

What Type of Puts Did Warren Buffett Sell?¹

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The title of this piece may look outlandishly puzzling to many. After all, the issue of what type of derivatives Berkshire Hathaway sold during the 2004-2008 period appeared irrefutably settled. Many commentators, including this author, have repeatedly told an identical story. The company itself had been and continues to be painstakingly disclosing the nature of these products, which at first sight appeared simple and easy to understand. That is particularly true when it comes to the equities side of the derivatives play: Berkshire, no one could doubt, chose to sell plain vanilla put options on each of four international stock indices (once more, S&P-FTSE-Nikkei-Eurostoxx). The contracts, admittedly, had some non-common characteristics (big size, long tenor) but they were pretty common in terms of their payout formula and risk parameters. Vanilla equity index options are as familiar to financial markets as the underlying indices themselves. In that sense, then, Berkshire had made a very large and very lengthy stock market bet but a very conventional one, and thus a bet that could be very easily understood and dissected.

Or did it? What if Warren Buffett (Berkshire's chairman initiated the trades and looks after them personally) had sold exotic, not vanilla, puts? Could this even be possible? All the information shared by the firm through its regulatory filings certainly seems to indicate that the puts are nothing if not vanilla. After all, that is why we outsiders have all thought so for so many years. This appeared irrefutable.

Well, allow me to venture into contrarian waters. A January 16th 2008 internal Lehman Brothers report details a transaction that could drastically alter our view of Berkshire's

¹ Forthcoming, *Corporate Finance Review* March-April 2014

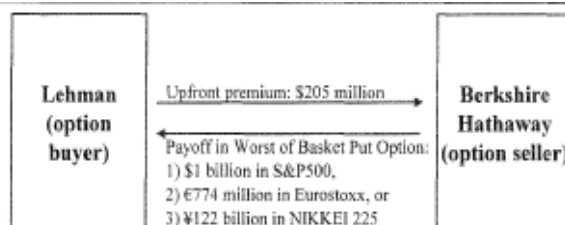
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equity puts exposure. Aided by the boxes and arrows so familiar to derivatives people, the document has Lehman buying a so-called “Worst-Of Basket Put” from Berkshire Hathaway. The basket had three components: the S&P 500, the Nikkei 225, and the Eurostoxx 50. The notional amount was \$1 billion for the S&P component, and the domestic currency-equivalent of \$1 billion for the Nikkei and Eurostoxx components given then prevailing exchange rates (specifically, 122 billion Yens and 774 million Euros). The strikes were all at-the-money, 1433-4158-17441 respectively for the S&P-Eurostoxx-Nikkei components. The presentation indicates that the option was sold in 2007, no specific date indicated. But given the currency rates and index levels, we can imply that the exact date must have been around January-February. The maturity date of the option was 2027. The upfront premium is calculated as \$205 million.

Worst-of put options have a very different payout formula than standard put options. Under this exotic variant, the buyer of the put would enjoy the single largest possible payout from all the basket components. If all basket components expire in-the-money, the payout would be that of the component that expired deepest in-the-money (i.e., the largest possible payout). If one component expires in-the-money while all the others expire out-of-the-money, the payout equals that of the component that expired in-the-money. If none of the components expire in-the-money, no payout accrues. That is, the end-user enjoys the greatest single percentage decline in the basket’s underlying assets. This is very different from a portfolio of individual vanilla puts on each of the underlying assets, as clearly here the end-user could enjoy the same payout as in the case of the worst-of plus any other payouts from any other of the puts that may also expire in-the-money (even if less deep in-the-money). With the worst-of, you only capture the payout from the deepest in-the-money put, but not any other possible payout from the other underlying components. Needless to say, the worst-of would be superior to a single vanilla as the latter can expire worthless while at least some other component of the former expires in-the-money.

