean	0.5671	0.8501	−0.0093
	Std	0.5607	0.8687	0.1514
	Max	1.7755	2.6719	0.4980
	Min	−0.2689	−0.3883	−0.2754

Note: Total entire sample results are shown, as well as for two subsamples: observations prior to the end of 2001 and post-2001 issues. Results are shown for daily rebalancing, for rebalancing when delta change is no less than 0.02, 0.04, 0.1, 0.2, and 0.3, and with daily rebalancing for portfolios with leverage equal to 2 and 3.

to the price of the underlying stock. It is the second partial derivative of the CBs price with respect to the underlying stock price.

Our estimate of the gamma of CBs is based on the Black and Scholes [1973] formula modified by Merton [1973] to incorporate continuous dividend yield.

$$\text{Gamma} = e^{-q(T-t)} \frac{\phi\left(\dfrac{\ln\left(\frac{S}{X}\right) + \left(r - q + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{(T-t)}}\right)}{S\sigma\sqrt{(T-t)}}$$

where $\phi(\cdot)$ is the probability distribution function of the standard normal distribution, and all other parameters are as defined in the delta-neutral hedge.

While delta-neutral hedging is a nondirectional strategy because theoretically we can benefit from capturing gamma regardless of the direction of the stock price move, gamma hedging is a directional one (as are other hedges that we explore subsequently in this article—the convergence hedge, option hedge, and capital structure hedge). Because the dimension of delta-gamma-neutral is two, we must make use of a second derivative relationship (which has nonlinear functions) to form the gamma-neutral portfolio. Our focus is to exploit the portfolio's gamma to derive incremental profits. We do not restrict our portfolio to have a gamma equal to zero in a delta-gamma-neutral strategy.

Rather, our approach is to study both bearish and bullish gamma hedges, which are based on bets on the direction of the future stock returns. The bearish gamma position is set up by going long CBs and going short underlying stocks with numbers larger than what we do in a delta-neutral portfolio. So when the stock price goes down, the portfolio can derive higher returns. The bullish position is the obverse of the bearish one. The returns we study are again the returns on the total long position of the assets in the simulated portfolio. No initial self-capital investment is required. Again, positive net capital is invested in a risk-free asset; while negative net capital is borrowed from the market.

Exhibit 11 reports the average portfolio returns of bullish gamma CBs hedging. The bullish portfolio is set up by going long CBs and short-selling the underlying stocks of 0.09 less than the delta in a delta-neutral portfolio. If stock prices actually go up as expected, then the portfolio gains will be enhanced. The portfolio is rebalanced when delta changes by at least 0.3. We find that the average portfolio returns are positive in the first 36 months, with the highest value of 7.78%. The returns are significant at a level of 1% from the third to the 17th month after the issuance date. The number of positive return observations is larger than that of negative ones in the previous 20 months.

Exhibit 12 reports summary statistics of the gamma portfolio's average month-end returns with respect to different delta adjustment parameter inputs for gamma hedging, with a delta-neutral portfolio as a benchmark for comparison. From the exhibit, unsurprisingly the volatility of both the bullish and bearish gamma hedging portfolios is larger than that of the delta-neutral hedging portfolio, due to their greater equity exposures. In contrast, the average returns of bullish gamma hedging portfolios before and after 2001 are stable compared with that of bearish gamma hedging. Furthermore, the bullish hedging from the issuance of CBs can generate better returns than that of both the delta-neutral portfolio and bearish gamma hedging. This is not surprising because of two reasons: 1) the underlying stock prices normally perform well during the first three years after the issuance of CBs; and 2) the gamma of the portfolio is positive definite—when the underlying share price rises, the convertible value rises a bit more than predicted by delta; while when the share price goes down, the convertible loses somewhat less. So a bullish bet is in a better position to take advantage these two factors.

Exhibit 13 shows the portfolio gamma as a function of the stock price change and the returns for the daily gamma hedging portfolio of both bearish hedging and bullish hedging with different parameters.

Average month-end gammas after the issuance during the post-2001 sample period are found to be larger than those of the earlier period, over the first 36 months after the CB issuance. As is shown in Panel A of Exhibit 13, gamma is larger when the underlying stock price is near the exercise price. In other words, stock prices of firms issuing CBs after 2001 are generally closer to the exercise price than those before 2001. This is also reflected in the patterns of conversion premia shown in Exhibit 1. The price of higher gamma portfolios may reflect a premium for gamma-seeking investors, which may explain the higher observed returns for the strongly bullish gamma portfolio (delta = –0.14) in the post-2001 period.

