An Evaluation of the Performance of Oil Price Benchmarks During the Financial Crisis

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I. Introduction

The events of late-summer, 2008 through the spring of 2009 have attracted considerable attention to the performance of oil price benchmarks, most notably the Chicago Mercantile Exchange's West Texas Intermediate crude oil contract ("WTI" or "CL" hereafter) and ICE Futures' Brent crude oil contract ("Brent futures" or "CB" hereafter). In particular, the behavior of spreads between the prices of futures contracts of different maturities, and between futures prices and cash prices during the period following the Lehman Brothers collapse has sparked allegations that futures prices have become disconnected from the underlying cash market fundamentals. The WTI contract has been the subject of particular criticisms alleging the unrepresentativeness of the Midcontinent market as a global price benchmark.

I have analyzed extensive data from the crude oil cash and futures markets to evaluate the performance of the WTI and Brent futures contracts during the LH2008-FH2009 period. Although the analysis focuses on this period, it relies on data extending back to 1990 in order to put the performance in historical context. I have also incorporated some data on physical crude market fundamentals, most notably stocks, as these are essential in providing an evaluation of contract performance and the relation between pricing and fundamentals. My conclusions are as follows:

1. The October, 2008-March 2009 period was one of historically unprecedented volatility. By a variety of measures, volatility in this period was extremely high, even compared to the months surrounding the First Gulf War, previously the highest volatility period in the modern oil trading era. Moreover, the behavior of fundamental measures, including stocks, was historically extraordinary as well.
2. For both CL and CB, the price collapse that occurred in Fall 2008 was accompanied by a dramatic increase in contango (measured by the spread between the first and second nearby prices), and an increase in the volatility in spreads between futures with different maturities.
3. By a variety of measures, the hedging performance of both WTI and Brent declined for a variety of cash instruments during the period of heightened volatility. This decline in hedging performance was most pronounced for front month WTI.
4. Hedging performance for first month WTI with respect to Midcontinent crude streams was sound. By a variety of measures, the hedging performance of both WTI and Brent declined for a variety of waterborne cash-traded crude streams, including those in the US Gulf, during the period of heightened volatility.
5. The performance of the second month WTI contract was comparable to that of the first and second month Brent contracts.
6. The decline in hedging performance, and increase in spread volatility, occurred at the same time as an unprecedented increase in the stocks of oil held at Cushing, Oklahoma (20 million barrels), in the US (66 million barrels) and the OECD as a whole (110 million barrels in August, 2008-March, 2009).
7. For most of the period studied, there is a strong relationship between Cushing stocks and spreads, and this relationship is that predicted by economic theory; namely, that higher stocks are associated with a rise in the deferred price relative to the nearby price. This is consistent with a market being driven by fundamentals.
8. During October, 2008-March, 2009, the relation between WTI spreads and stocks became more variable, but this relation still was consistent with the spread-stock relation reflecting economic fundamentals. That is, higher contangos were associated with higher stocks.

9. With respect to Brent, during October, 2008-March, 2009, the relation between Brent spreads and US stocks was opposite that predicted by economic theory; stocks and Brent spreads moved in opposite directions during this period. Because US and OECD stocks exhibited similar movements during this time period, this suggests that Brent spreads may not have been reflecting supply demand fundamentals (as proxied for by OECD stocks).[1]

10. US cash crude spreads exhibited behavior similar to WTI futures spreads. They experienced large moves at the same times. This suggests that US market-wide conditions, rather than factors specific to the WTI contract, were the decisive determinants of pricing behavior during this period.

11. The behavior of the WTI-West Texas Sour (WTS) spread provides further evidence that conditions in the Midcontinent were the decisive factor. Both of these crude streams utilize Cushing storage. During the November, 2008-March, 2009 period, the front month WTI-front month WTS spread exhibited behavior similar to that observed in prior periods, but the second month WTI-front month WTS spread was substantially more volatile. This is consistent with physical market conditions at Cushing (and the Midcontinent more generally) being the primary driver of price relations during this period.

One interpretation of these results is that: (a) the unprecedented increase in fundamental uncertainty caused a decline in the hedging performance of both the WTI and Brent contracts, and (b) the similarly unprecedented surge in stocks that occurred simultaneously caused a significant increase in the contango, most notably in the WTI market.

In particular, the metastasizing financial crisis caused:

- A substantial decline in the demand for crude products (and hence crude oil). In particular, distillate demand plummeted during this period.
- A substantial build-up of crude inventories around the world, but most notably in the US Midcontinent; since oil supply does not adjust in the short run, the steep drop in demand resulted in large and rapid accumulation of stocks.

[1] Due to the lower frequency of OECD inventory data, it is not possible to test this conjecture rigorously.

- A large and rapid drop in prices of crude oil and refined products.

The accumulation of stocks was a world-wide phenomenon. There are extensive published reports, including those released by the International Energy Agency, that large amounts of crude were stored in tankers at sea. This is highly unusual, and reflects the markedly unusual conditions prevailing at the time. The substantial inventory build at Cushing was thus part of a global phenomenon, although the US Midcontinent more reflected this more (and more transparently) than elsewhere. For the most part, the nearby WTI futures contract was accurately reflecting these Cushing and Midcontinent fundamentals, and was consistent with the patterns observed for OECD stocks.

These conditions dominated the market for several months. Eventually, output cuts reduced the demand for storage and permitted a return of more typical pricing relationships, and importantly, a restoration of the previously observed hedging effectiveness of the primary world crude pricing markers, including WTI.

Based on this interpretation, and the totality of the extensive data analysis, I conclude that the behavior of the WTI futures contract during the financial crisis reflected the truly unprecedented conditions prevalent during that period. Fundamental volatility was extraordinarily high during this period. Moreover, the collapse in demand caused by the acute worldwide economic contraction made it optimal to increase sharply the amount of oil in storage. These factors combined to inject volatility in futures spreads and cash-futures spreads.

However, in 2Q09, hedging performances of the WTI and Brent contracts have returned to approximately their pre-crisis levels. Thus, the data do not support a general claim that the hedging performance of WTI (or Brent) has declined except under truly exceptional circumstances.

Therefore, it is important not to read too much into the hedging performance of the futures market during October, 2008-March, 2009. This behavior was quite explicable by the extreme shocks to fundamentals that occurred during this remarkable period, and is not a harbinger of a long-term decline in performance. A return to more normal circumstances, and most importantly, a recovery of demand that leads to the return of inventories to more typical levels, will result a return to the pricing behavior experienced before the crisis.

The remainder of this report is organized as follows. Section II sets out the statistical methods deployed and the data utilized. Section III analyzes the behavior of volatility; of spreads and basis; and hedging effectiveness of the WTI and Brent contracts, with a focus on the November, 2008-March, 2009 period. Section IV evaluates the behavior of fundamentals, notably US stocks, Cushing stocks, and refining activity. Section V summarizes the report.

II. Methodology and Data

I evaluate the behavior of several indicia of oil contract performance. I first review the behavior of the spread between the first and second nearby contracts for the WTI and Brent contracts. I then evaluate the basis between the front month CL and CB contracts, and several cash market indicators. The futures-cash pairs examined are:

- CL-Dated Brent
- CL-Dubai

- CL-Gulf Coast Gasoline (“GCG”)
- CL-Louisiana Light Sweet (“LLS”)
- CL-MARS
- CL-West Texas Sour (“WTS”)
- CB-Dated Brent
- CB-Dubai
- CB-Gasoil
- CB-Singapore Gasoil

Then, for each of these futures-cash pairs, I use a variety of methods to estimate the correlation between the futures price change and the cash price change. Correlation is a measure of the hedging effectiveness of a futures contract, that is, the amount of risk that can be reduced by using the futures contract as a hedge. Specifically, the fraction of variance that can be eliminated by using the futures contract as a hedge of a particular cash grade equals the square of the correlation between the futures price change and the cash price for that grade.

It is well known that correlations can vary through time. Therefore, it is imperative to utilize methods that permit such time variation. I use two approaches.

The first is to estimate “rolling” correlations. That is, I estimate correlations between each futures-cash pair over a three-month long period, rolling that period forward in time by one observation period from the beginning of the data set to the end.

The second is to estimate a bivariate “GARCH” model. The GARCH model is a time series model of variances and covariances. It posits that variances and covariances vary through time in a specific way. In particular, variances at a given point in time depend on variances at the previous date, and the squared innovation (unexpected price movement) in each price. Covariances behave similarly. This is one of the most widely utilized methods in the time series analysis of financial prices.

In previous, published research, I have shown that variances and covariances in commodity prices can vary with futures spreads. Moreover, theory predicts such a relationship. A deep backwardation typically occurs under tight supply-demand conditions, and prices are usually more volatile given such tight fundamentals. A steep contango typically reflects constraints on storage capacity. Under these circumstances, these constraints limit the ability to accommodate fundamental supply and demand shocks by adjusting inventories, requiring prices to bear the burden of the adjustment to these shocks.

Specifically, in oil markets, variances and covariances can depend on whether the market is in contango or backwardation, and the magnitude of the contango/backwardation.[2] To capture this effect, I estimate models that allow variances and covariances to depend on the levels of backwardation and contango

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[2] Craig Pirrong, Metallgesellschaft: A Prudent Hedger Ruined, or a Wildcatter on Wall Street? J. of Futures Markets (1995). The models estimated in that paper, and herein, have multiple equations. For each commodity pair, there is a covariance equation. In addition, for each element of the commodity pair, there is a variance equation. These three equations allow the estimation of the time-varying variances of prices for each element of the pair and the time-varying covariance between them; given this information, it is possible to estimate a time-varying correlation (because the correlation is the ratio of the covariance to the square root of the product of the variances).

in the market. I refer to this as "backward and contango adjusted GARCH" ("GARCH BCAG").

Theory also predicts that correlations between futures of different maturities, and between cash and futures prices can depend on futures spreads. For instance, the cash-and-carry arbitrage relationship is attenuated when stocks are low and the market is in backwardation. Under these circumstances, the correlation between nearby and deferred futures prices is likely to be low. Similarly, if the marginal cost of storage becomes quite inelastic when inventories become large, then (a) the market will be in a large contango, and (b) nearby-deferred spreads will be volatile, and correlations between these prices low, because small fundamental shocks can have a large effect on the marginal cost of storage, causing nearby and deferred prices to move differently in response to such shocks.

I estimate two different types of GARCH BCAG models. In the first model, the covariance between the futures price change and the cash price change depends on (a) a constant, (b) the lagged covariance, (c) the lagged product between the unexpected futures price change and the unexpected cash price change, (d) the lag of the square of the log difference between the nearby price and the first deferred price, if that difference is positive, and (e) the lag of the square of the log difference between the nearby price and the first deferred price, if that difference is negative. Variable (d) measures the effects of backwardation on the covariance between futures and cash, whereas variable (e) measures the effects of contango on this variance.

The second model incorporates variables (d) and (e), but assumes that when the nearby and deferred futures are equal, the correlation between the futures and cash price changes is a constant (estimated by the model).

Both models assume that the variances of the cash and futures prices depend on (a) a constant, (b) the lagged variance, (c) the lagged squared unexpected price change, (d) the lag of the square of the log difference between the nearby price and the first deferred price, if that difference is positive, and (e) the lag of the square of the log difference between the nearby price and the first deferred price, if that difference is negative.

The futures data used in the analysis were daily settlement prices obtained from the Commodity Research Bureau. The cash prices were from Platts, and provided by the Chicago Mercantile Exchange.

Since the various cash price and futures price markers were determined at different times on a given trading day, for most of the analysis it is impractical to utilize daily price data. For instance, the measured close-to-close price change in Dubai crude occurs between 0430 ET and 0430 ET the following day, whereas the measured close-to-close price change in WTI occurs between 1430 ET on successive trading days. Thus, information that can affect NYMEX price changes on a particular day at a time subsequent to the determination of the Dubai price on that day will only be reflected in the Dubai price data for the following day. This time mis-match tends to reduce measured correlations in daily data. As a result, to minimize the impact of time mismatch, I perform all correlation analyses on weekly data.

III. Volatility, Spreads, and Basis

The figure labeled "CL Front-LLS Variance (BCAG)" represents the variance of the weekly (log) change in the WTI nearby futures price, and the variance of the weekly (log) change in the LLS cash price.[3] The figure depicts the weekly variances over the period 3 January, 1990-14 July, 2009.

The figure demonstrates that the variances of cash and futures prices vary over time. Most notable, though, is the behavior of volatility in 2008 and 2009. Specifically, these variances were low, by historical standards, during the period of historically high (nominal) oil prices in the summer of 2008. Moreover, these variances were *extremely* high commencing in the fall of 2008, and reached a peak in the winter of 2009. Indeed, the variances were approximately 4 times higher at their peak in 2009, than the highest post-Gulf War I peaks, and more than double the levels observed even during the first Gulf War.

Converting these variances into annualized standard deviations (volatilities), whereas the average level of volatility in the post-Gulf War-pre-Financial Crisis period was on the order of 33 percent per year, in February, 2009, this volatility was over 100 percent. Thus, the period of the Financial Crisis was one of unprecedented volatility in oil prices.

The Financial Crisis also had a dramatic effect on the spreads between nearby and deferred oil futures prices, both WTI and Brent. Two figures illustrate the behavior of these spreads.

[3] The basic results do not depend on the choice of estimation method, or the cash price indicator.

The figure labeled “CL Front-Back Log Difference” graphs the difference between the log of the CL front month and the log of the CL back month price, for the July, 2005-July, 2009 period. The figure labeled “CB Front-Back Log Difference” graphs the difference between the log of the CB front month and the log of the CB back month price, for the July, 2005-July, 2009 period.[4]

Both figures show that the spreads were relatively stable prior to the late-summer of 2008, for WTI varying between approximately -.04 (contango) and .01 (backwardation). Then, in October, 2009, the (log) spread for both WTI and Brent began to decline dramatically, before returning to previously-observed levels in the spring of 2009. Moreover, for both WTI and Brent, the spread graphs exhibit sharp downward spikes in the December, 2008-February, 2009 period (for WTI) and November, 2008-May, 2009 (for Brent).[5]

The general dramatic decline in spreads in both WTI and Brent can be explained readily given the substantial economic contraction and financial crisis that occurred during this period. Economic theory predicts that a substantial decline in demand for a commodity makes it optimal to accumulate inventories, especially when it is very costly to adjust output (as is the case in oil). Prices adjust into contango to provide a financial incentive to engage in such accumulation. When, as is the case in oil, the marginal cost of storage is increasing in the amount

[4] Since there are no time mismatch issues associated with these futures spreads, these graphs are constructed using daily data. The logarithm transformation mitigates the effect of price levels on the basis. A log difference is essentially a percentage difference. The relationship is much more variable when the log transformation is not used.

[5] There is an upward spike in the WTI spread on 22 September, 2008. This occurred on the expiry date of the October contract.

stored (due, for instance, to operational constraints in storage facilities, or the necessity to utilize seaborne storage), very wide contangos may be required in the face of a very large economic shock that sharply reduces the demand for oil, and hence increases sharply the optimal amount of oil to store. That is, the very large change in spreads during the financial crisis is exactly the kind of price response to be expected in the face of an economic shock that dramatically reduces demand. It is also, to a degree, consistent with the increase in oil inventories observed over this period; this issue is discussed in more detail in Section IV below.

The "spikes" in the spreads are more difficult to attribute to economic fundamentals, and instead are more likely reflective of technical features in the WTI and Brent markets. The three large downward spikes in the WTI spread occurred on 12/19/2008, 1/15/2009, and 2/12/2009; there was a large upward spike in this spread on 2/19/2009. The 12/19/2008 and 2/19/2009 spikes occurred on contract expiry dates. The 1/15/2009 and 2/12/2009 occurred a few days before contract expiration.

The three spikes in Brent occurred on 11/13/2008, 3/16/2008, and 5/14/2009. The first two are expiry dates, the third a day prior to expiry.

The occurrence of these spikes on or near expiry suggests that they were due to technical factors associated with the end of trading of futures contracts, rather than fundamental factors.

A statistical analysis supports this view. In the 1/3/1990-6/30/2008 period, the standard deviation of the change in the CL log spread prior to the last three days in the expiry month was .0022, whereas in the last three trading days this volatility was .0085. Thus, even before the financial crisis, the spread was substantially more volatile in the few days prior to expiration than in the period between the prior expiration and the fourth trading day of the month. This again provides evidence that technical factors related to expiration were affecting price behavior as expiry neared.

The disparity became even more extreme in LH2008-FH2009. In that period, the spread volatility prior to the last three trading days was .012, but the spread volatility in the last three days was .0334. Thus, during the height of the financial crisis, spread volatility was extremely high during the last three trading days, even in comparison to its already elevated level during the financial crisis, but prior to the last three trading days. This suggests that the technical factors became even more important during this period of time.

Brent exhibited similar behavior, though not quite as severe. For the period prior to 30 June, 2008, the spread volatility was .0023 prior to the last three days of the expiry month (almost exactly the same as observed for WTI), and .0051 during the last three days. Thus, technical factors associated with expiration evidently affected the Brent contract prior to the financial crisis, but not to the same extent as observed for WTI. During the financial crisis, LH2008-FH2009, Brent spread volatility prior to the last three trading days of a given contract was elevated, .0045, and the volatility during the last three days was also elevated, to .0109. So again, there is evidence of the impact of expiration-driven technical features on Brent; that these technical pressures were greater during the financial crisis than before; but that the effect of the crisis on these technical pressures was less severe for Brent than WTI.

My interpretation of these findings is as follows. The unprecedented economic uncertainty associated with the financial crisis created unprecedented volatility in oil cash and futures prices. Moreover, the substantial economic contraction associated with the crisis dramatically reduced demand for oil, making it optimal to increase oil inventories by a marked amount. Naturally, the market moved into contango to reward such inventory accumulations. The combination of volatility and increases in oil storage exacerbated the technical frictions that contribute to basis volatility late in the trading of an expiring contract, leading to especially elevated basis volatility for the WTI contract. Subsequent analysis, notably that of stocks, will support this interpretation.