The worst-of put is in essence an option where the buyer gets to choose at maturity which underlying basket asset to use to calculate the final payout. Obviously, the choice would be that asset which has declined the most versus the respective strike. In

the Lehman example, if come early 2027 the Nikkei, say, has declined more than the S&P and the Eurostoxx vis a vis their early 2007 levels then the final payout would equal the Nikkei payout, and no more.



- ◆ Lehman buys from Berkshire Hathaway an European-style put option in one of three indices: \$1 billion in S&P500, €774 million in Eurostoxx, or ¥122 billion in NIKKEI 225.
 - Trade Date: 2007
 - Expiration Date: 2027
 - Upfront Premium: \$205 million
 - Strikes: At trade date, the option was at-the-money (1,433.79 for S&P500, 4,158.73 for Eurostoxx and 17,441.16 for NIKKEI 225)
 - Settlement: At expiration date, Lehman will choose the index that will provide the greatest payoff subject to a minimum of zero

The key, of course, is whether this was a real transaction or an imaginary one employed by Lehman for illustrative purposes only (an example of a potential situation that the firm may encounter with a counterpart, say). It feels like it was in fact real. The language is full of certainties (“was”, “will”, “has”, “can’t”, “are”, “is”), and there are plenty of other suggestive details that make it hard to think that this is all just a coincidence and Lehman happened to choose as an imaginary example a trade that shares so many similarities with things Berkshire actually did. The option is struck at-the-money and Berkshire told us that all sold put options were sold at-the-money. The maturity date is 2027, and Berkshire told us that all sold put options expire during 2019-2028. The underlyings are the S&P-Nikkei-Eurostoxx and Berkshire told us that it had sold puts on those indices. Lehman mentions that the transaction does not require collateral postings from Berkshire, a key characteristic in fact of the puts sold by the firm. The trade is classified as Level 3 (hard to value) under US accounting rules, and we also know that Berkshire labels its puts exposure as Level 3. The way Lehman

traders attempted to hedge their position (using 10-year over-the-counter options) is actually described. And, most telling, Lehman provides an actual description of the mark-to-market evolution of the trade since inception (the position was worth \$380 million at the time, an unrealized gain of \$175 million for the bank; increases in volatility in the three indices and a sharp 17% decline in the Nikkei are shared as factors behind such positive evolution). Lehman was using the presentation to internally highlight how its complex derivatives valuation and control process operated, and as such it makes sense that they would actually illustrate things with a high-profile, real-life transaction.

So did Berkshire sell worst-of basket puts? It seems that it did, at least to Lehman and at least for \$1 bn. But the entire equity puts exposure has been around \$30-40 billion. Maybe a \$1 billion here and there indulging in some exotic variant would not be something to write home about. The really interesting question, thus, is whether this would have been a one-off or rather just one sample of many similar trades.

Vanilla or Tutti Frutti?

It may be quite hard for outsiders to confirm whether or not Buffett's equity derivatives forays have the taste of plain simple vanilla or a more colorful exotic flavor. Again, the public disclosures inevitably lead us to the former (I haven't read anyone ever even suggesting that the contracts may be exotic). Perhaps it is possible to work backwards from the put portfolio data, such as quarterly changes in liabilities or intrinsic values or premiums collected, and ascertain the precise nature of the contracts, but that is beyond the immediate purposes of this paper. Maybe this kind of analysis can be thoroughly conducted at a later date.

But hypothesizing for now that Berkshire sold worst-of options, can we get an idea as to the possible performance of those contracts? Is it possible to indicate which of the basket assets, if any, would have clearly outperformed and thus dominated the option's market value? Can we identify such episodes in the life of the trades?