In the construction of the gamma-hedged portfolios above, we change the delta by adding or subtracting a fixed number. We also perform the analyses using a flexible approach for adjusting deltas: Using the midpoint of the current delta and the delta calculated from the expected future price, we then change the delta with a flexible number. The results remain unaffected. On the whole, bullish gamma hedging from the issuance of CBs appears to be a robust investment strategy.[14]

IMPLIED VOLATILITY CONVERGENCE HEDGE

Delta-neutral and gamma hedging involve taking opposite long/short positions between CBs and their

Exhibit 11

Returns of Bullish Gamma Hedge from Issuance Date

Months	Returns	*t*-value	Positive	Negative	Total	Significance
1	0.98%	2.60	80	45	125	2
2	1.19%	2.52	68	55	123	2
3	2.47%	3.66	78	44	122	3
4	2.93%	4.17	79	42	121	3
5	3.40%	4.13	76	44	120	3
6	3.86%	4.43	75	42	117	3
7	4.45%	4.81	73	41	114	3
8	4.59%	4.45	77	34	111	3
9	3.89%	3.40	66	43	109	3
10	3.76%	2.98	64	43	107	3
11	4.33%	3.38	61	46	107	3
12	4.79%	3.43	65	38	103	3
13	5.51%	3.72	58	43	101	3
14	6.00%	3.78	62	36	98	3
15	6.86%	3.91	60	38	98	3
16	5.88%	3.31	56	40	96	3
17	5.75%	3.21	56	40	96	3
18	5.18%	2.59	52	43	95	2
19	5.31%	2.57	50	43	93	2
20	5.22%	2.56	50	42	92	2
21	5.26%	2.47	41	50	91	2
22	4.68%	2.18	41	48	89	2
23	4.77%	2.12	42	47	89	2
24	5.27%	2.16	41	46	87	2
25	5.74%	2.18	37	48	85	2
26	5.85%	1.99	32	52	84	2
27	6.57%	2.17	38	44	82	2
28	7.28%	2.26	36	46	82	2
29	7.78%	2.42	39	42	81	2
30	6.70%	2.04	37	43	80	2
31	7.16%	2.17	37	42	79	2
32	5.41%	1.19	37	40	77	0
33	5.24%	1.06	32	43	75	0
34	5.05%	0.95	32	42	74	0
35	5.99%	0.99	32	38	70	0
36	6.43%	0.94	33	31	64	0

Note: This exhibit reports the portfolio returns of bullish gamma hedging. The portfolio is rebalanced when delta changes no less than 0.3; and the bullish position is set up by long buying CBs and short-selling the underlying stocks of 0.09 less than what should be hedged in delta-neutral portfolio. In the last column, 1, 2, and 3 denote statistical significance at the 10%, 5%, and 1% levels of a two-tail test, respectively.

EXHIBIT 12

Returns of Gamma Hedging with Different Inputs from Issuance Date

Rebalancing Policy		Total	Before 2001	After 2001
Delta Neutral Hedging	Mean	0.0463	0.0705	0.0007
	Std	0.0130	0.0115	0.0126
	Max	0.0723	0.1106	0.0740
	Min	0.0111	0.0164	−0.0421
Bullish Gamma Hedging Delta − 0.09	Mean	0.0504	0.0584	0.0366
	Std	0.0154	0.0206	0.0268
	Max	0.0778	0.0935	0.1353
	Min	0.0098	0.0121	0.0051
Bearish Gamma Hedging Delta + 0.09	Mean	0.0418	0.0821	−0.0355
	Std	0.0127	0.0285	0.0374
	Max	0.0702	0.1319	0.0225
	Min	0.0125	0.0205	−0.0928
Bullish Gamma Hedging Delta − 0.14	Mean	0.0527	0.0517	0.0564
	Std	0.0173	0.0189	0.0324
	Max	0.0807	0.0845	0.1692
	Min	0.0090	0.0097	0.0055
Bearish Gamma Hedging Delta + 0.14	Mean	0.0390	0.0883	−0.0558
	Std	0.0138	0.0311	0.0461
	Max	0.0705	0.1437	0.0221
	Min	0.0090	0.0223	−0.1226

Note: The complete sample results are shown (Column Total) in the last two columns for issues prior to the end of 2001, and post-2001 issues. Results are shown for delta-neutral hedging, for bullish hedging with parameters of minus 0.09 and 0.14 from the initial delta values, respectively, and for bearish hedging with parameters of plus 0.09 and 0.14 from the initial delta values.

underlying stocks. In this section, we explore convergence hedging strategies, which are transactions between different CBs. As we know, CBs consist of two main assets: a warrant and a bond. So we can have an implied volatility convergence hedge and a credit spread convergence, correspondingly.