This can be interpreted another way. The market for spreads between nearby and deferred contracts is essentially discovering the (shadow) price of storage. The market for storage in Cushing is not a centralized market, but a search market. One would expect that a dramatic increase in fundamental uncertainty in the oil market (demonstrated graphically by the huge volatility spike discussed above) and a surge in demand for storage capacity (demonstrated by the dramatic increase in oil in-store in Cushing as documented below) would lead to increased transactions costs in the storage market due to the necessity of negotiating more transactions in conditions of uncertainty (and likely information asymmetry). One would expect too that in a search market, greater uncertainty would lead to greater dispersion across transactions and over time in the price of storage. In turn, these developments would tend to widen the spread and make it more volatile as the market groped to discover the price of storage under conditions of historic uncertainty.

It should be noted that US cash market spreads exhibited behavior similar to that of NYMEX WTI, although to a somewhat lesser degree. The chart titled "US Oil Nearby-Deferred Spreads" depicts the nearby-deferred spread for LLS, WTI cash, and WTS, as well as NYMEX WTI for the November, 2008-February, 2009 period. Note that the cash spreads spike downward each time there is a downward spike in the nearby NYMEX WTI spread; the NYMEX WTI spikes are more pronounced (except for cash WTI), but the coincidence of these spikes provides evidence that these movements were driven by broader fundamental forces in the US oil market, rather than something peculiar to the NYMEX CL contract. Note particularly that the cash WTI spread is almost identical to the NYMEX WTI spread; this indicates that convergence occurred even during these exceptional episodes. Moreover, with respect to the December, 2008 spike, the January-February cash WTI spread widened even further in the day after the expiry of the NYMEX January contract.[6] This suggests that conditions in the Cushing cash market, not something peculiar to the NYMEX expiry alone, drove the pricing relations during this period.

Relatedly, the behavior of NYMEX WTI-WTS spreads suggests that constraints in Midcontinent storage, or frictions in the market for this storage, played the major role in driving price relations during this period. Note that in the December, 2008-June, 2009 period the front month CL-WTS spread was not

[6] The cash contract trades for at least one more day than the NYMEX future.

especially volatile (especially compared with its behavior in the 2005-2007 period, and compared to the spread between front month CL and other cash grades), but the back month CL-front month WTS spread was very wide and volatile during the December, 2008-March, 2009 period. Moreover, this spread spiked up when other front month CL spreads spiked down. Given that WTS (Midland) is in the region tributary to Cushing, this suggests that Cushing/Midcontinent physical market factors were decisive during this highly volatile period.

Put differently, although NYMEX front month WTI price relations (spreads) were extraordinary during this time, the relations between WTS and other cash grades were similarly remarkable. Thus, rather than reflecting something specific to the futures market or the CL futures contract, the spread behavior during the period of the financial crisis was reflecting fundamental conditions in the Midcontinent market.

These results suggest that price relations can be stressed by extreme fundamental conditions, and that these stresses are likely to affect the front month contract most acutely. Although this finding is not immaterial, its importance should not be overemphasized. By the time that the expiring contracts most clearly reflected the extraordinary circumstances prevailing at the height of the crisis, the vast majority of open interest in the contracts had already liquidated, most of it rolling to the first deferred contract. Thus, most hedgers, and most using the contract for speculative purposes, were not exposed to the effects of these factors. Those most at risk were those holding financially settled positions with cash flows tied to the settlement price of the WTI contract on expiration day. Moreover, as will be demonstrated in the next section, the first deferred contract (to which most hedgers and speculators will have rolled prior to the third trading day before expiration) demonstrably suffered substantially less from the effects of economic volatility and contract technical features.

IV. Hedging Effectiveness

The analysis of hedging effectiveness is based on several sets of figures, each set corresponding to a different method for estimating correlations between futures and cash price changes. Figures with "Correlation" in the title depict rolling correlations between the futures prices (front and back month) and cash price in the title. Those with "BCAG" in the title are based on the BCAG methodology, while those with "GARCH BCAG" are derived using the GARCH BCAG methodology. Each figure depicts hedging performance beginning in March, 1990 and ending in July, 2009. I present the time series of hedging effectiveness over a long time period in order to put the events of LH2008-FH2009 in historical perspective.

Some general observations are in order before I present a more detailed analysis. First, regardless of the methodology, correlation/hedging effectiveness varies over time. Therefore, it is necessary and useful to evaluate performance during a particular period with reference to performance over other periods. Second, the level and variability of correlations also differs across products. Not surprisingly, correlations for more closely-related commodities (e.g., CL and LLS) tend to be higher, and exhibit less variation than correlations for less closely-related ones (e.g., CL and GCG).

With those considerations in mind, first consider the rolling correlation charts.

An examination of the rolling correlations supports several findings:

1. Correlations for WTI front and back month contracts declined commencing in late-2008, and returned to levels comparable to those observed in earlier periods at the end of 1Q09. The timing of the decline differed among cash grades, with the Dubai correlation declining beginning in October, and the LLS and Brent correlations declining beginning in December.

2. For front month WTI, the decline in correlation was less severe than had been observed at earlier times, with the exception of Dubai, where hedging effectiveness plunged to 0 before rebounding sharply.

3. Declines in back month WTI correlation were far less severe than for front month. Moreover, most of the declines were modest, and of a magnitude smaller than numerous declines observed in prior years. Thus, the rolling correlation analysis implies that the financial crisis did not have a remarkably large impact on the hedging effectiveness of the back month contract.

4. Brent rolling correlations also declined during the period of the financial crisis. The correlation declines were of a magnitude similar to those observed frequently in prior years.

5. In contrast to WTI, the decline in Brent hedging effectiveness was (slightly) larger for the first deferred contract than the front month contract.

6. For both WTI and Brent, the largest decline in hedging effectiveness was observed for Dubai, and for this cash grade, the decline in WTI hedging effectiveness was greater. This is not surprising, given the generally closer relation between Dubai and Brent.

In brief, the rolling correlation data show that the financial crisis and its associated effects on crude markets caused a decline in hedging effectiveness, but despite the unprecedented nature of the crisis, the decline in hedging effectiveness was not unprecedentedly large. The front month WTI contract was most adversely affected. This likely reflects the technical factors discussed in sections III and V. In contrast, the first deferred WTI hedging effectiveness was not as seriously affected, and behaved similarly to the effectiveness of the Brent contracts.

Next consider the GARCH BCAG hedging effectiveness estimates.

7. WTI front month and back month hedging effectiveness declined 4Q08, and rebounded to reach pre-crisis levels at the end of 1Q09. The decline in correlation for the front month was larger during this period than estimated previously for CL Front-Dated Brent, CL Front-Dubai, CL Back-Dubai, CL Front-GCG, and CL Front-LLS.[7] Thus, with the exception of Dubai, the decline in correlation for the first deferred contract during the financial crisis was of a magnitude similar to other declines observed in the 1990-FH2008 period.

8. With the exception of Gasoil, Brent front month and back month hedging effectiveness also declined 4Q08, and rebounded to (approximately) pre-crisis levels at the end of 1Q09. The observed correlation declines were not unprecedentedly large, because similar (or larger) declines occurred in prior years.

Finally, consider the results for the BCAG analysis.

9. Again, WTI hedging effectiveness declined during the period of the financial crisis for all cash grades considered. The declines were larger for the front month contract. Moreover, the declines were typically larger during LH09-FH08 than had been observed in prior years. .

10. Brent correlations declined during the period of the crisis, but these declines were small relative to (a) the declines that had been observed previously, and (b) the declines observed for WTI.

11. The differential performance between WTI and Brent under the BCAG measure reflects the fact that in this model the estimated effect of contango on correlation is smaller for Brent, than WTI. This could reflect the impact of constraints at the Cushing delivery point on WTI cash price dynamics. As will be discussed in section V below, large Cushing storage levels (and consequently large CL contango) clearly affects WTI pricing.

Overall, the hedging effectiveness/correlation results demonstrate that the financial crisis did degrade hedging effectiveness for both the WTI and Brent futures. The decline was most pronounced for front month WTI. The correlation

[7] There was insufficient data to estimate this model for MARS.

declines for back month WTI and the two Brent contracts considered were comparable, and for two of the three measures considered, of a magnitude similar to declines observed in prior, non-crisis periods.

One interesting finding is that the decline in CL front month hedging effectiveness for WTS was noticeably smaller than for other cash grades considered. This is true for all three measures of hedging effectiveness: rolling correlation, and the two GARCH measures. This provides evidence that Midcontinent price relations were less affected than relations between the Midcontinent and other regions. Given that WTS (based on Midland, TX prices) is tributary to the NYMEX delivery location at Cushing, this suggests that all Midcontinent oils were reflecting common fundamentals related to conditions at the Cushing market, and that the Cushing/Midcontinent fundamentals were somewhat unique and location-specific.

V. Fundamentals and Price Behavior

Although unusual price behavior can sometimes be identified through an examination of price data alone, quantity data can greatly improve the ability to identify such behavior, and to assist in the diagnosis of its causes. In this section, I examine futures price and inventory data together to shed additional light on the performance of crude oil price benchmarks during the LH2008-FH2009 period.

The economic theory of storable commodities implies that futures spreads (e.g., the difference between the nearby and deferred prices) should covary with inventories of the commodity in a specific way. In particular, the difference between the deferred price and the nearby price should be greater, the greater the quantity of inventories. This relationship should be closest between spreads and stocks at the contract delivery point (rather than a more aggregated inventory figure), and for contracts with relatively short times to expiration. It is important to note that spreads do not cause inventories, or vice versa; prices and inventories are determined simultaneously, and the relation just described is an equilibrium one.

Deviations in the predicted relationship are indicia of potential problems in the performance of a futures contract. For instance, high inventories in conjunction with a severe backwardation is a classic indicator of a squeeze.

The figure titled "CL Front-Back Spread vs. Cushing Stocks" depicts the relation between the spread between the first deferred and nearby WTI contracts (vertical axis) and crude oil inventories (in mmbbl) at the CL delivery point, Cushing, OK. The (weekly) data extend from 9 April, 2004 to 17 July, 2009.

Note that for most of the points in the figure, the theoretically predicted relation holds; spreads rise with stocks. These points, for the most part, correspond to stock levels of less than 30 million barrels, and most of these points correspond to dates before 1 October, 2008. Indeed, for the 9 April, 2004-26 September, 2008 period, the correlation between Cushing stocks and WTI spreads is .7192, indicating that the spreads and inventories covaried as predicted by the fundamentals-based economic theory of storable commodity price behavior.

There are some points in the graph that are outliers. In particular, the point with a spread of $8.49/bbl, and an inventory level of 28.68 mmbbl is distant from the other points in the scatter. This point corresponds to the expiration date of the January, 2009 contract (19 December, 2008). Given the spread levels of around $2/bbl for other points with similar stock levels, this large spread stands out. It should be noted, moreover, that cash WTI spreads were almost identical, and remained this wide the day after the expiration of the January contract.

Moreover, it is informative to note that the dispersion of spreads for stock levels of approximately 35 mmbbl is substantially greater than the dispersion observed for lower stock levels. These spreads range from between $.78/bbl and $6.06/bbl. In contrast, for stock levels of about 25 mmbbl, the spreads range from $.54/bbl to $3.16/bbl, and all but one of these spreads is less than $2.00/bbl.

This greater dispersion in spreads, which corresponds primarily to the first quarter of 2009, likely reflects at least in part, a highly inelastic marginal cost of storage at Cushing. Such inelasticity would be expected as the quantity stored at Cushing nears effective capacity. Although nominal capacity at Cushing was far higher during this period (approximately 47.5 mmbbl), effective capacity can be lower due to operational constraints, and the fact that different types of oil that cannot be mixed are held in inventory at Cushing.

Moreover, as noted earlier, the market for spreads is discovering the price of storage. The market for storage in Cushing is a search market, and a negotiated one. High uncertainty, and a surge of oil seeking storage in Cushing (reflected in the large increase in stocks at Cushing discussed below) would tend to increase search and negotiation costs, and lead to greater dispersion in the price of storage across transactions negotiated at approximately the same time, and over time. Thus, one would expect that the massive increases in uncertainty and the demand for storage would lead to greater dispersion in price relations as the market groped to discover the appropriate shadow price of storage in highly dynamic, uncertain, and fluid conditions.

Even though there was greater dispersion in the spread-stocks relation in the period after the financial crisis hit with its full force, it is evident that fundamentals were still relevant in determining this relation. The correlation between spreads and stocks during the 3 October, 2008-17 July, 2009 period was .4844. This is not as high as observed in prior years, which provides further evidence of the effect of storage constraints at Cushing, but it is still positive as theory predicts, and is economically different from zero.

There is other evidence that suggests that Cushing constraints affected pricing of the WTI contract. The figure titled "CL Front-Back Spread vs. US Stocks" plots the nearby-first deferred WTI spread against the total oil stocks in the United States reported by the EIA for the January, 2000-July, 2009 period. Note again that most points in the figure exhibit the theoretically predicted relation; higher stocks are associated with greater spreads. Indeed, during the period January, 2000-August, 2008, this correlation was .6459. Given the high degree of aggregation of the stock data (where aggregation is across space and grades), this correlation is surprisingly high.

However, there are a set of points in the upper part of the diagram that deviate quite noticeably from the main body of points in the scatter diagram. These points with high spreads and relatively moderate levels of inventories, correspond to the height of the financial crisis, October, 2008-March, 2009. They indicate that WTI spreads were far higher during this period than one would have predicted given (a) the level of US stocks observed during this period, and (b) the relation between US stocks and spreads from the period prior to the crisis. This further suggests that constraints at Cushing were affecting the pricing of the WTI contract during the height of the financial crisis.

The correlation between US stocks and spreads during this period provides additional evidence of this. The correlation between US stocks and spreads during the 1 September, 2008-17 July, 2009 period was only .1613 (in contrast to the .6459 correlation observed from 2000 to the end of August, 2008). This provides evidence that WTI prices were more greatly affected by Cushing-specific factors during this period, than had been the case in prior years.

It is interesting to note that Brent futures spreads also exhibited a weaker relation with fundamentals (as proxied by stocks) during the period of the financial crisis. Indeed, the degradation in the relation between inventories and spreads was more pronounced for Brent than for WTI.

Specifically, from January, 2000-August, 2008, the correlation between Brent spreads and US inventories was .5207. This is smaller than the WTI-US stocks correlation, but this is to be expected as Brent is more out-of-position relative to US stocks than is WTI. Nonetheless, the positive relationship (which is also statistically significant) is consistent with the view that US stocks responded to global supply-demand factors, and that Brent spreads reflected these fundamentals. During the period 1 September, 2008-17 July, 2009, however, the correlation became negative: -.5536 to be exact. This is diametrically opposed to the behavior of Brent spreads prior to the financial crisis, and is not what one would expect to observe if Brent spreads were reflecting world-wide supply-demand fundamentals. Since US and OECD stocks exhibited similar movements during this time period, this raises questions about whether Brent spreads reflected fundamentals (as captured by OECD inventories) during this period.

In sum, there is evidence that the financial crisis had a marked effect on the performance of both oil price benchmarks. The most plausible explanation is that the crisis sharply curtailed the demand for oil. Given the inelasticity of oil production in the very short run, this sharp demand decline could only be accommodated by a sharp drop in prices, and a substantial increase in inventories of crude. Inventories in Cushing rose dramatically, apparently approaching the effective storage capacity there. As inventories approached effective storage capacity, the marginal cost of storage at Cushing became very inelastic. Since spreads with large positive inventory levels equal the marginal cost of storage, this inelasticity makes spreads more volatile, since as a result of this inelasticity small changes in storage, or small changes in effective storage capacity (due to operational considerations), lead to substantial changes in spreads. These effects are amplified by the effects of greater uncertainty and a sharp increase in the demand for storage on transactions costs in the market for physical storage.

The figure labeled “Cushing Stocks” depicts the marked increase in Cushing stocks starting in early-October, 2008. Stocks rose to the largest absolute level observed in the sample period, and rose more rapidly than at any time during this period. Moreover, it should be noted that the fraction of US stocks held in Cushing also rose rapidly, to a level not observed heretofore. This is illustrated in the figure labeled “Cushing Stocks/US Stocks,” which shows that this ratio rose to a record high by January, 2009, and the rate of increase to reach that high more was more rapid than observed previously.

Therefore, the behavior in WTI futures prices and spreads during the period of the financial crisis most likely reflected constraints on the Cushing delivery point that were exacerbated by an unprecedented decline in demand, and a concomitant unprecedented increase in inventories.[8]

VI. Summary and Conclusions

The financial crisis of 2008-2009 had a pronounced effect on the behavior of oil prices, and the performances of the two primary price benchmarks, WTI futures, and Brent futures. The crisis was associated with a dramatic increase in price volatility; a widening of spreads; an increase in the volatility of these spreads; and a decline in hedging effectiveness. These effects were evident for front month and second month WTI and Brent, but were most pronounced for front month WTI, especially within a few days of contract expiration.

The financial crisis was also associated with an unprecedented spike in oil inventories in the United States and around the world, and at the WTI delivery point of Cushing, Oklahoma. The economic theory of storable commodity pricing, and the data, strongly suggest that this phenomenon is connected with the behavior of price benchmarks during the financial crisis.

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[8] It should be noted that operators at Cushing added approximately 8 million barrels of capacity during 2008.