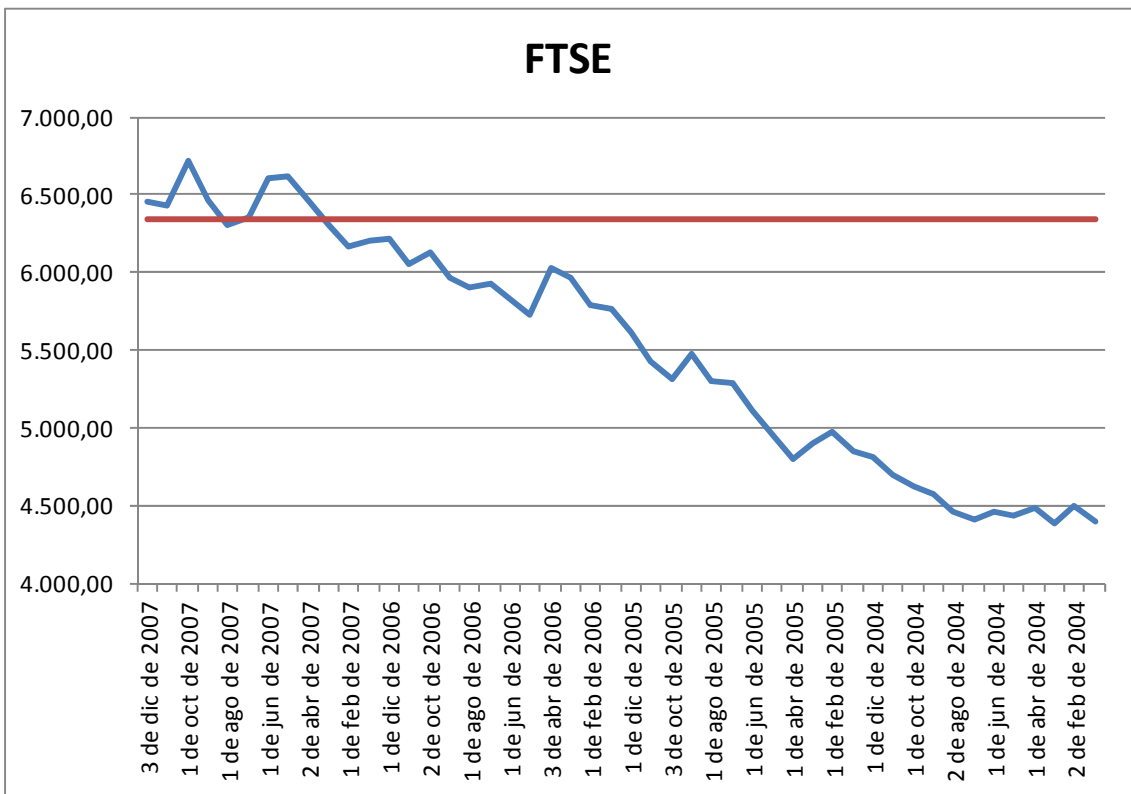
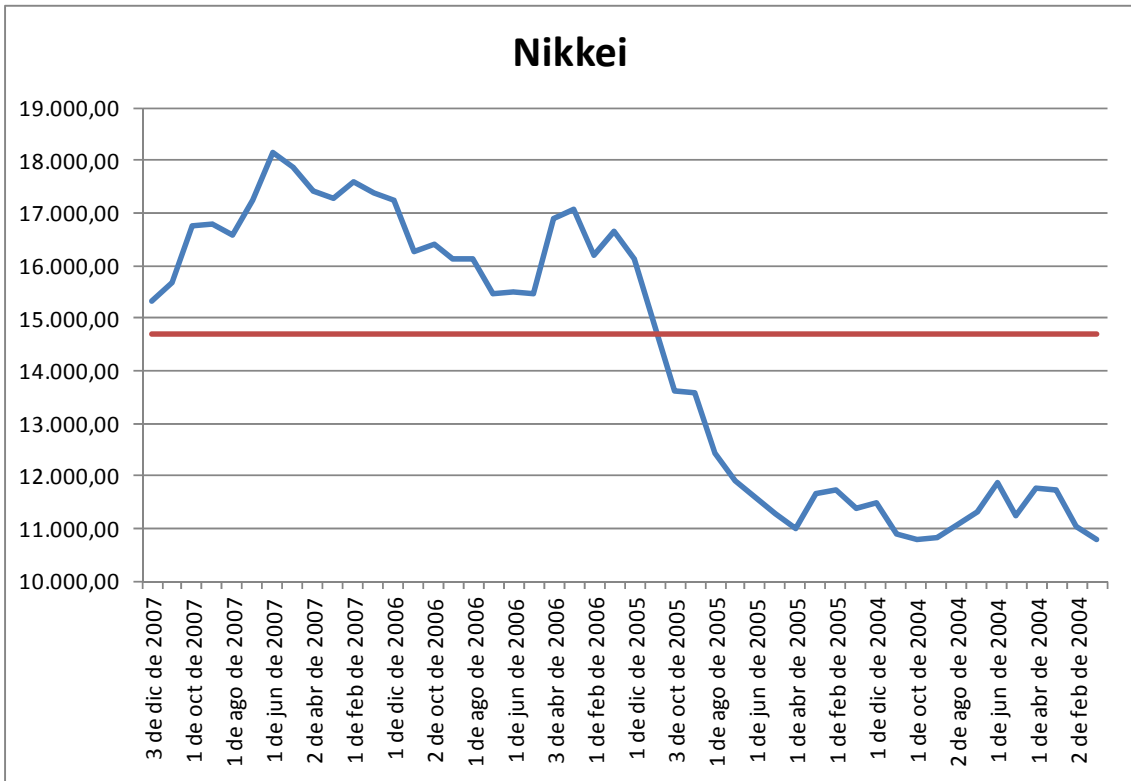
Recall that here the option's expected payout (and thus market value) is not the result of aggregating expected payouts from individual contracts on different indices, but is