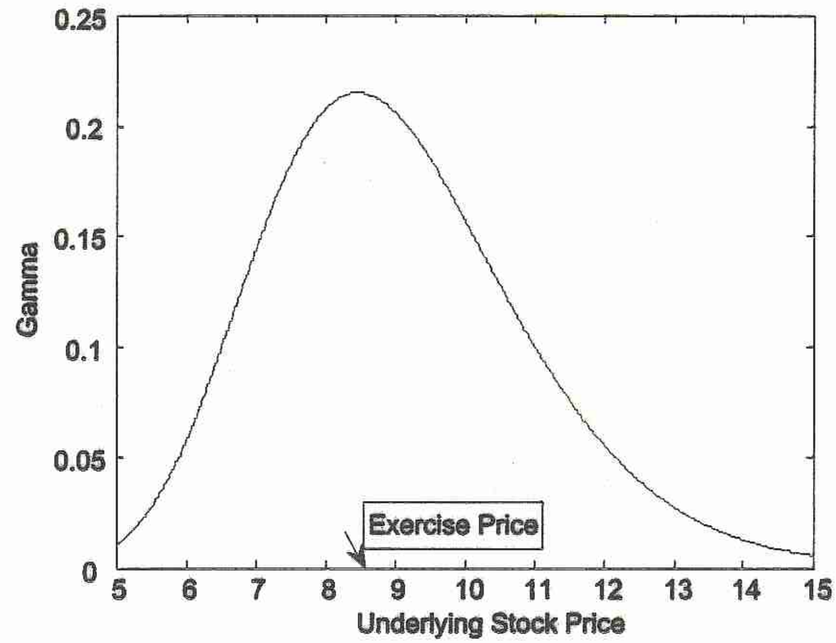
The valuation of CBs requires the assumption of: 1) the underlying stock volatility to value the option, and 2) the credit spread for the fixed income portion that takes into account the firm's credit profile and the ranking of the convertible within the capital structure. Based on the market price of the convertible, we can determine the implied volatility (using the assumed spread) or implied spread (using the assumed volatility). The performance of an implied volatility hedge can test the market efficiency of the option component. A credit spread convergence hedge can test the efficiency of the bond component. The implied volatility is calculated by using the Black–Scholes–Merton formula on the option part of the CBs. And the option part of CBs is the difference between the CB price and calculated theoretical bond value.

The convergence test does not state that the implied volatility or credit spread of two CBs should be the same. Such factors as ratings, dates, and conversion price of CBs could be reflected in spreads and can be taken into account ex ante. What we want to test is whether the abnormal volatility differences between two CBs can be pursued to make profit. Exhibit 14 depicts