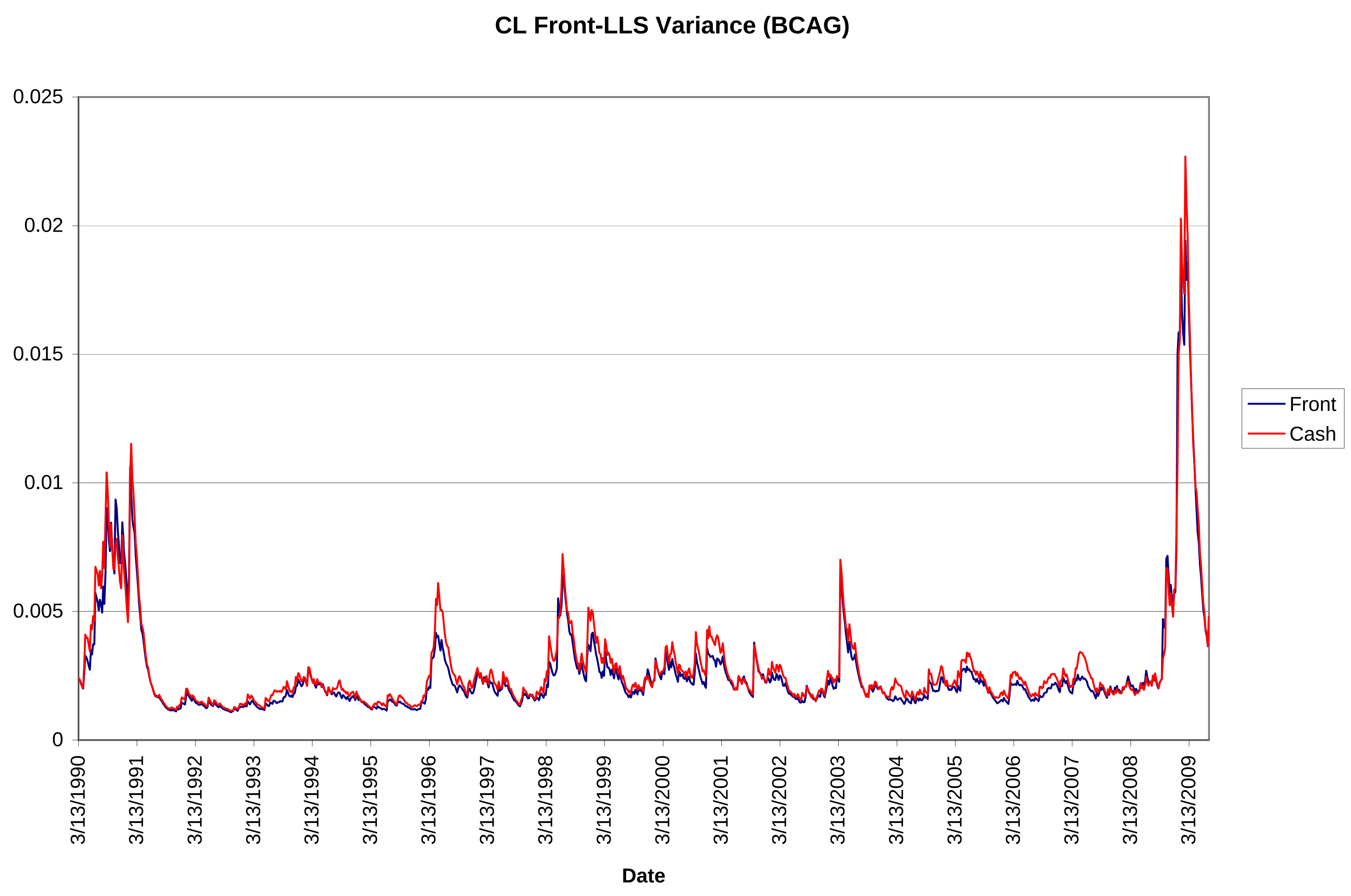
Specifically, in an efficiently operating market, a sharp demand decline like that caused by the financial crisis should lead to a large increase in inventory. This large accumulation can cause stocks to approach capacity constraints at a point like Cushing. Although storage at Cushing was less than nominal capacity there even when inventories peaked, the data suggest that Cushing was effectively constrained, and that as a result, the supply of storage was extremely inelastic. Since (a) in a market with large storage nearby-deferred spreads price the marginal cost of storage, and (b) when the marginal cost of storage is highly inelastic, small fundamental shocks have large effects on this marginal cost, then (c) such fundamental shocks will have large effects on spreads. Moreover, the dramatic increase in uncertainty and an increase in the demand for storage likely increased transactions costs, and the dispersion and volatility of negotiated storage rates at Cushing.

Thus, the behavior of pricing benchmarks during the period of the financial crisis was driven by the extraordinary circumstances of that period, and are not a harbinger of performance under more normal circumstances.

It should be emphasized that these effects were concentrated during the period of severe worldwide economic contraction and extreme volatility in the autumn of 2008 and the winter of 2008-2009. The performance of the pricing benchmarks had largely returned to pre-crisis levels by early-spring, 2009.

For both WTI and Brent, there is evidence that technical factors associated with expiration inject additional volatility into the price in the expiring future. These problems were more severe for WTI during the period of the financial crisis, likely due to the fact that the aforementioned constraints at Cushing exacerbated the effects of expiration-driven technical features. The similar behavior of WTS suggests that this phenomenon was caused by fundamental conditions in the Midcontinent market, rather than factors specific to the NYMEX WTI futures contract. Although not immaterial, the importance of this is diminished by the fact that most interest has rolled to the next-expiring contract well before these effects become manifest.

Even during the height of the financial crisis, WTI pricing relationships continued to co-vary with fundamentals as predicted by economic theory. In particular, spreads widened as inventories (US and Cushing) declined (and vice versa), although this relation was weaker than that observed prior to the crisis. In contrast, in a reversal from pre-crisis behavior, during the crisis, Brent spreads exhibited a negative correlation with inventories (US and Cushing); this is opposite from what one would expected to observe in a competitive market that accurately reflects fundamentals. This suggests that any divergences between the hedging performance of WTI and Brent are not clearly attributable to the latter reflecting fundamentals and the former not. In fact, the stock-spread relation suggests that the opposite is the case.



CL Front-LLS Variance (BCAG)
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0.02
0.015
0.01
0.005
0
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
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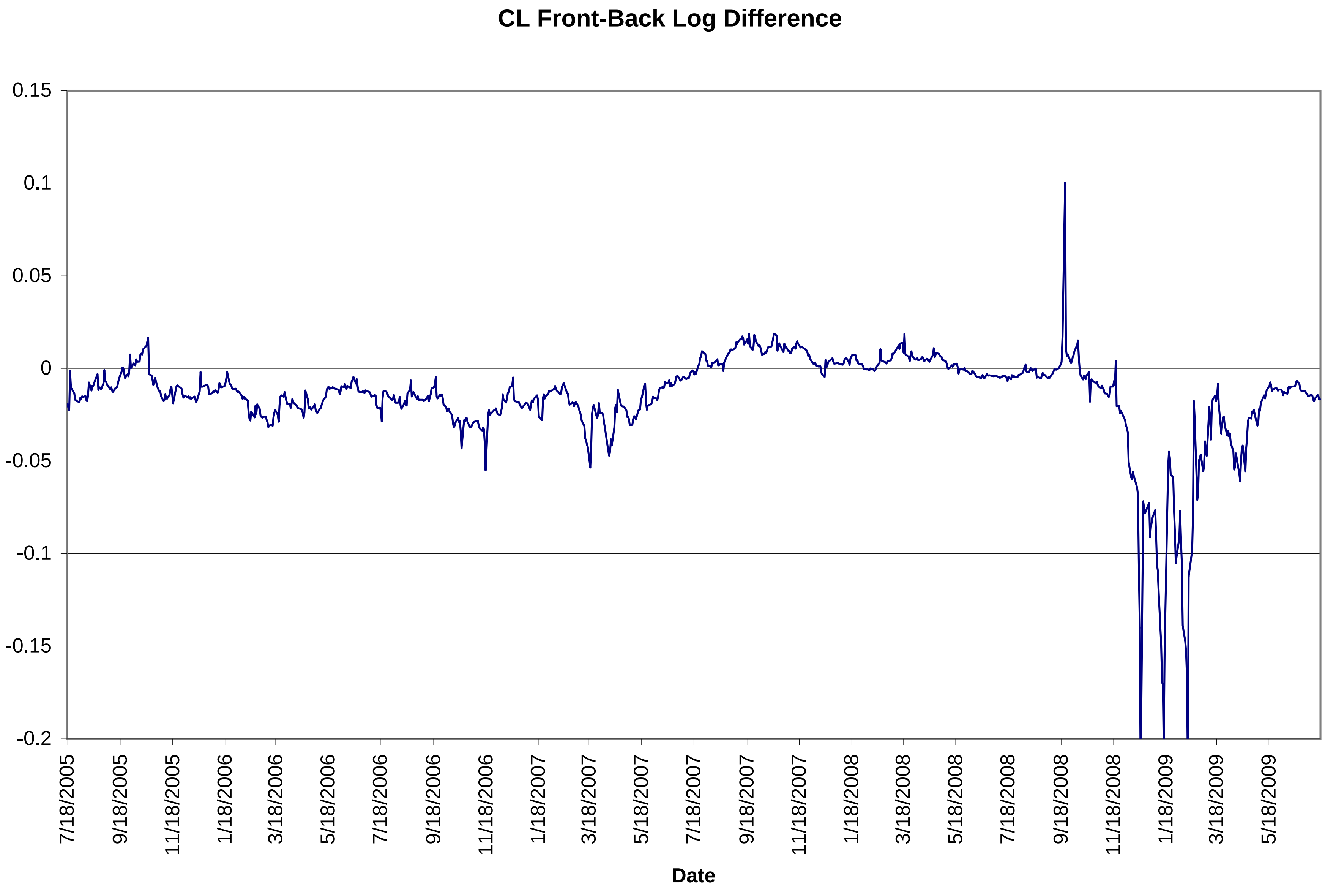
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date
Front
Cash



CL Front-Back Log Difference
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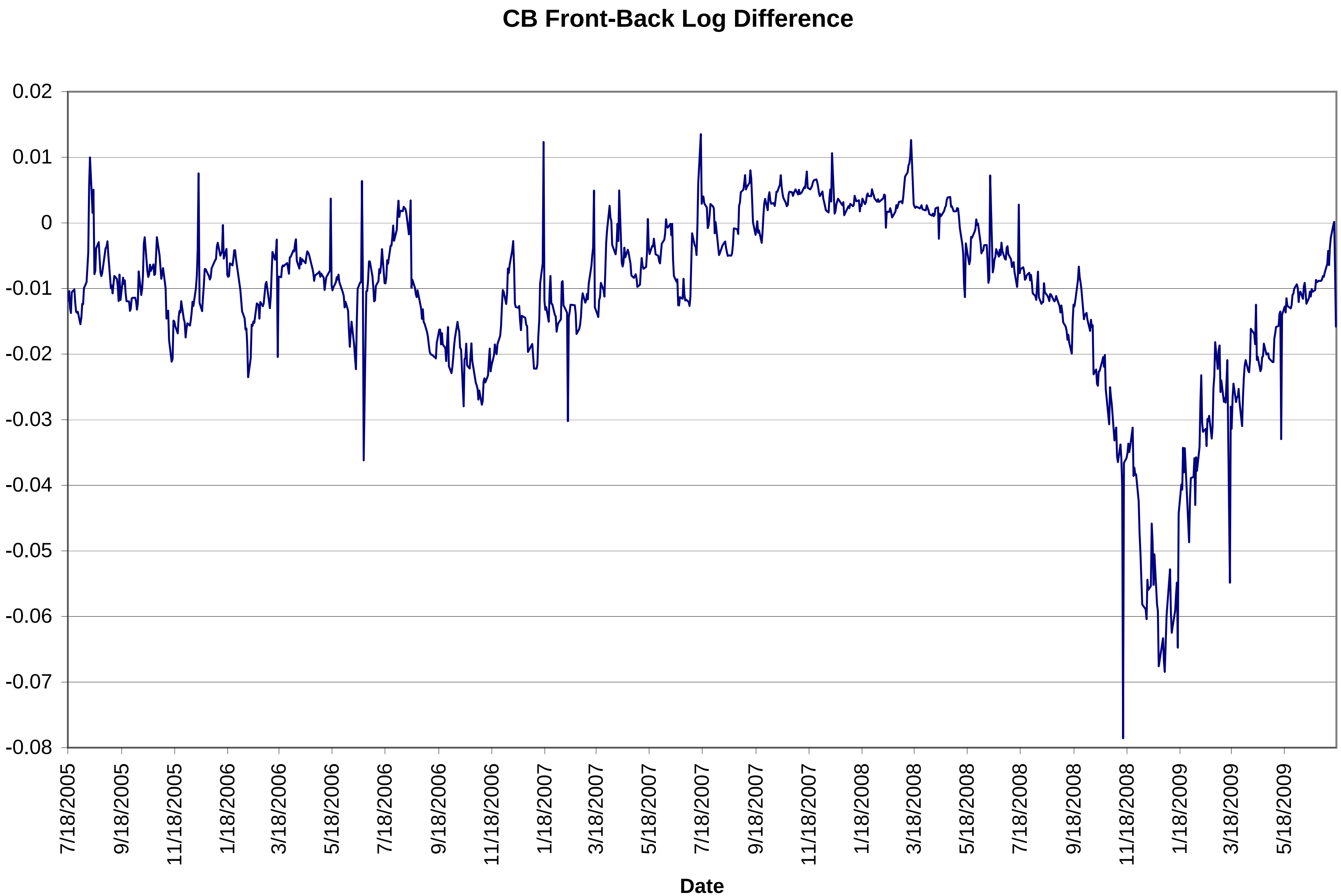
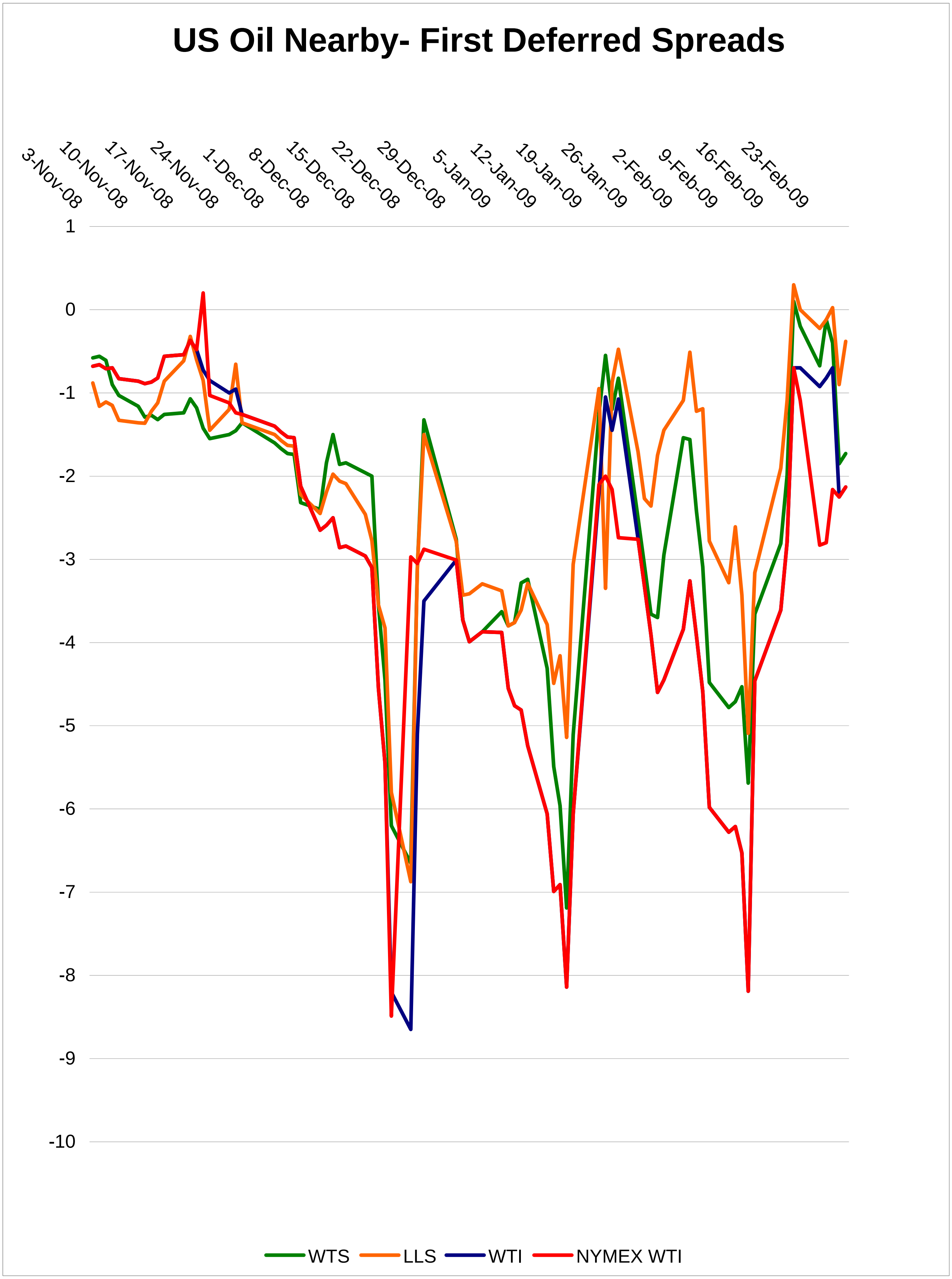
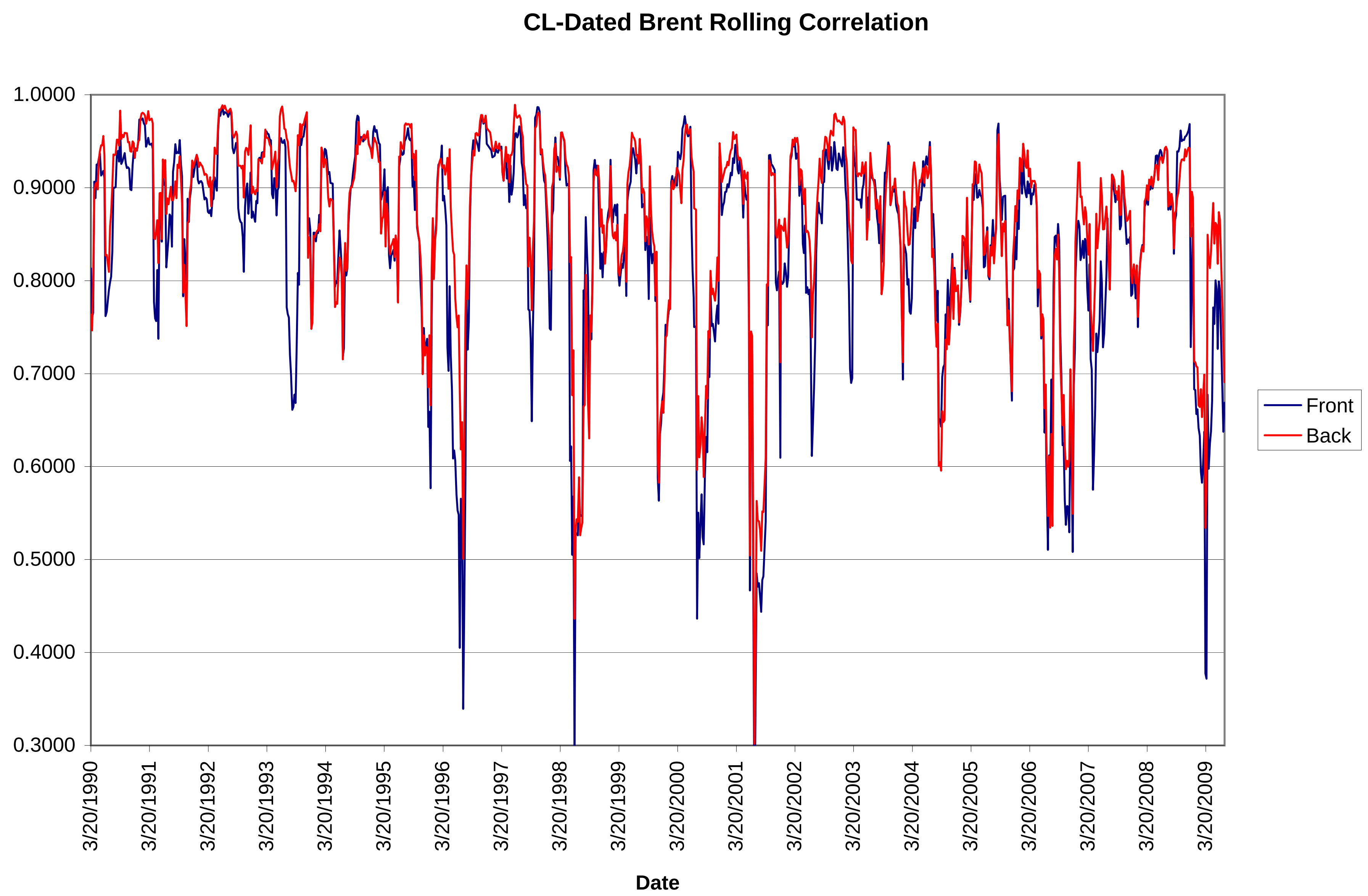
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
7/18/2005
9/18/2005
11/18/2005
1/18/2006
3/18/2006
5/18/2006
7/18/2006
9/18/2006
11/18/2006
1/18/2007
3/18/2007
5/18/2007
7/18/2007
9/18/2007
11/18/2007
1/18/2008
3/18/2008
5/18/2008
7/18/2008
9/18/2008
11/18/2008
1/18/2009
3/18/2009
5/18/2009
Date