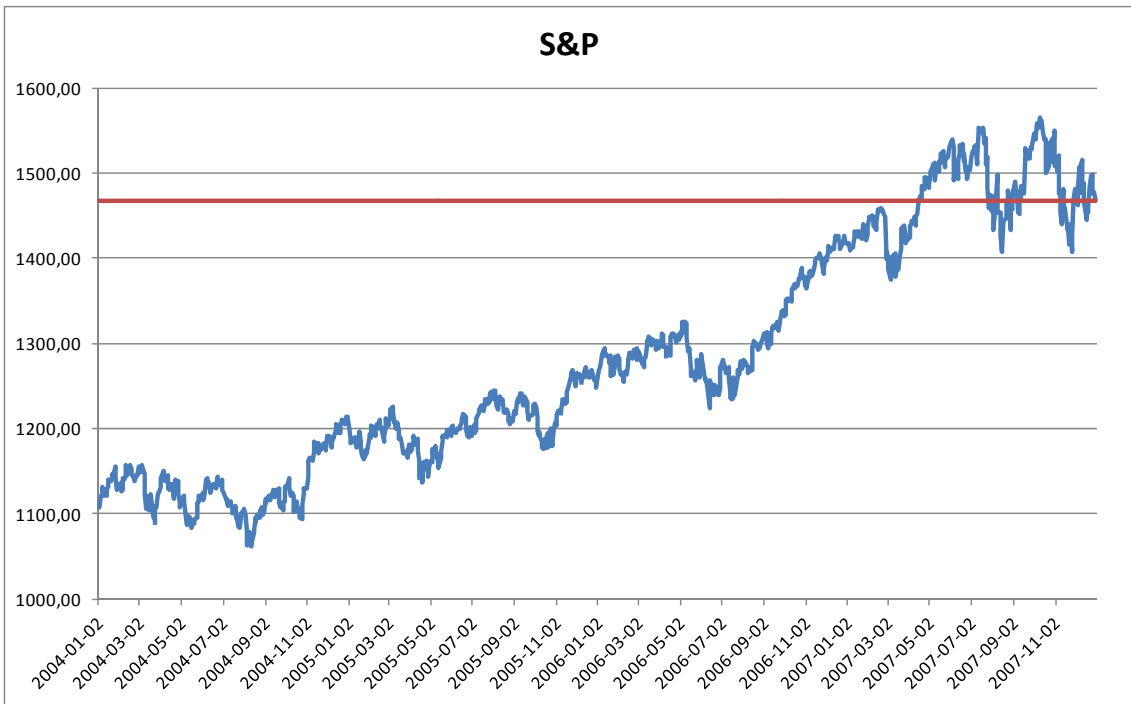
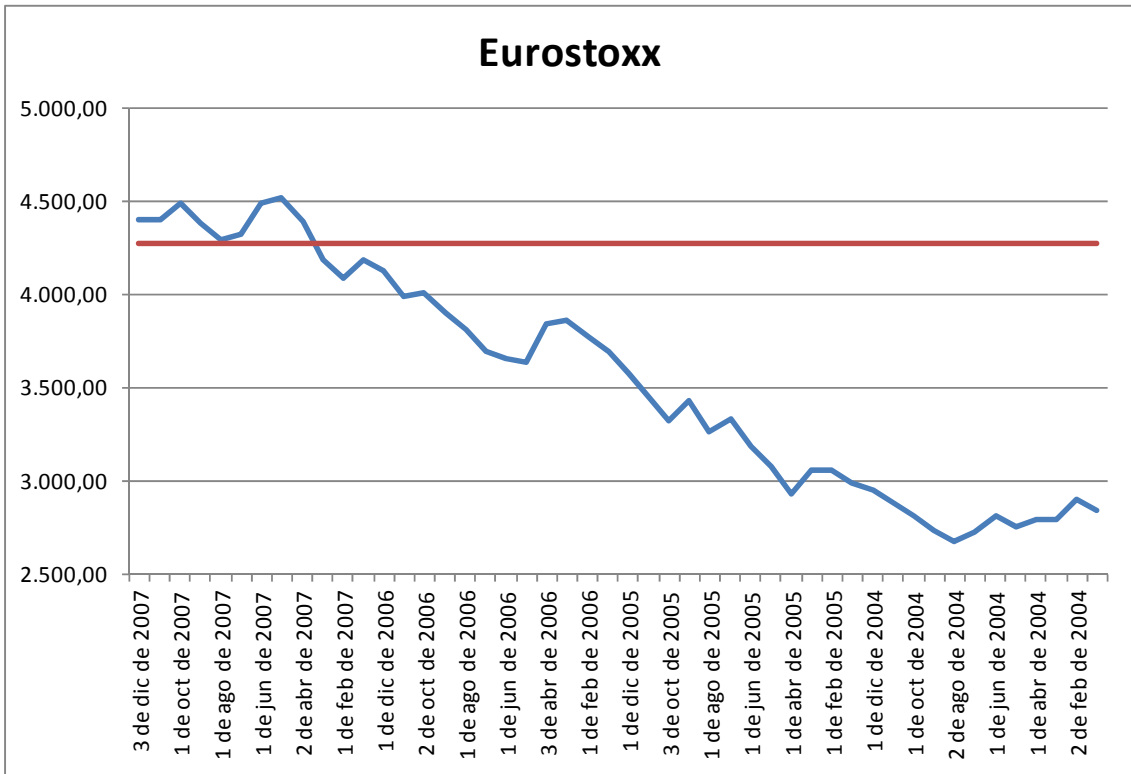
entirely dominated by the largest single expected payout. The worst-of put buyer would get the payout from the best performing individual put, but nothing else from the other individual puts (even if they would have expired in-the-money themselves). Thus, if one of the individual basket components “takes off” and begins to outshine the others, the option’s value would start getting dominated more and more by that component and less and less by the other components. The relative outperformance can get so drastic that the underperforming components stop having any noticeable influence over the put’s value, which in essence becomes equivalent to the worth of an individual put on the outperforming component. In the Berkshire case, the worst-of put would have a value equal to that of the individual S&P put, or the individual Nikkei put, or the individual Eurostoxx put, or the individual FTSE put were the S&P, Nikkei, Eurostoxx, or FTSE respectively to drastically outperform (i.e., decline much more than the others in this case). Any combination that results in the S&P drastically underperforming (e.g., not declining nearly as much as at least one of the other indexes) could effectively lead to an option which value becomes insensitive to what happens in S&P land. Worst-of options completely neglect underperforming assets and worship only outperforming ones, as the option’s payout is linked exclusively to the best performing basket component.