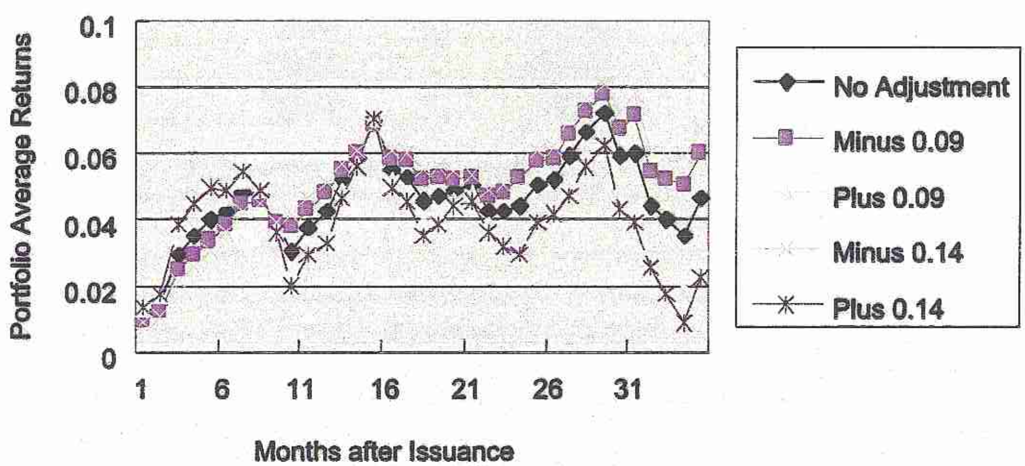
EXHIBIT 13

Gamma and Gamma Hedge from Issuance Date

Panel A. Variation of Gamma with Respect to Underlying Stock Price



Panel B. Portfolio Returns in a Gamma Hedge

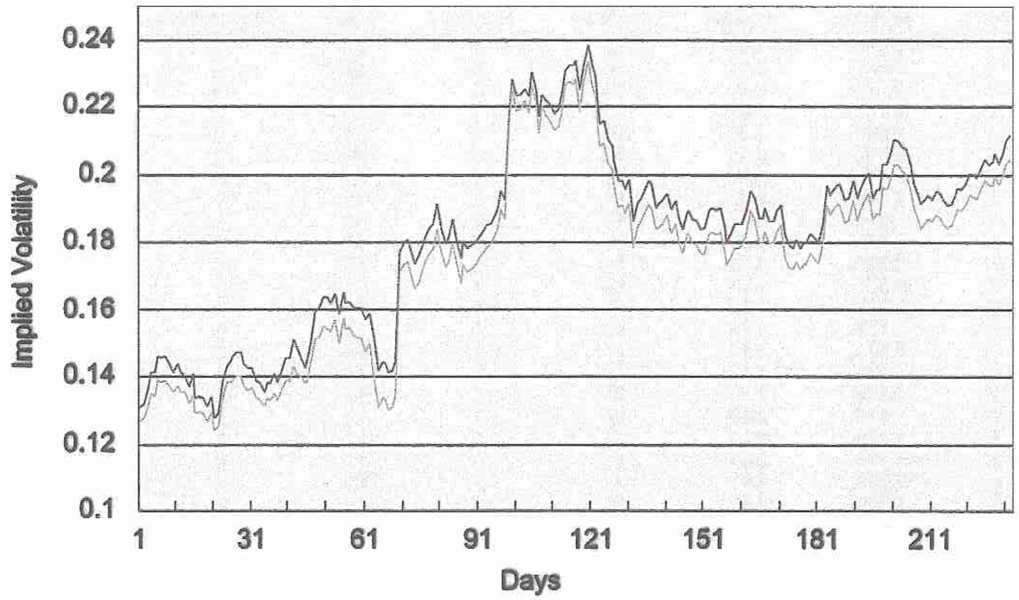


Note: Panel B depicts the average daily gamma hedging portfolio of both bearish hedging and bullish hedging. Returns are shown for delta-neutral hedging (No Adjustment), bullish hedging with parameters of minus 0.09 and 0.14 from the initial delta values, and bearish hedging with parameters of plus 0.09 and 0.14 from the initial delta values.

the implied volatility relationship of two different CBs of the same issuer. We find that the implied volatility difference does exist, and the difference shows jumps from time to time.

In order to examine the possible effects of different ratings, the CBs studied here are required to belong to the same issuer, and the ratings of the different CBs are required to be the same. To identify the opportunity, the

EXHIBIT 14
Implied Volatility Relationship



portfolio is set up when the implied volatility difference of CBs is large enough compared with the historical data. We buy CBs with lower implied volatility and short CBs with higher implied volatility of the same issuer. No initial self-capital investment is required for the hedging strategy, and the returns are calculated as the returns of total long assets. In order to delete opportunities resulting from the same jumps, we require that in any consecutive five trading days (one week), only one portfolio be set up the first time an abnormal implied volatility difference exists.

Exhibit 15 reports the average portfolio returns of implied volatility hedging. The portfolio is set up by buying low implied volatility and short-selling large implied volatility CBs of the same issuer. It is a zero initial self-investment capital hedging strategy. The returns are listed as days from the first set-up day of the portfolio when the implied volatility difference is large enough. The exhibit only reports the results of the first 66 days, because after 66 days, the returns are not economically or statistically significant anymore. The returns are positive and mostly significant at a level of 5% during the first 66 days. The highest return is 4.07% at 54 days from the set-up of the portfolio. The number of positive-return observations is generally larger than that of negative-return ones during this whole period. Overall, only a few opportunities for benefiting from convergence hedging are observed—indeed, only 20 are identified over the entire sample period.

We find that the market corrects the implied volatility difference, but it does take some time for the implied volatility to converge. This may be due to thin trading in the underlying CBs. A recommended trading strategy based on these results is to identify the opportunity and then buy and hold the hedging position for about three months from the first time the opportunity shows up.[15]

CREDIT SPREAD CONVERGENCE HEDGE

In this section, we study the performance of a credit spread convergence hedging strategy. The credit spread is calculated as the difference between the yield of the 10-year Treasury bond and the yield of the CB; the yield of the CB is calculated from the difference between the CB's price and the calculated theoretical option value based on historical volatility.

Exhibit 16 depicts the credit spread relationship of two different CBs of the same issuer. It is evident that the credit spread is volatile, although it does exhibit some mean-reverting behavior.