CB Front-Back Log Difference





US Oil Nearby- First Deferred Spreads
3-Nov-08
10-Nov-08
17-Nov-08
24-Nov-08
1-Dec-08
8-Dec-08
15-Dec-08
22-Dec-08
29-Dec-08
5-Jan-09
12-Jan-09
19-Jan-09
26-Jan-09
2-Feb-09
9-Feb-09
16-Feb-09
23-Feb-09
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
WTS
LLS
WTI
NYMEX WTI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0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
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3/20/1991
3/20/1992
3/20/1993
3/20/1994
3/20/1995
3/20/1996
3/20/1997
3/20/1998
3/20/1999
3/20/2000
3/20/2001
3/20/2002
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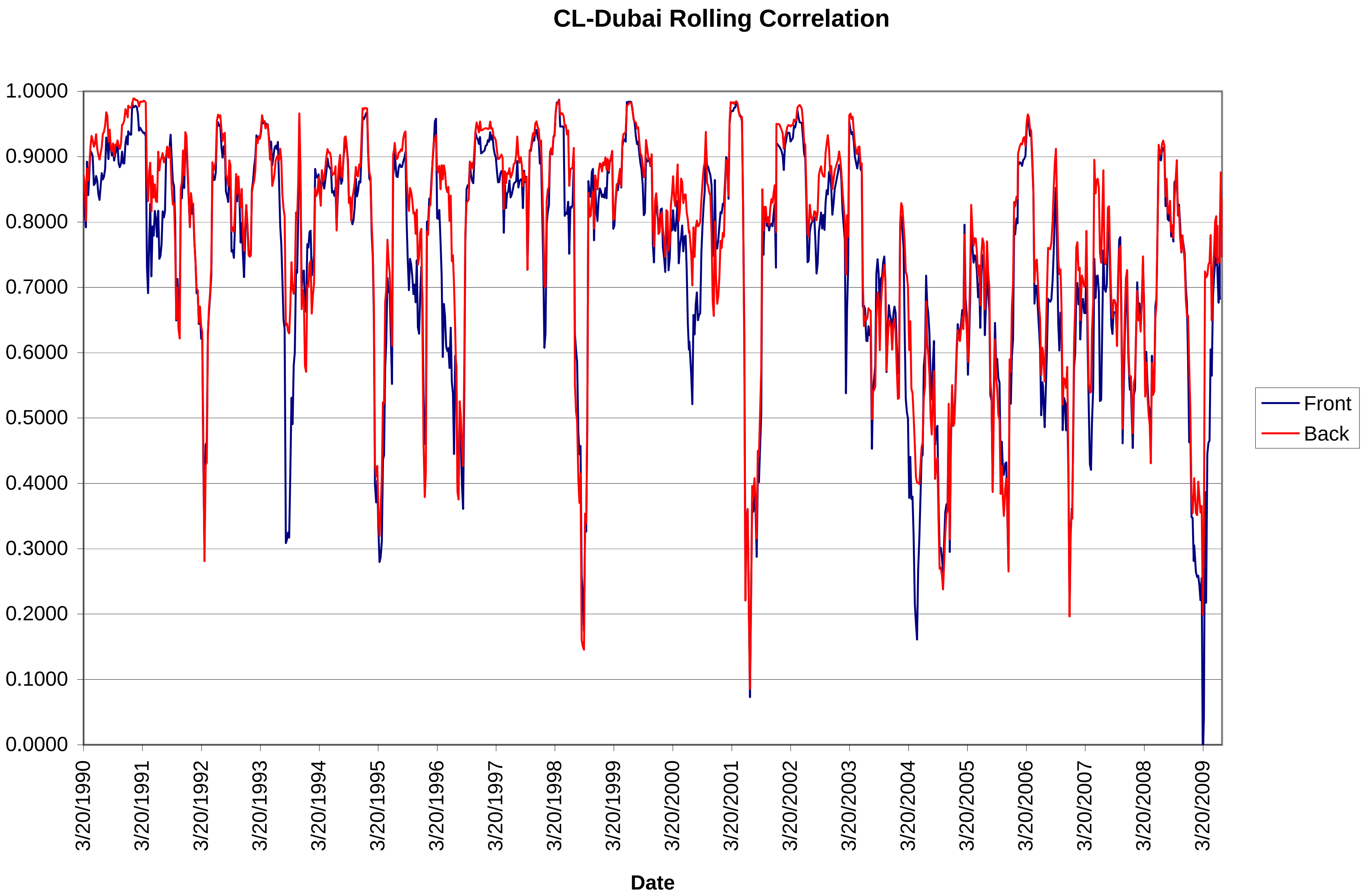
3/20/2005
3/20/2006
3/20/2007
3/20/2008
3/20/2009
Date
Front
Back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0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
3/20/1990
3/20/1991
3/20/1992
3/20/1993
3/20/1994
3/20/1995
3/20/1996
3/20/1997
3/20/1998
3/20/1999
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3/20/2001
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3/20/2008
3/20/2009
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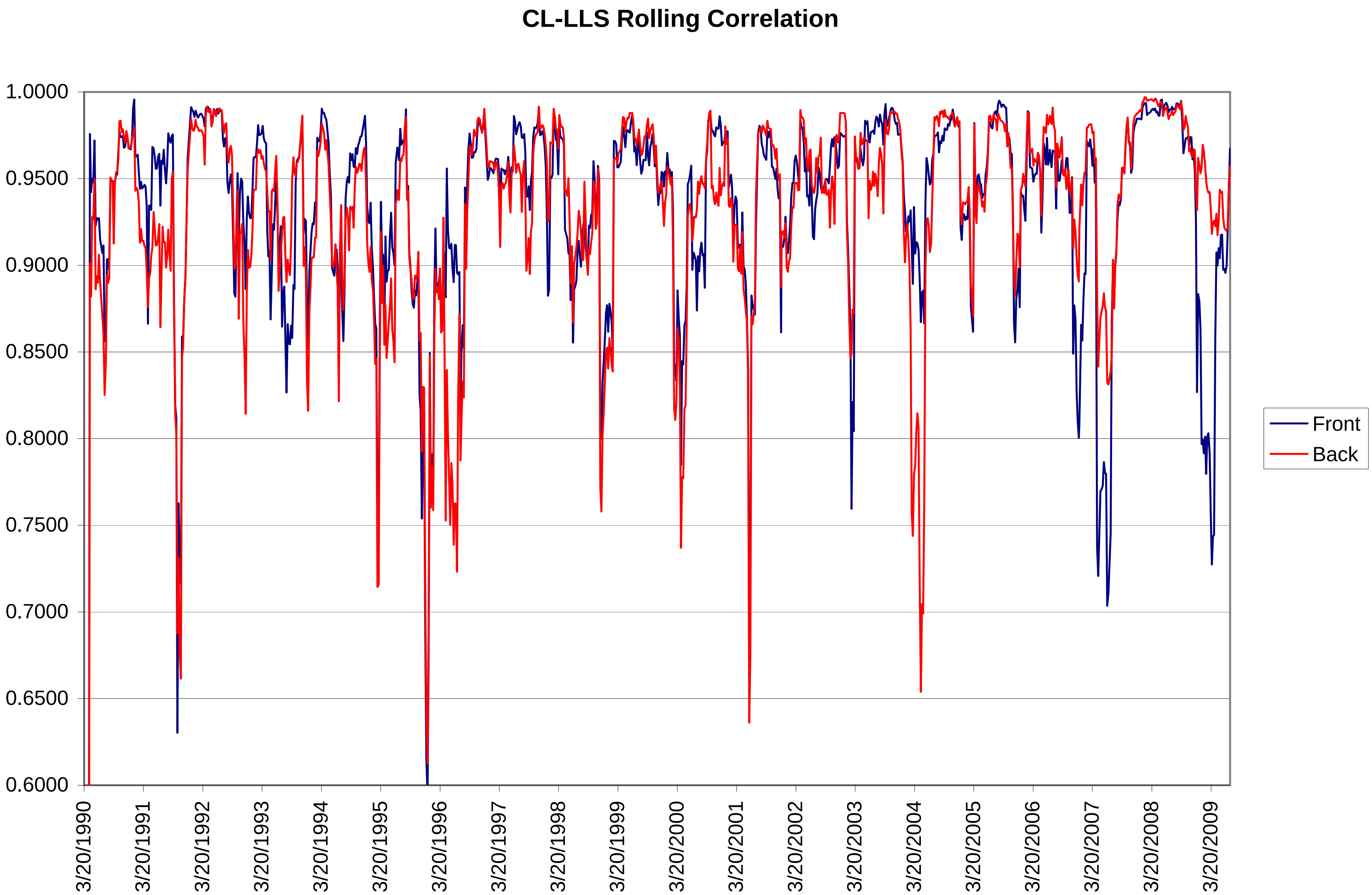
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0.8500
0.8000
0.7500
0.7000
0.6500
0.6000
3/20/1990
3/20/1991
3/20/1992
3/20/1993
3/20/1994
3/20/1995
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3/20/1999
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3/20/2009