We witnessed such a scenario by year-end 2007, for instance. One of the four indexes did take off from the pack and suffered quite impressive relative declines versus the other three. During 2007, the Nikkei dropped 14% while the S&P-FTSE-Eurostoxx actually experienced (minor) increases. The Japanese index opened the year at 17090 and closed it at 14690, while the S&P opened at 1410 and closed at 1470. Given that all the indexes had experienced a consistent upward trend in the 2004-2006 period and that the S&P-FTSE-Eurostoxx closed the year higher (i.e., at very few points during the period did the indexes quote above year-end 2007 levels; basically only during the final months of that year), and that the Nikkei had quoted above 14690 since late 2005 (having reached a period high of around 18000 in mid-2007) and, again, that the puts were written at-the-money (at the index spot level prevalent when the options were being transacted), the conclusion is that while the Nikkei trade must have at that point been on average deeply in-the-money, while the S&P-FTSE-Eurostoxx trades must

been out-of-the-money (perhaps deeply so) or just very slightly in-the-money. See below graphs comparing the evolution of the indices to their year-end 2007 levels, and a table estimating year-end 2007 in-or-out-of-the-moneyness for each index assuming two families of strike prices (the ones referred in the Lehman example, and more conservative lower ones that try to roughly capture average index levels during the put writing period; we assume a FTSE strike of 6000 in both cases).

In the world of worst-of options, this may have implied that the Nikkei component of the basket now dominated so much that the value of the entire put became fully identified with the value of the Nikkei bet, disregarding the other components that now seemed so far behind. Under such scenario, it would make sense that changes in the value of the put position would very closely mirror, *ceteris paribus*, changes in the dollar exchange rate versus the Yen. Under this scenario, we could in fact have an option where a non-US index ruled the mark-to-market and where the US index meant very little or essentially nothing. The Nikkei performing better makes the Nikkei more relevant *and* the S&P less relevant at the same time, until we are essentially talking about a vanilla Nikkei put (in technical jargon, this phenomenon is called cross-gamma: decreases in the Nikkei makes the S&P delta smaller). The possibility that the S&P 500 component would end up the winner come put expiration date may have appeared mathematically implausible, given that imperial dominance of the Nikkei put. And, as we know, in worst-of land if you can't be the winner you can't be anything.





	year-end 2007 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	1468	-2,44%	-8,74%
Nikkei	14691	15,77%	8,18%
Eurostoxx	4270	-2,69%	-12,37%
FTSE	6348	-5,80%	-5,80%

The Nikkei essentially continued being the worst performing index (Nikkei bet the best performing one) until at least early 2013, as it didn't experience any meaningful recovery from the savage 2008 global financial crisis-market meltdown, instead languishing at the 9000-11000 level for several years in a row. In 2013 it experienced a very pronounced rise, closing at 16300. Coupled with the never ending torpor of the Eurostoxx, which never came even close to approaching pre-crisis highs and only very rarely quoted above 2004 levels and enjoyed a much milder 2013 bump ending up at 3070, that late Nikkei rally would have made the Eurostoxx the worst performing asset as of year-end 2013. That is, while the Japanese index puts could now on average be just slightly in-the-money if not actually out-of-the-money, the Euro index puts would continue to be massively in-the-money. The FTSE and, notoriously, the S&P never looked back and took off like rockets from March 2009. Those puts ended 2013 safely out-of-the-money, hugely so in the case of the S&P. Interestingly, we would now presumably have a situation where the S&P would have little or no influence over the put, as if that particular exposure did not exist anymore. This would make Berkshire's liabilities more directly exposed to the value of the dollar (against the Euro and the Yen specifically), as the chances of a dollar-denominated payout would appear subliminally reduced. In that sense, perhaps the best scenario for Berkshire would be one where the S&P is the worst performing index, thus depriving the firm of any currency exposure on the put.