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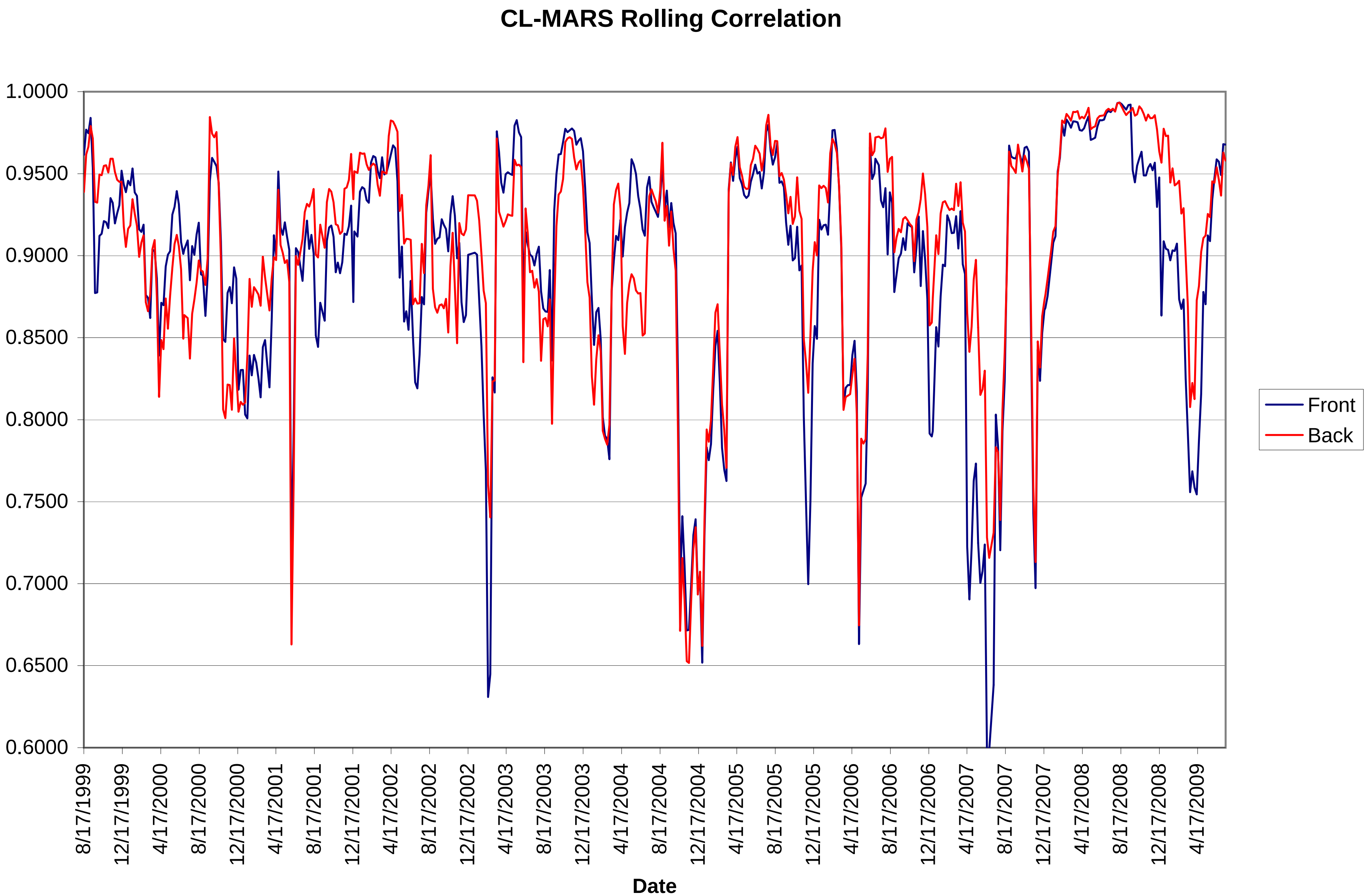
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0.8000
0.7500
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0.6000
8/17/1999
12/17/1999
4/17/2000
8/17/2000
12/17/2000
4/17/2001
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12/17/2001
4/17/2002
8/17/2002
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8/17/2008
12/17/2008
4/17/2009
Date
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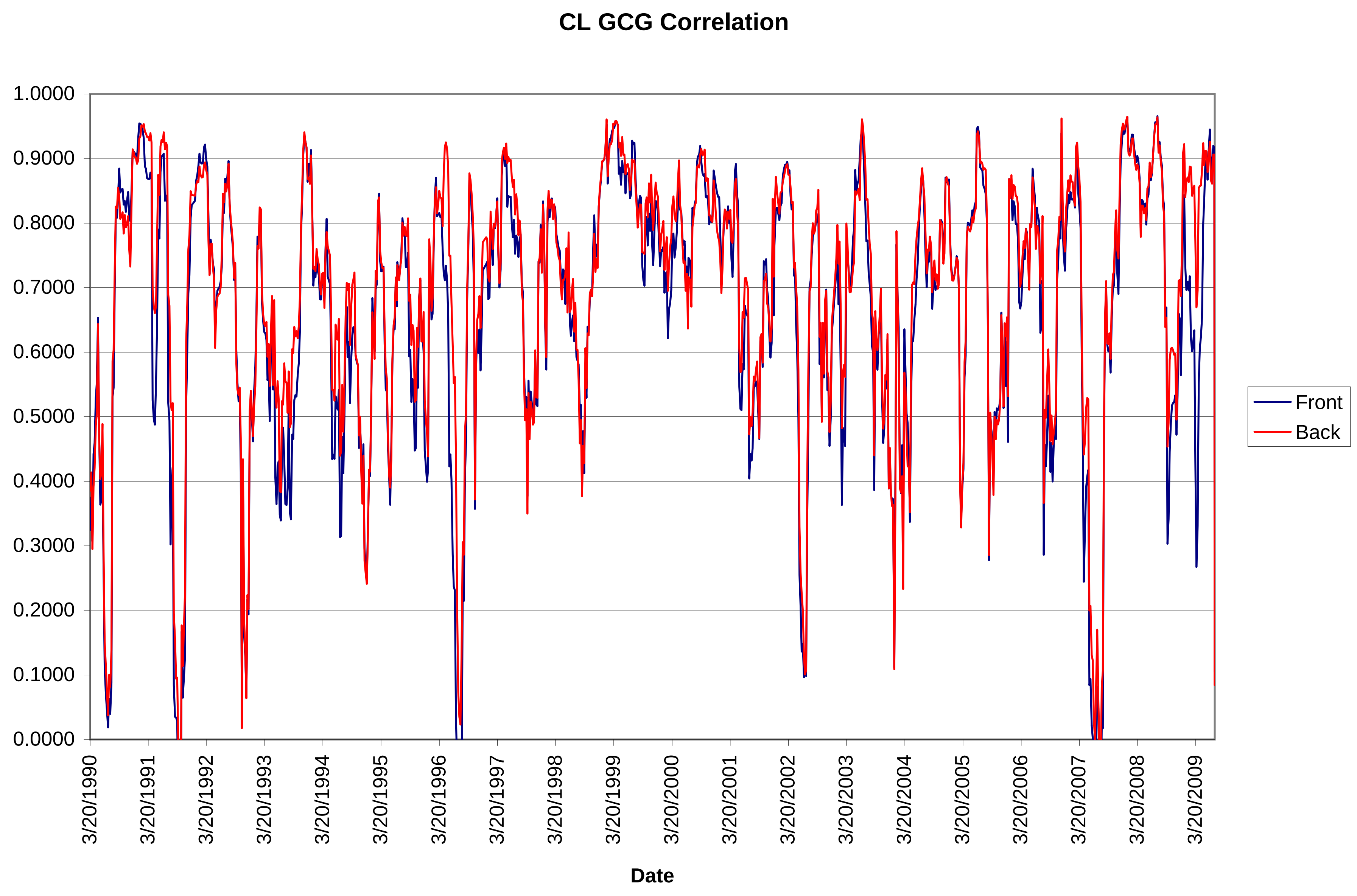
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0.0000
3/20/1990
3/20/1991
3/20/1992
3/20/1993
3/20/1994
3/20/1995
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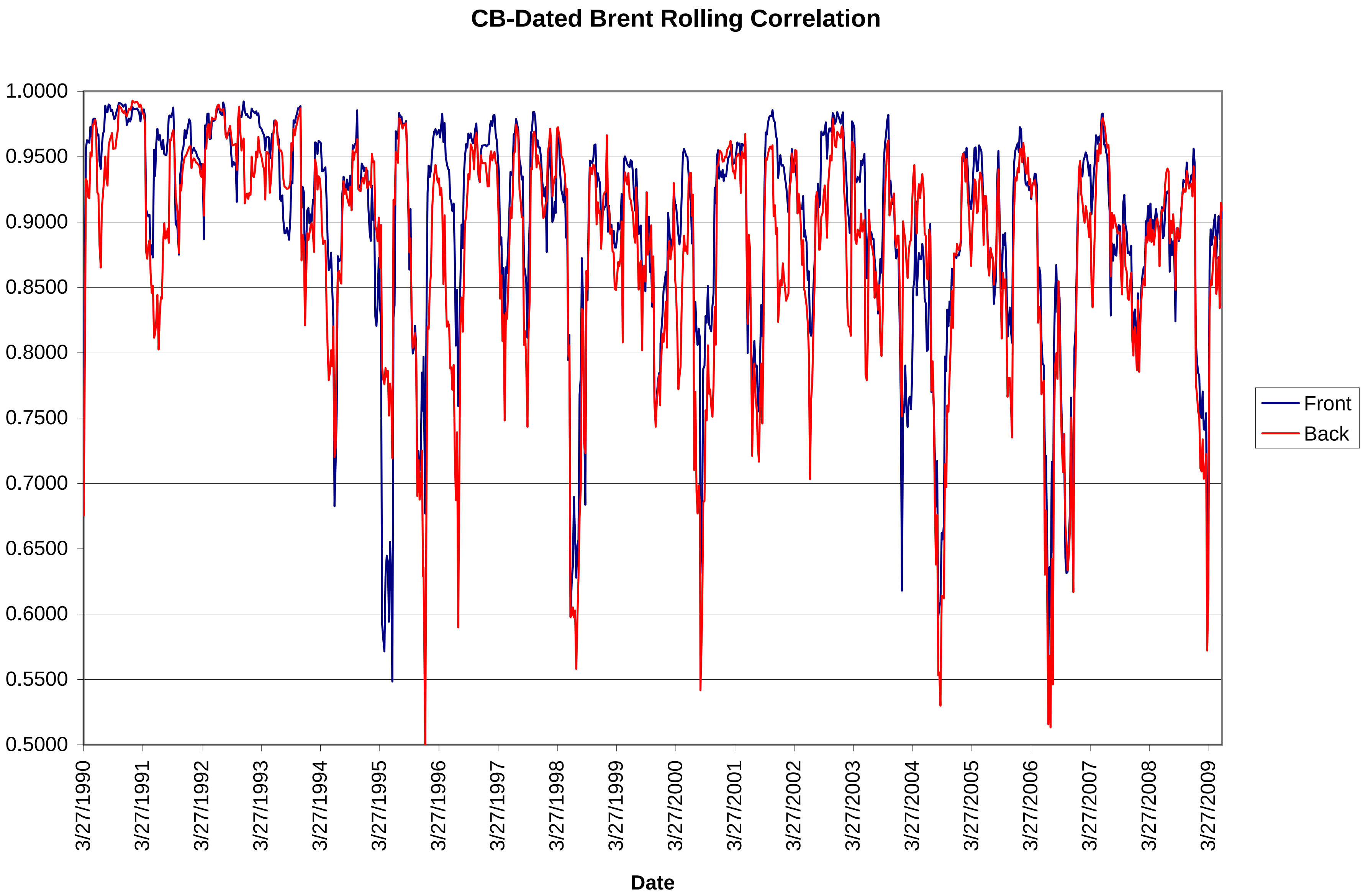
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0.7500
0.7000
0.6500
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0.5500
0.5000
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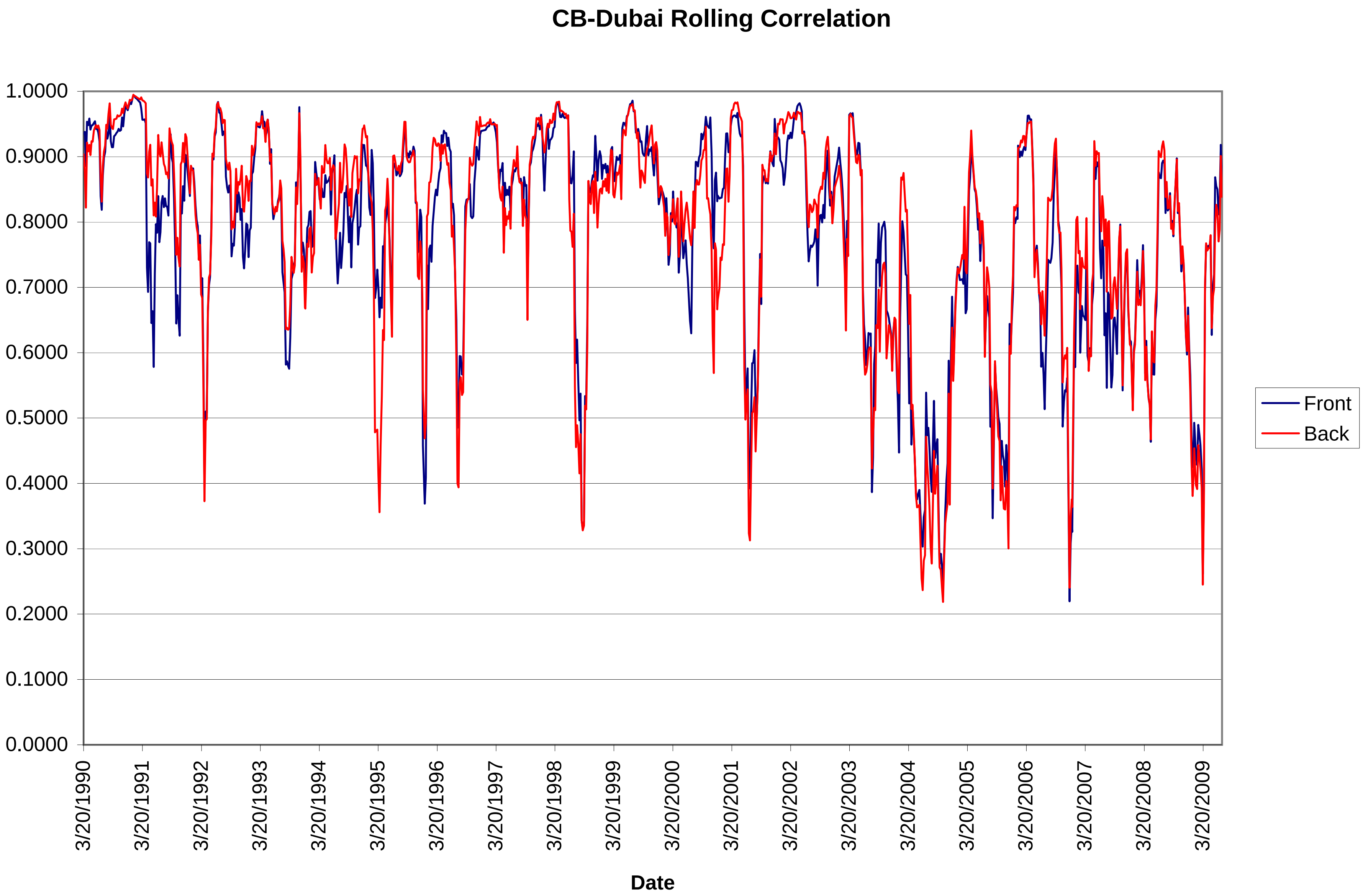
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0.0000
3/20/1990
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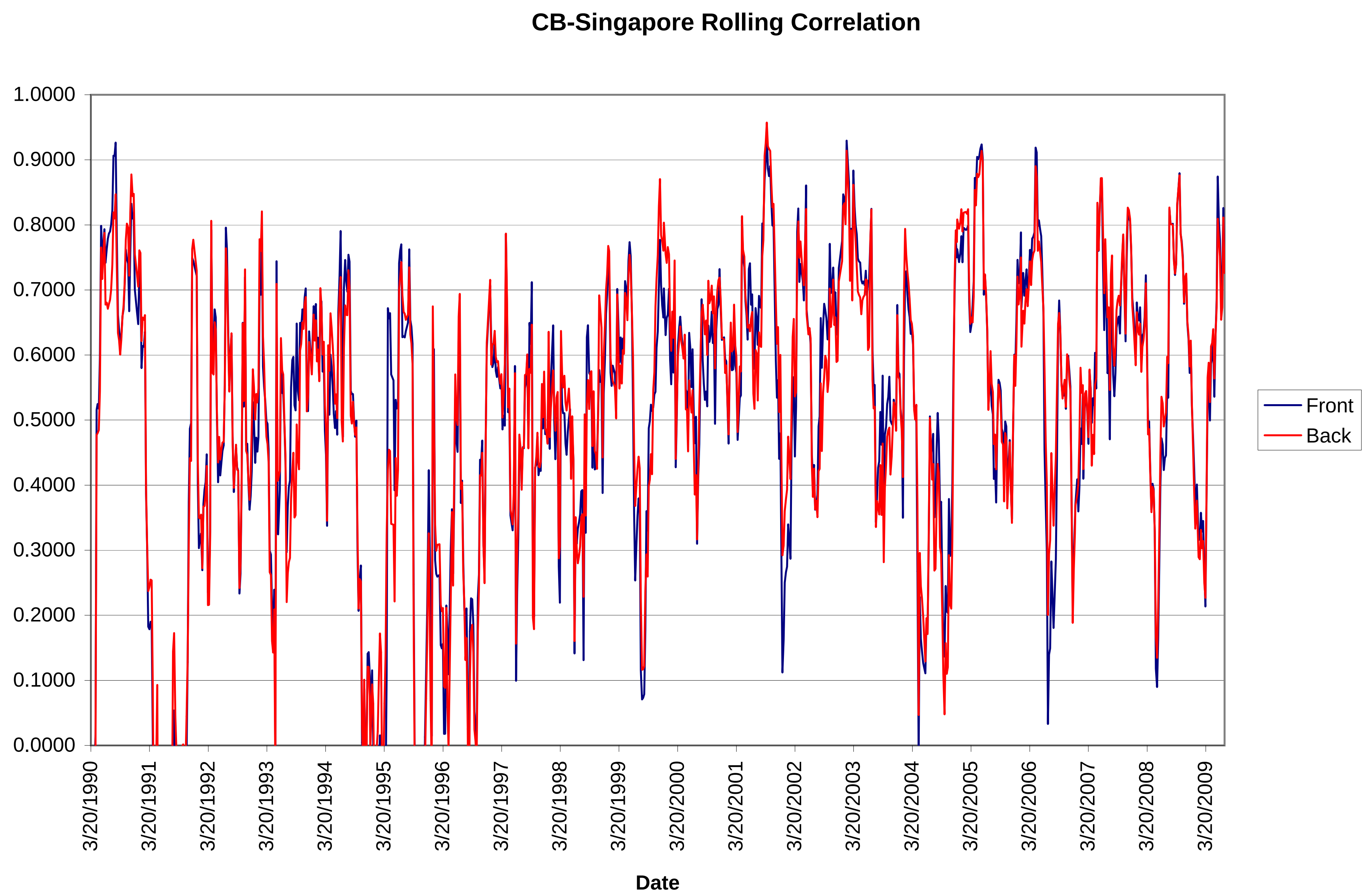
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0.0000
3/20/1990
3/20/1991
3/20/1992
3/20/1993
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3/20/1995
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Date
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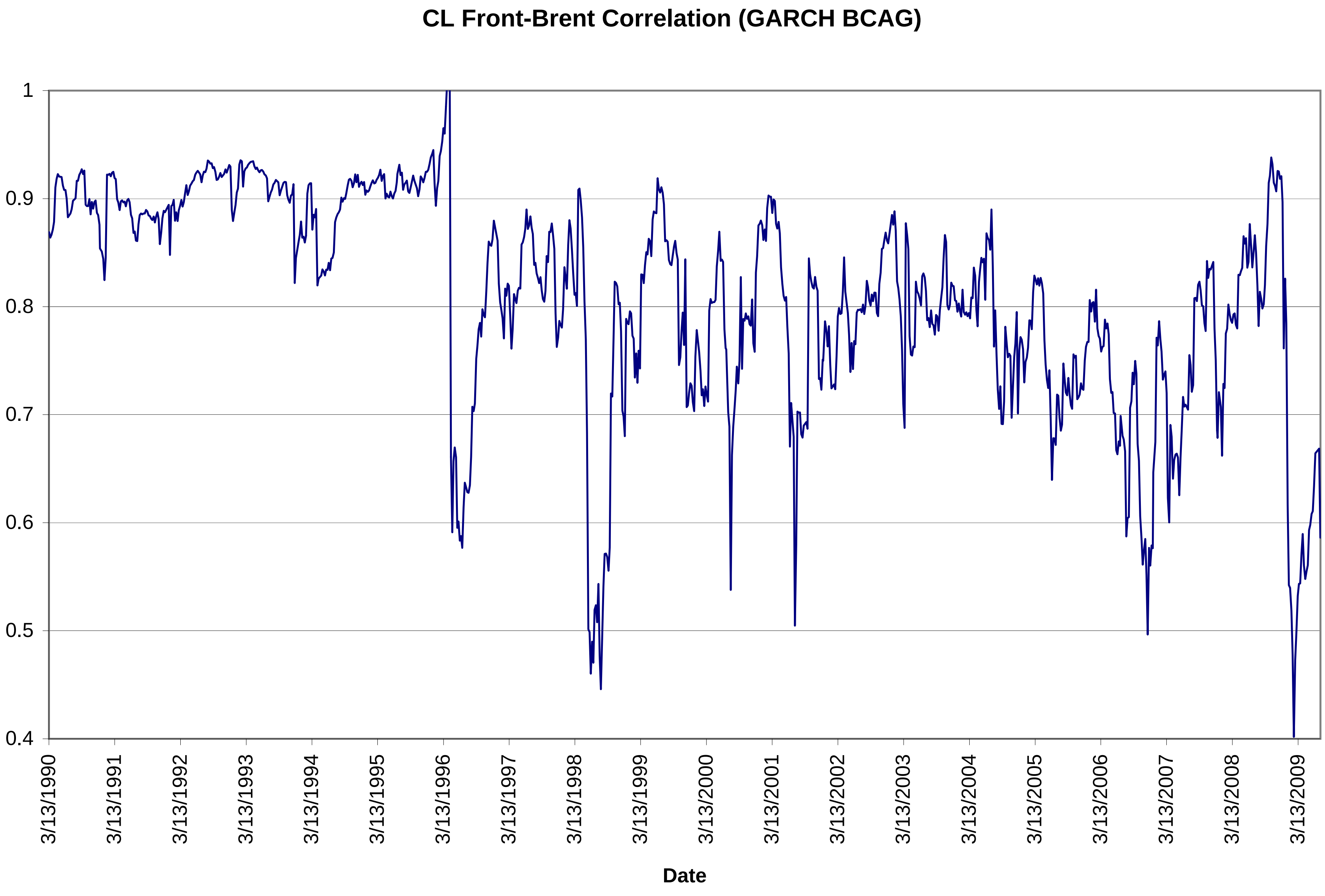