	year-end 2013 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	1830	-27,70%	-35,56%
Nikkei	16290	6,60%	-1,81%
Eurostoxx	3070	26,17%	19,21%
FTSE	6730	-12,17%	-12,17%

	year-end 2012 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	1466	-2,30%	-8,59%
Nikkei	10670	38,82%	33,31%
Eurostoxx	2709	34,85%	28,71%
FTSE	6089	-1,48%	-1,48%

	year-end 2011 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	1270	11,37%	5,93%
Nikkei	8300	52,41%	48,13%
Eurostoxx	2290	44,93%	39,74%
FTSE	5600	6,67%	6,67%

	year-end 2010 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	1250	12,77%	7,41%
Nikkei	10230	41,35%	36,06%
Eurostoxx	2790	32,90%	26,58%
FTSE	5890	1,83%	1,83%

	year-end 2009 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	1115	22,19%	17,41%
Nikkei	10550	39,51%	34,06%
Eurostoxx	2960	28,81%	22,11%
FTSE	5410	9,83%	9,83%

	year-end 2008 spot	Lehman strikes moneyness	Conservative strikes moneyness
S&P	903	36,99%	33,11%
Nikkei	8070	53,73%	49,56%
Eurostoxx	2530	39,15%	33,42%
FTSE	4560	24,00%	24,00%

The Lehman evidence appears to suggest that Berkshire entered into worst-of puts and thus subjected itself to the exposures just described (we would have to make the additional assumption that the worst-of puts would not have been restructured or unwound in mid 2009 and late 2010 respectively, when Berkshire reportedly made some modifications to its put portfolio). But, once more, Berkshire makes no mention of worst-of puts and all indications lead us to believe it sold individual vanilla puts. For instance, it makes no reference to correlation as a risk factor, when that is a key parameter for pricing worst-of options. It repeatedly indicates that it is using the Black-Scholes formula to value the puts, but can Black-Scholes technology be used to value worst-of puts? (you actually could, at least through the original 1980s early pricing models). It says that for the firm to lose it all, all four indices would have to reach zero; of course, this is not a necessary condition in the case of worst-of puts as just one

index going to zero would be enough (though technically Berkshire wouldn't be telling a complete inaccuracy as you don't know beforehand which index would perform the worst and so you should assume that any of the four would have to go to zero). On the other hand, the labeling of the puts as convoluted Level 3 assets would seem to make much more sense if those were worst-of puts.

Why would Berkshire sell worst-of puts instead of individual vanilla puts? Worst-of puts are cheaper than a portfolio of individual vanillas (with same notional amounts on each of the underlyings) but more expensive than one single individual vanilla. Maybe the market was demanding that type of product, perhaps as a back-to-back hedge on accumulated risk. Maybe Buffett began with the idea of betting on the S&P alone, and the counterparts told him he could raise more premium by selling a worst-of. Maybe he didn't want to face the larger exposure from selling a group of individual puts (including larger potential loss payouts, larger liabilities, more pronounced risk factors). Or maybe, at the end of the day, he never sold a single worst-of put.

Somewhere Over the Rainbow

The seller of worst-of puts (members of the "multifactor" or "rainbow" options family, referring to those products which payoff is linked to the performance of several, not just one, underlying assets) is exposed to mark-to-market risks in a different manner than the seller of plain vanilla puts. This means that now the liabilities number, and thus the quarterly gains or losses, generated by the trade would change for different reasons and with different intensity. In essence, by deciding to sell worst-of puts rather than vanilla the seller becomes exposed to new risks.