CL Front-Brent Correlation (GARCH BCAG)
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0.7
0.6
0.5
0.4
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
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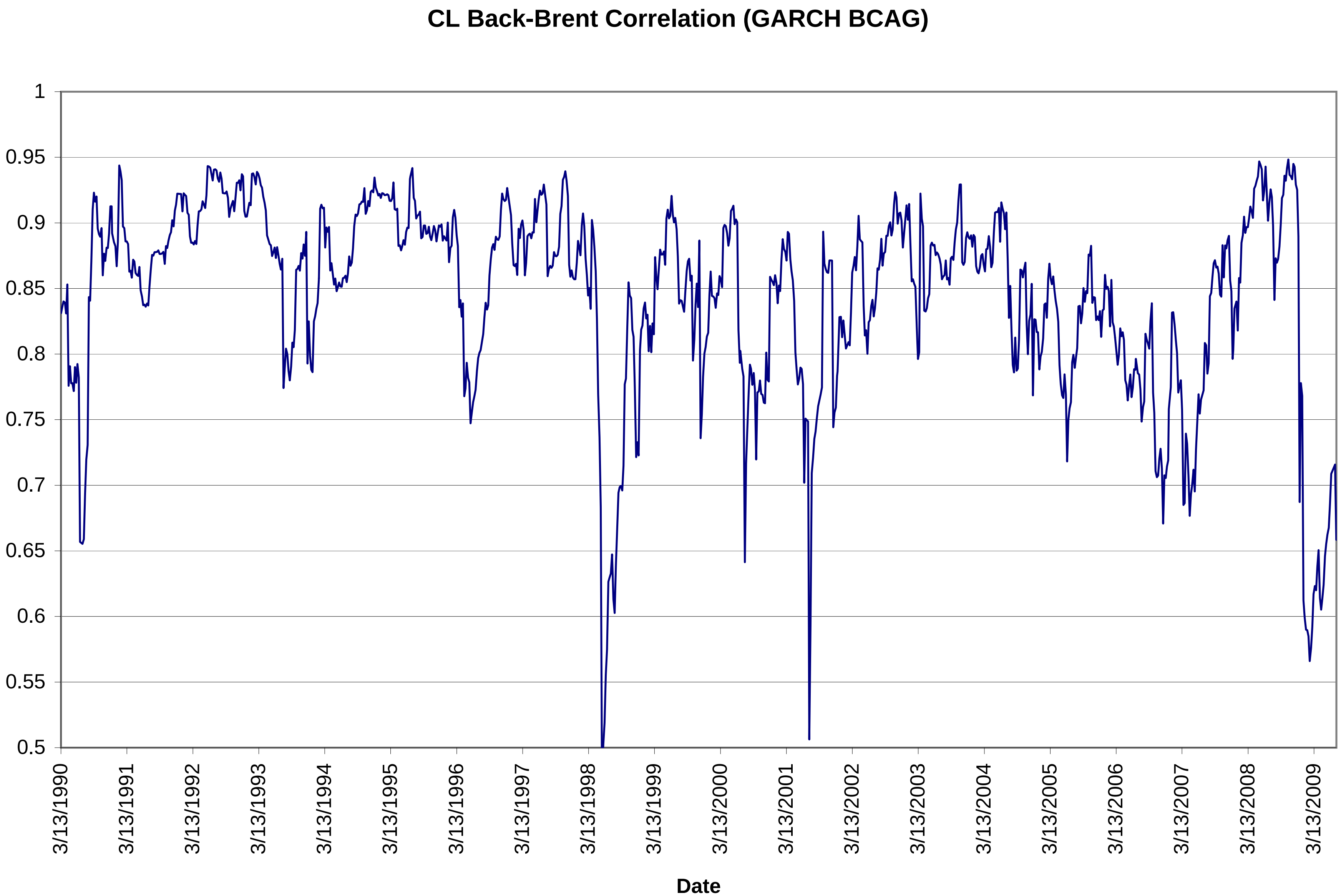
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0.5
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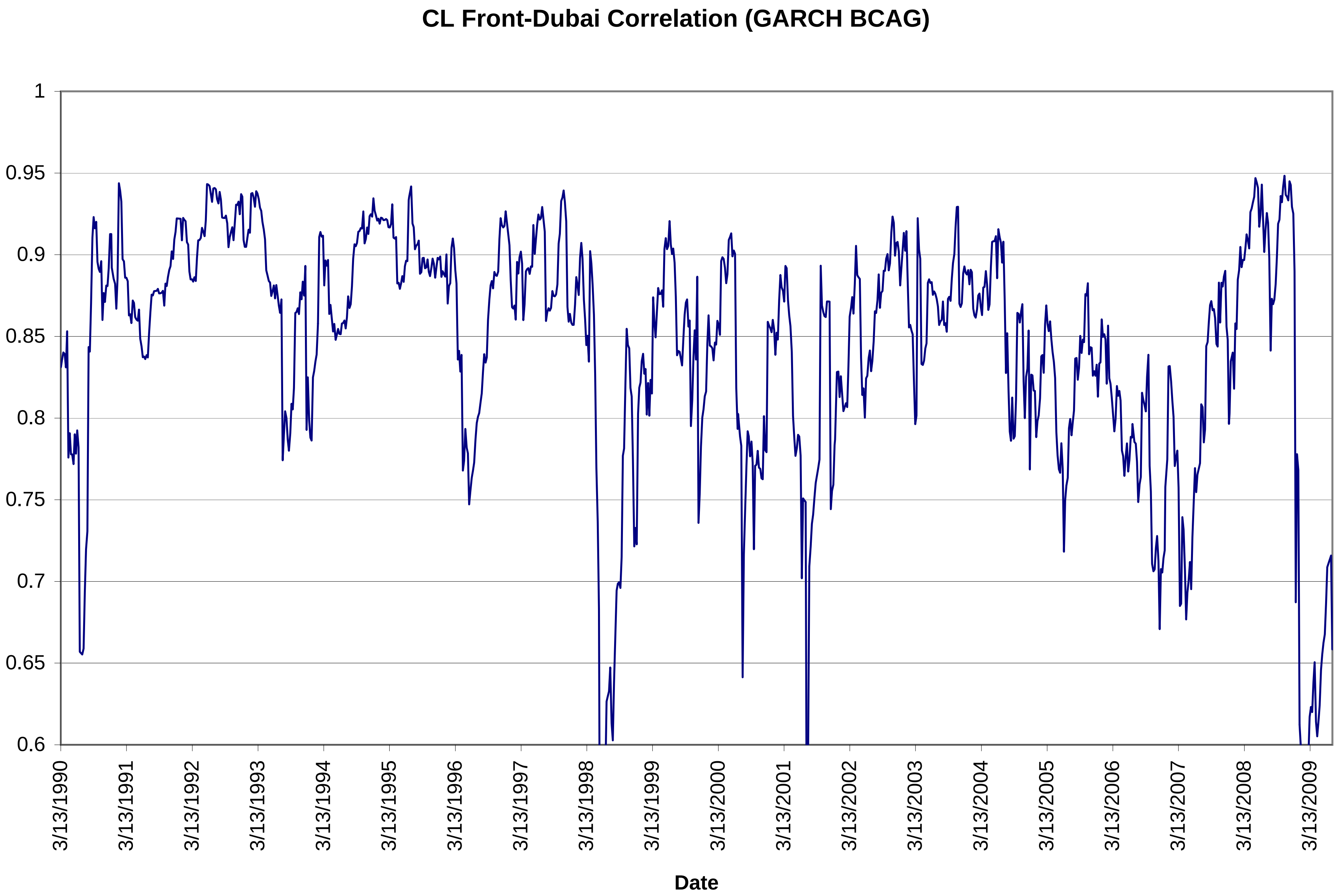
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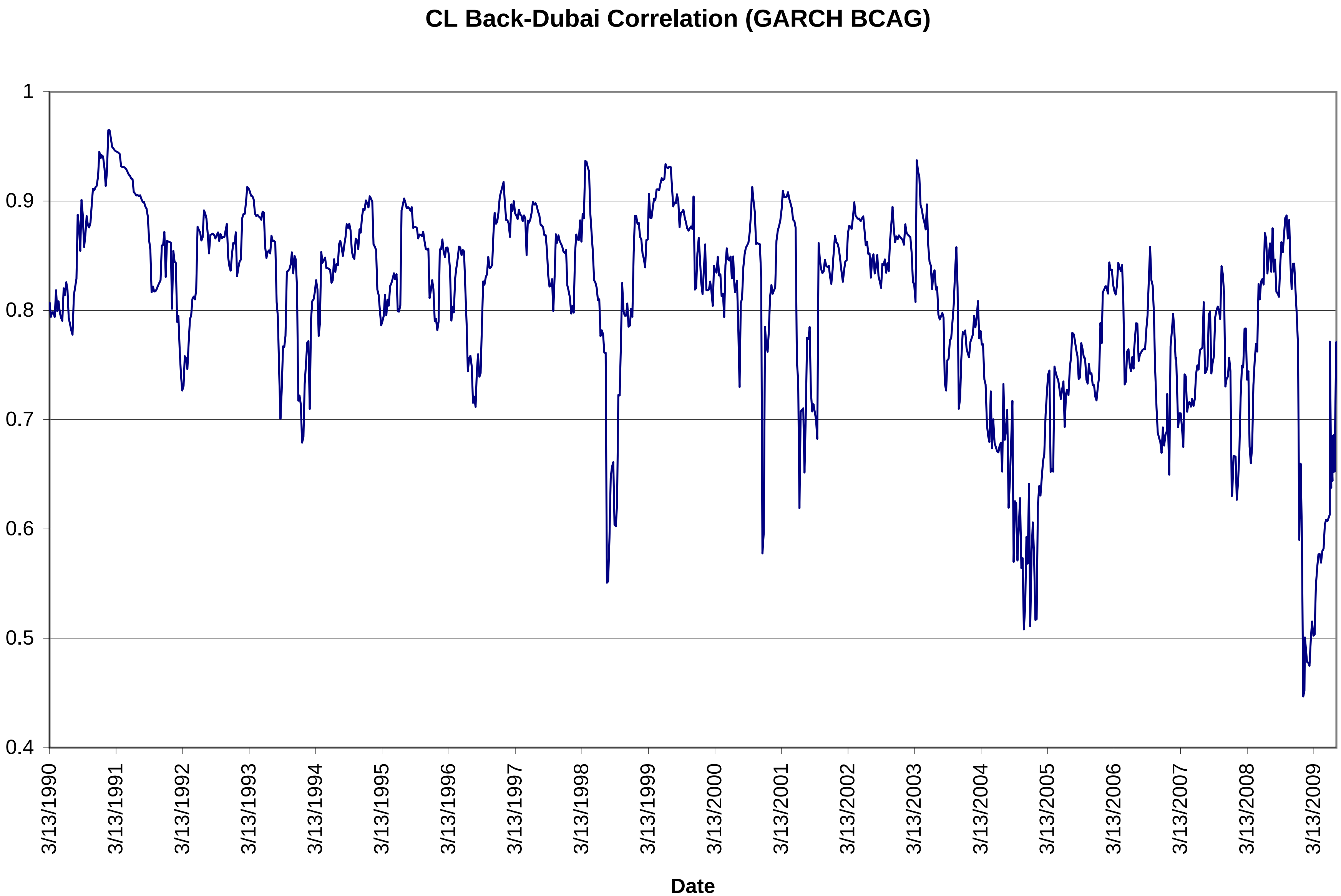
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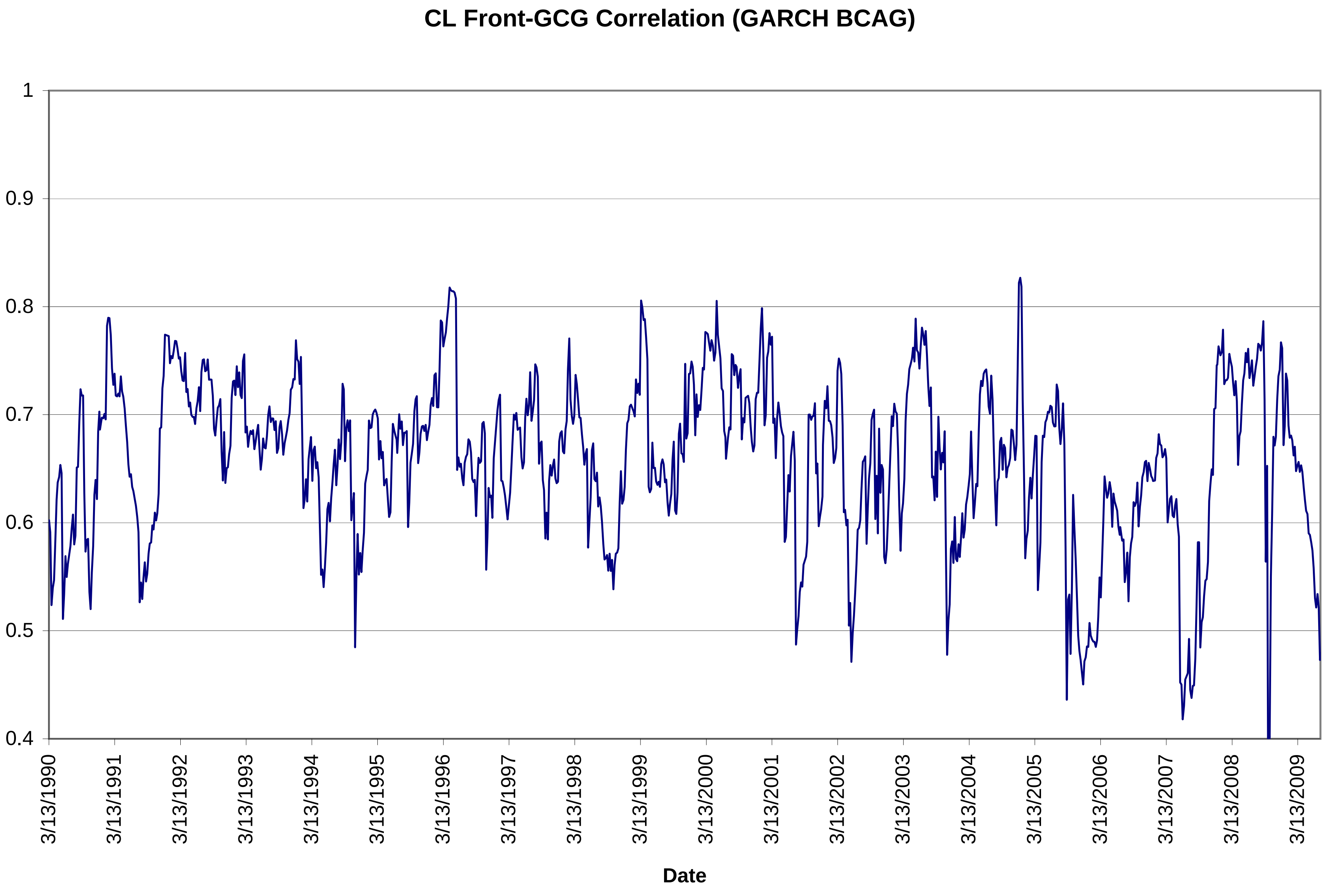
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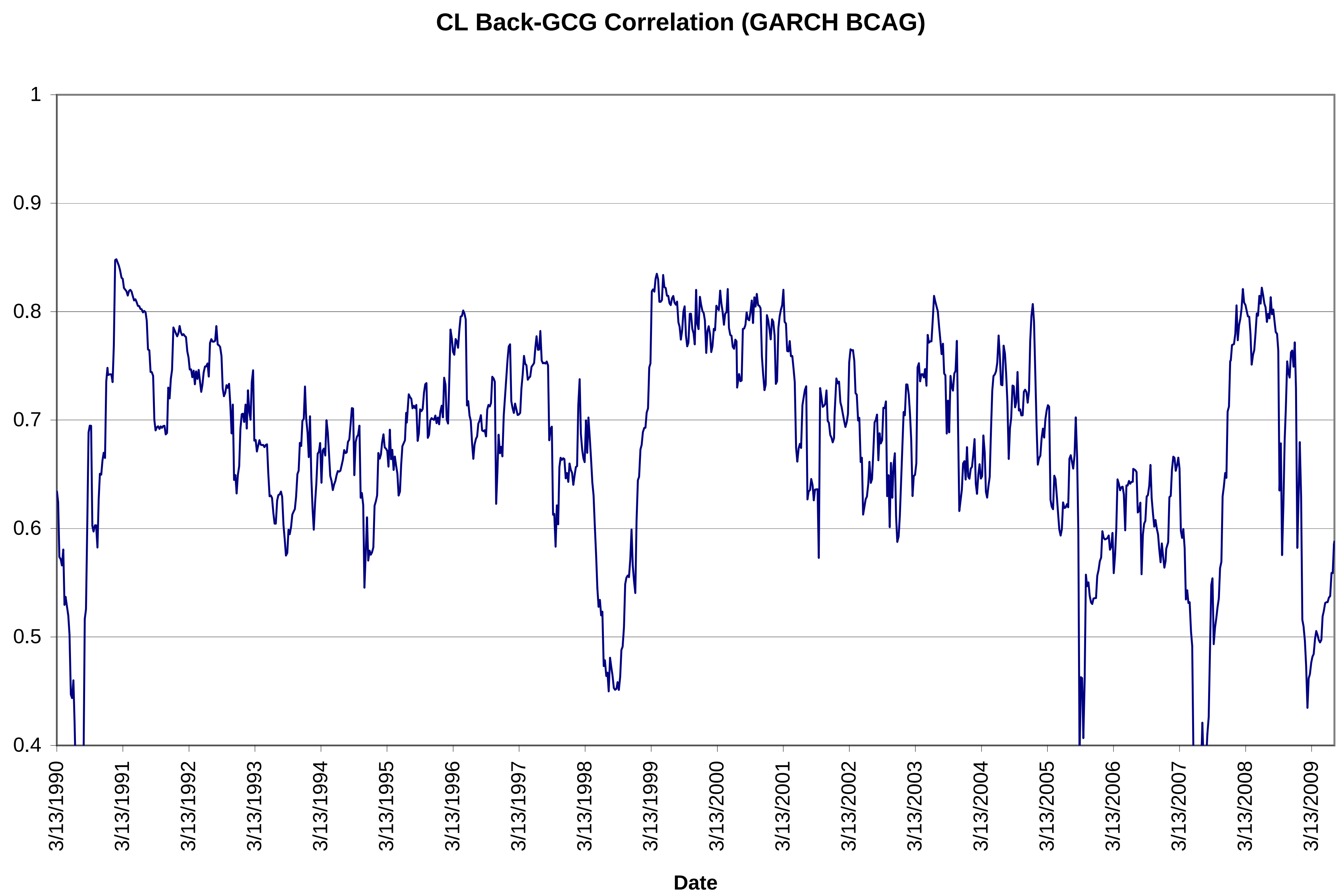
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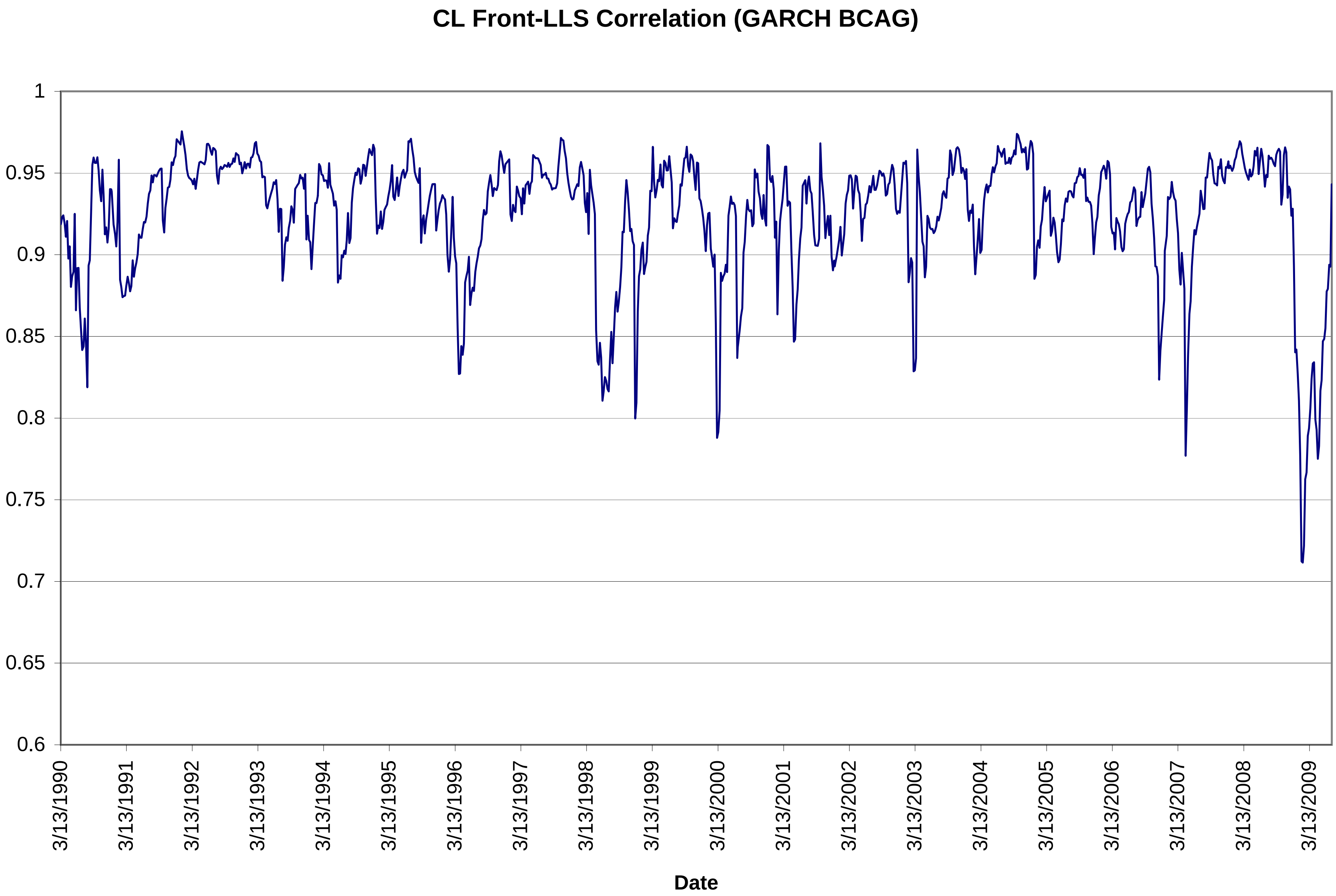
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3/13/1991
3/13/1992
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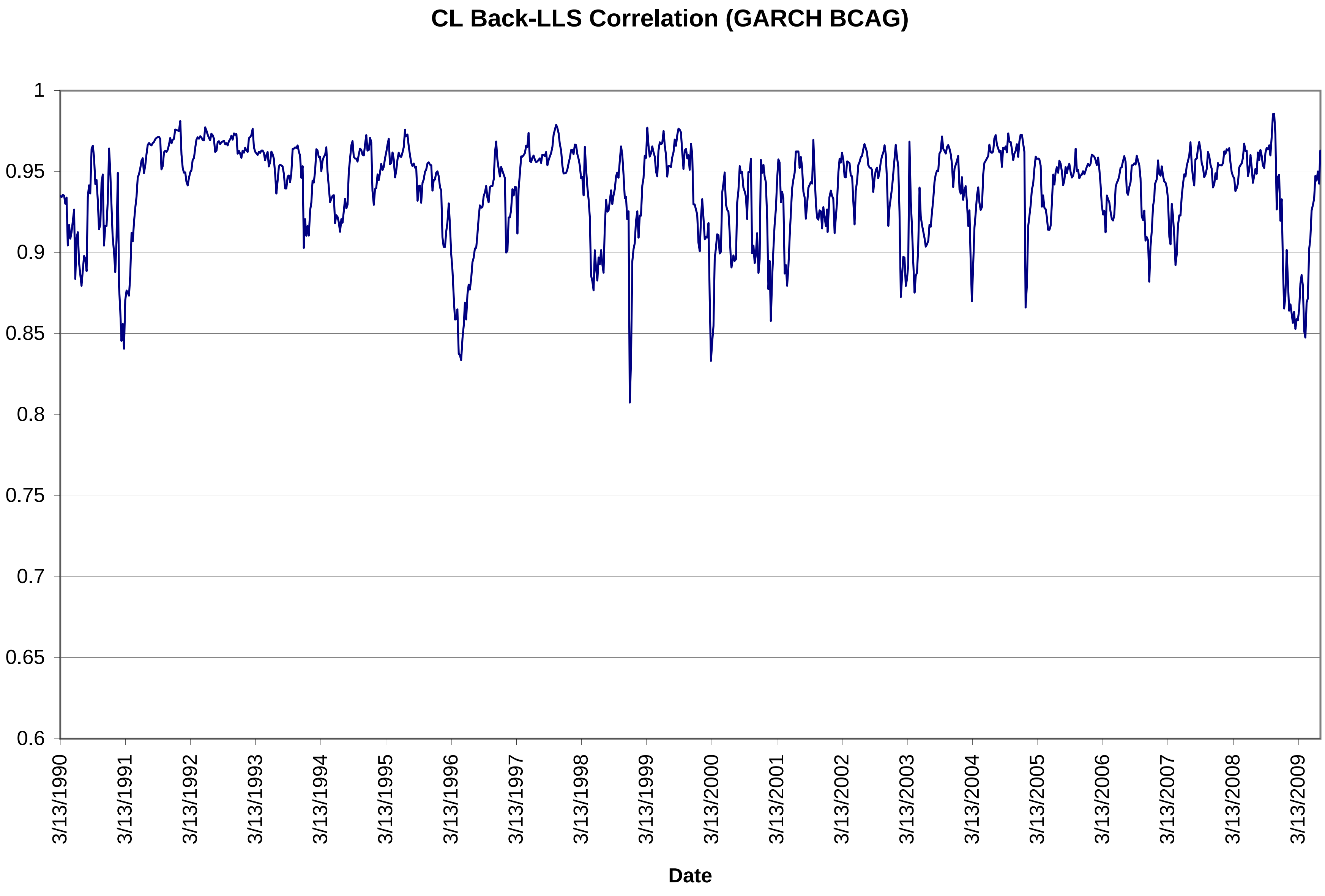

CL Back-LLS Correlation (GARCH BCAG)
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0.9
0.85
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0.75
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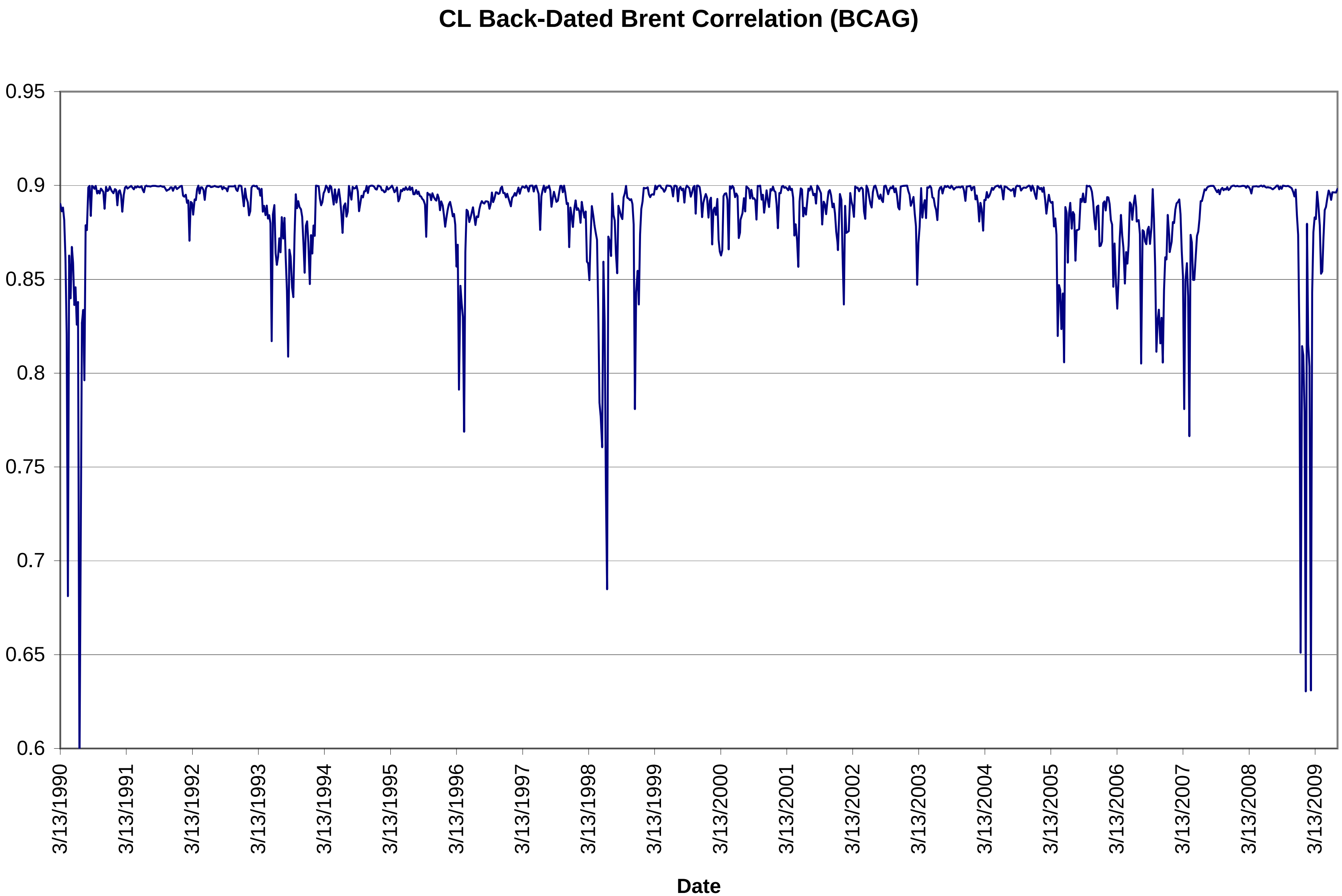
3/13/2009
Date



CL Back-Dated Brent Correlation (BCAG)
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
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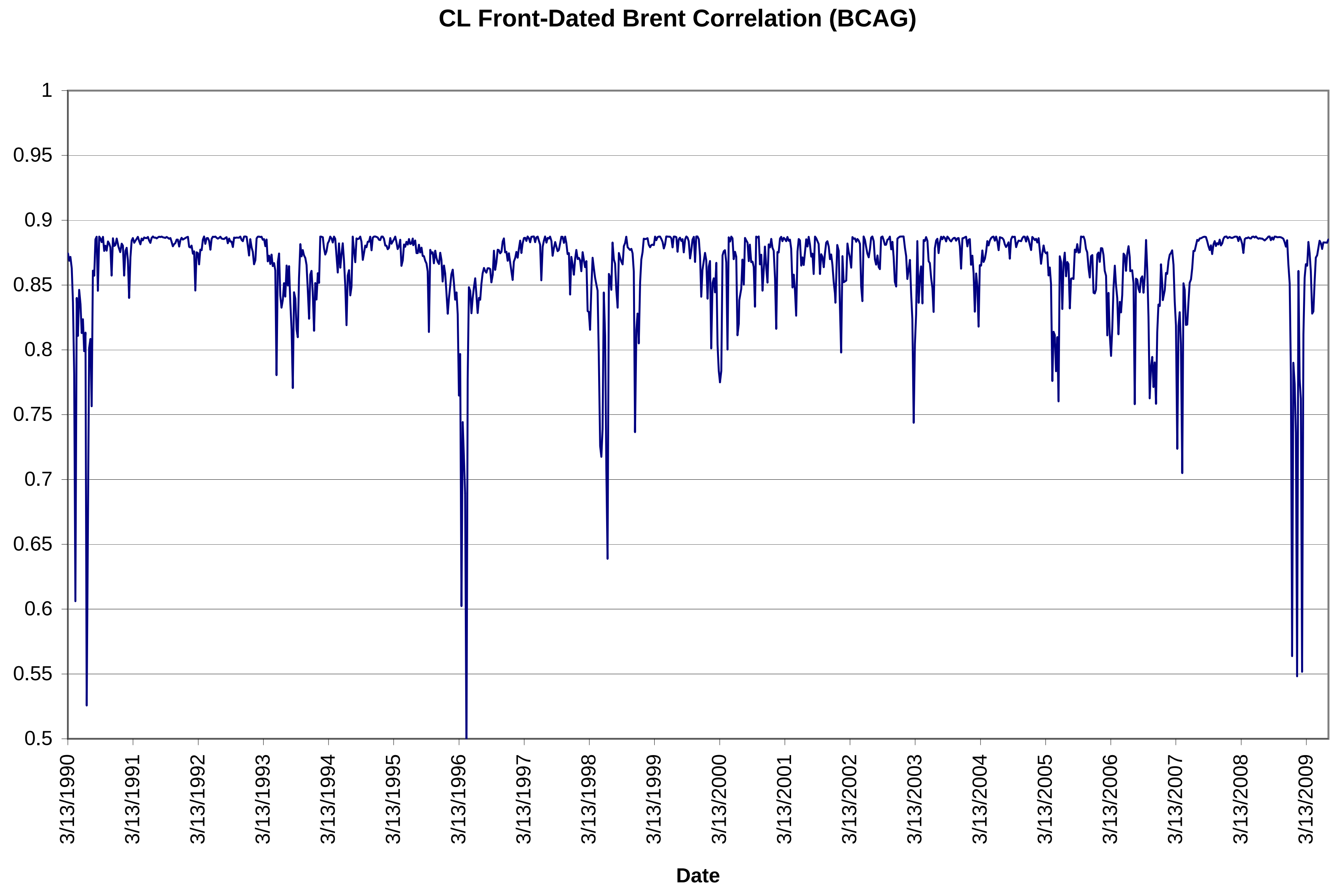
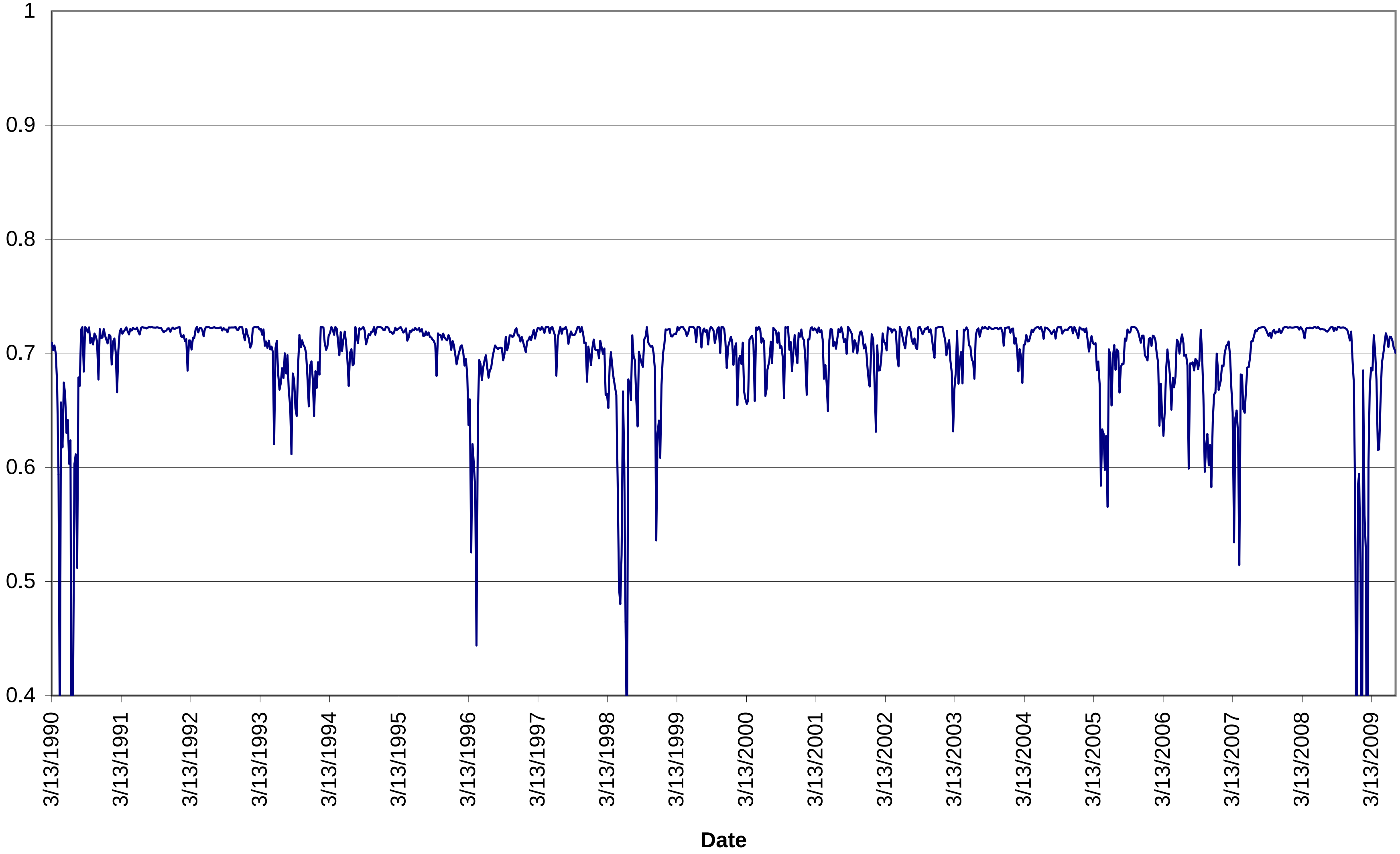
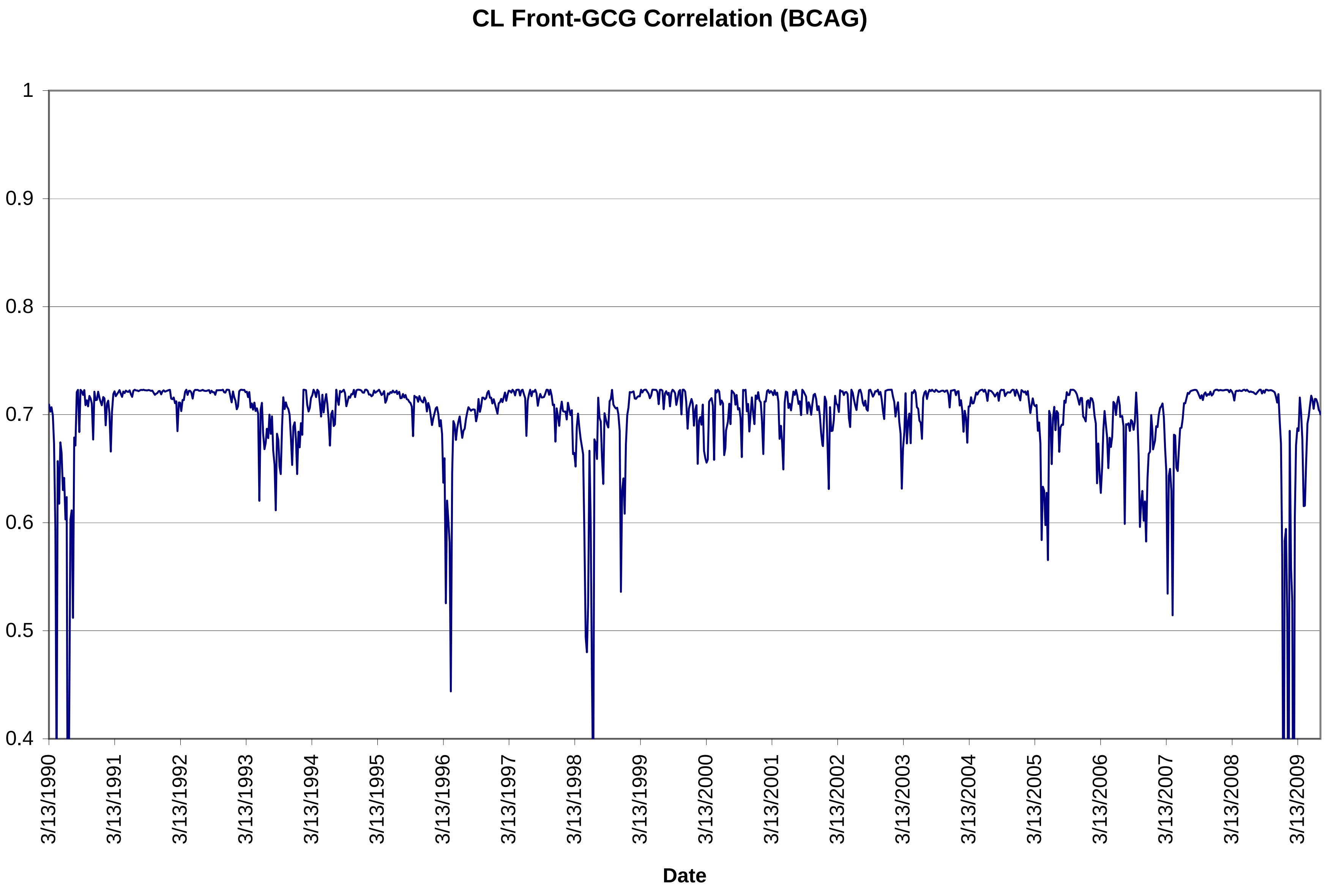
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date