For example, correlation risks. The worst-of put benefits from dispersion, as a large range of possible outcomes for the basket components increases the probability not only that at least one will expire in-the-money but that at least one will expire really deep in-the-money. Since you are entitled to the very best payout, you appreciate the chance of the option generating a very large payout. Also, the only way this option doesn't pay out is if none of the underlying basket assets ends up in-the-money, and

for this to happen the components would have to be positively correlated (move all in the same direction, which of course includes all moving upwards above the respective strikes). Negative correlation or lack of correlation could deliver at least one in-the-money component. Thus, the buyer of a worst-of put is short correlation (long dispersion), making the seller long correlation (short dispersion). As opposed to standard basket option structures, where payout is based on the average performance of the basket components including in-the-money and out-of-the-money ones, increases in correlation diminish the value of the worst-of. Dispersion makes it easier for at least one of the basket components to be in-the-money and for a very large payout to take place, the opposite being true for lack of dispersion. In contrast, best-of-puts (where the payout would be that of the worst performing put, or best performing underlying asset) gain with correlation as now you need all the components in-the-money in order to enjoy a payout, and dispersion is an enemy of that while very high positive correlation includes such scenario (all assets moving down below their respective strikes).

Worst-of puts have “negative cross-gamma”. This means that when one of the assets underperforms relative to another, the sensitivity of the option’s value with respect to the latter asset is reduced. In other words, the relative strength of one asset leads to relative weakness in the other asset: as the overperforming asset matters more, the underperforming asset matters less (its delta becomes smaller in absolute value, even if that asset has improved its individual in-the-moneyness; what matters is relative not absolute performance). Of course, this is a marked change with regards to a portfolio of vanilla puts, where the deltas of every single option can matter a lot at the same time and do not have to cancel each other out. In a worst-of put the deltas of underperforming assets can diminish all the way into oblivion, with that basket component now effectively having no impact whatsoever in the option’s total value. In the case of a portfolio of vanillas, it is unlikely for single delta to stop having an impact, even if that component would be quite out-of-the-money and notwithstanding the relative performance of the other components. In vanilla land the individual relevance of a single underlying asset is independent of the relevance of the other underlyings: an underlying can still matter even if at least one of the other underlyings matters

subliminally more. In worst-of land that's not the case: superstar underlyings erase the influence of the others, essentially killing their deltas. For a vanilla portfolio the total value will always be the sum of the values of the independent components, and all deltas will change that total value. For a worst-of, the value can be determined uniquely by one of the components, its particular delta now the option's delta.

A similar "Greek extermination" process can apply to the vega of a worst-of. As the underperforming component takes off, its vega becomes relative weightier and the other vegas lose shine, until potentially they may not matter at all. The volatility/ies of an underlying asset/s can end up having no impact on the option's value, a clear departure from vanilla land. Rho and theta can also end up dominated by one or two underlying basket components.

It follows that a worst-of put would be less exposed from a mark-to-market point of view than a portfolio of vanillas. The standard Greeks can be quite smaller, as they would likely not equal the sum of the individual Greeks. The worst-of delta, vega, and rho figures would be subdued. The liabilities incurred by the seller could thus be much less severe than under the cumulative vanilla portfolio scenario.

How would Berkshire have fared? Well, it seems from our previous analysis that the Nikkei Greeks would have dominated almost throughout. And the S&P and FTSE Greeks would have been progressively exterminated, their relative contribution having been exorcised, especially in the case of the US index. What happens in Japan and in Europe would now drive the entire option's market value. As for correlation, the option would have certainly experienced a highly correlated event in late 2008 and early 2009, with all indexes tanking and all volatilities exploding. The worst-of put's accounting worth would have suffered from such lack of dispersion. Interestingly, the put liabilities reported by Berkshire for those dates feel, at \$10 billion out of a \$35 billion notional exposure, somewhat low under the assumption that those are individual single-index vanilla puts.