CL Front-Dated Brent Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

CL Front-GCG Correlation (BCAG)




CL Front-GCG Correlation (BCAG)
1
0.9
0.8
0.7
0.6
0.5
0.4
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
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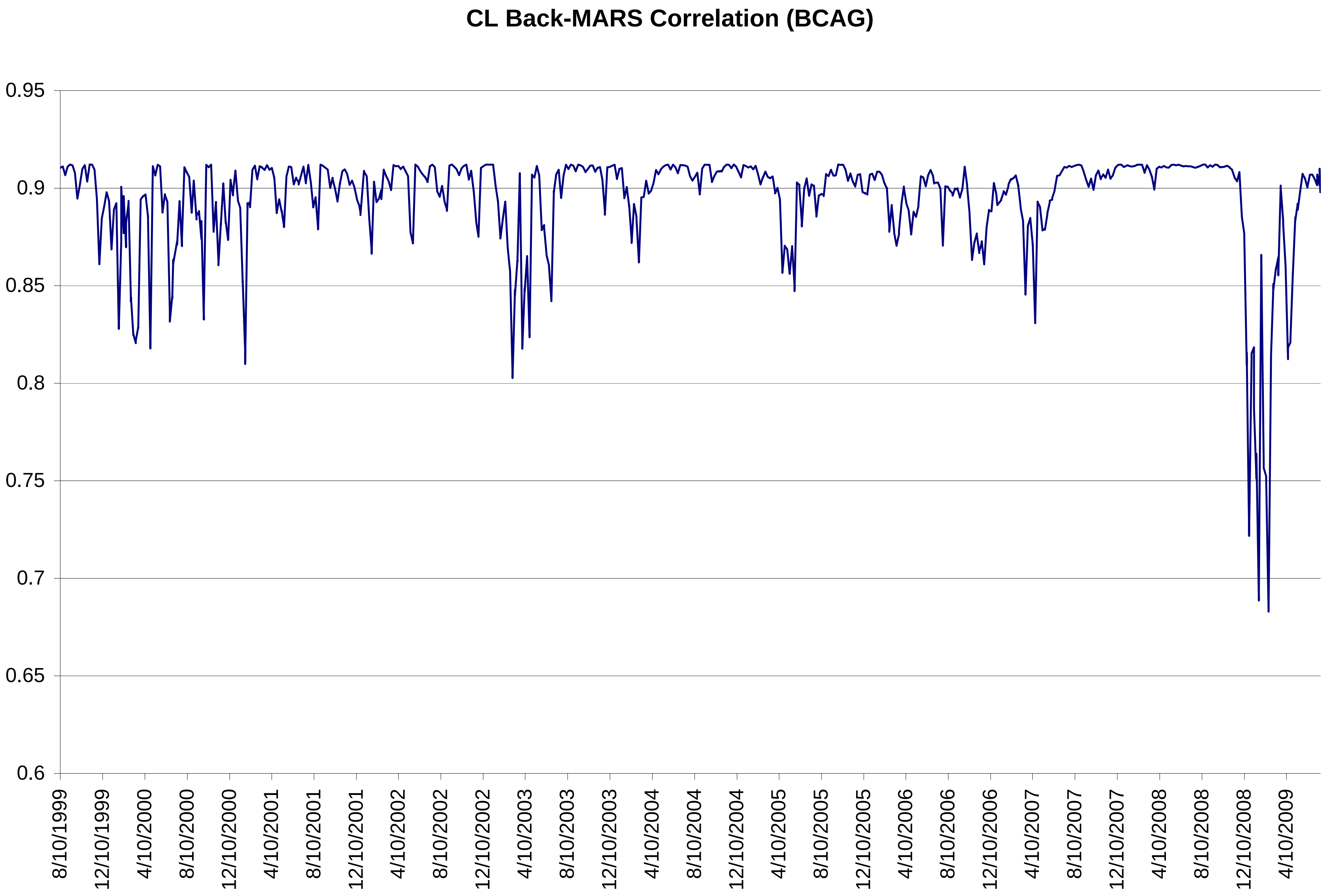
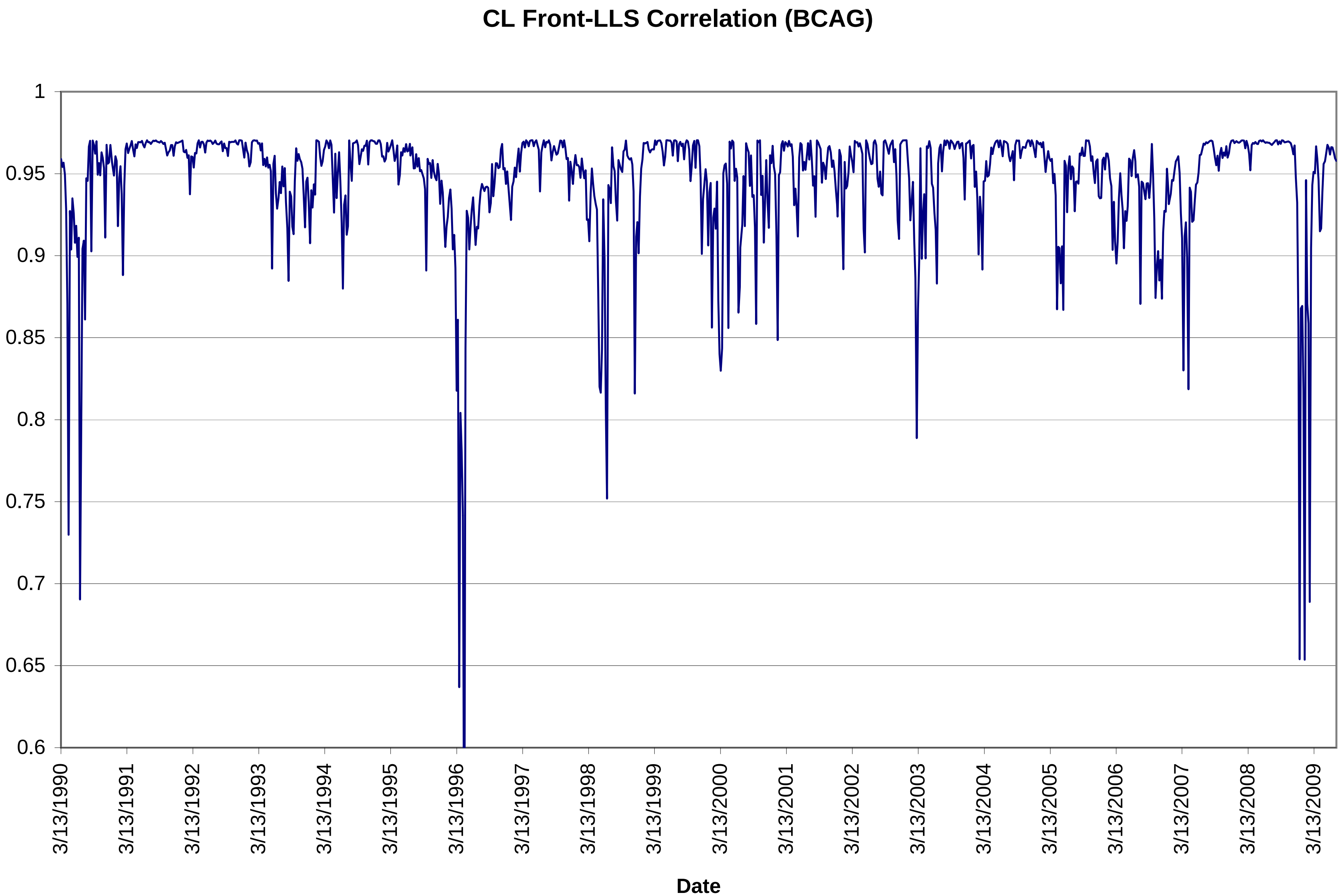
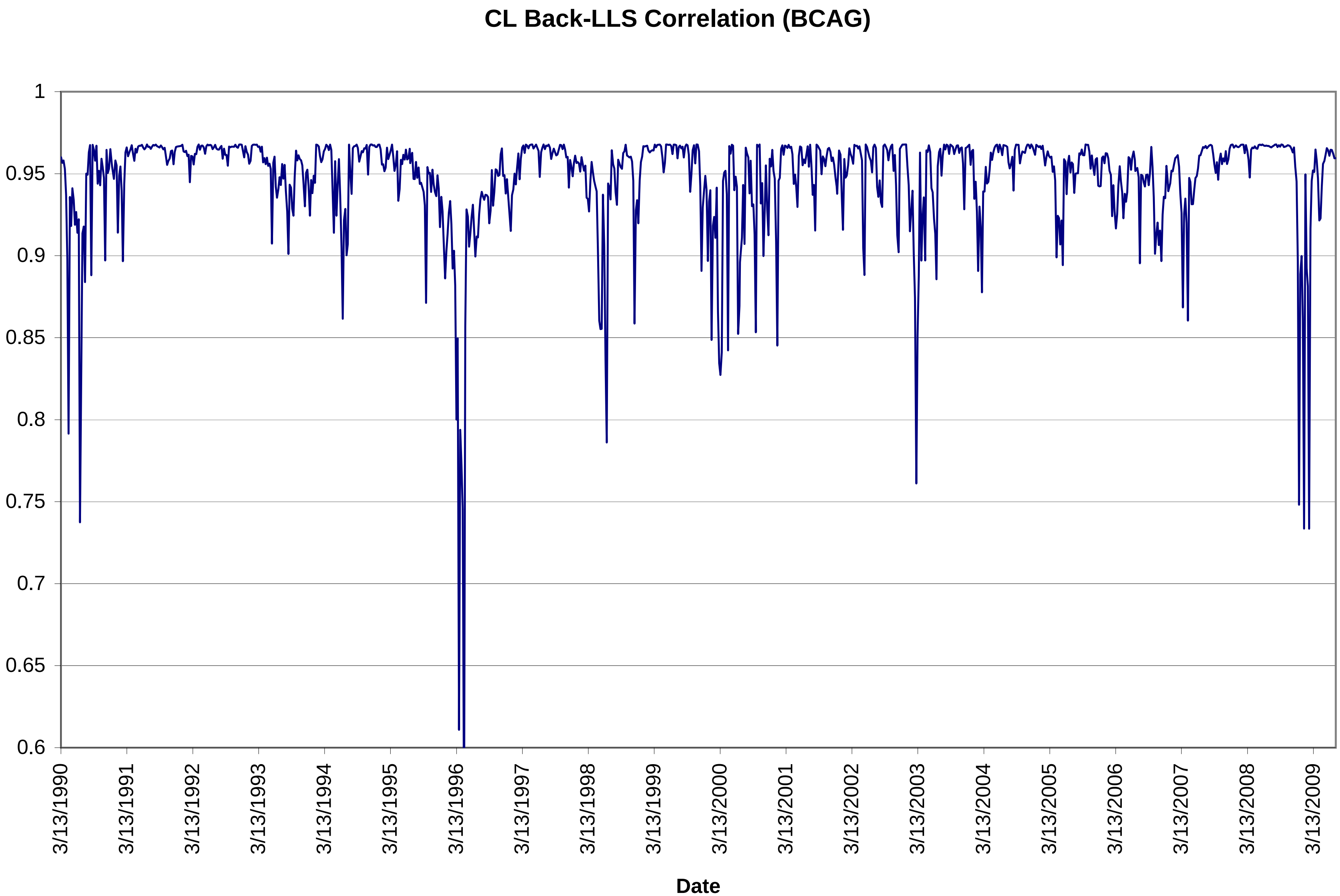
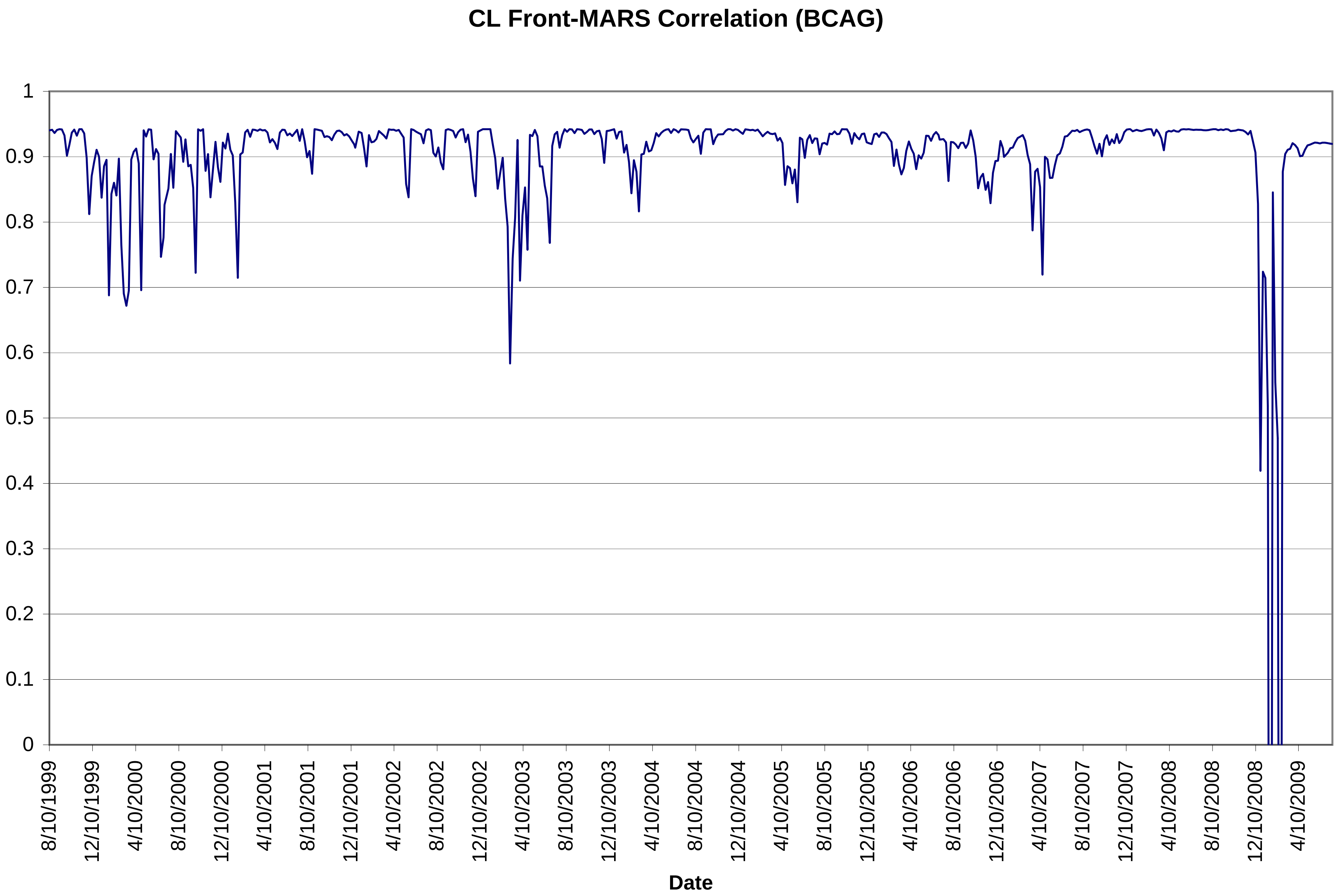
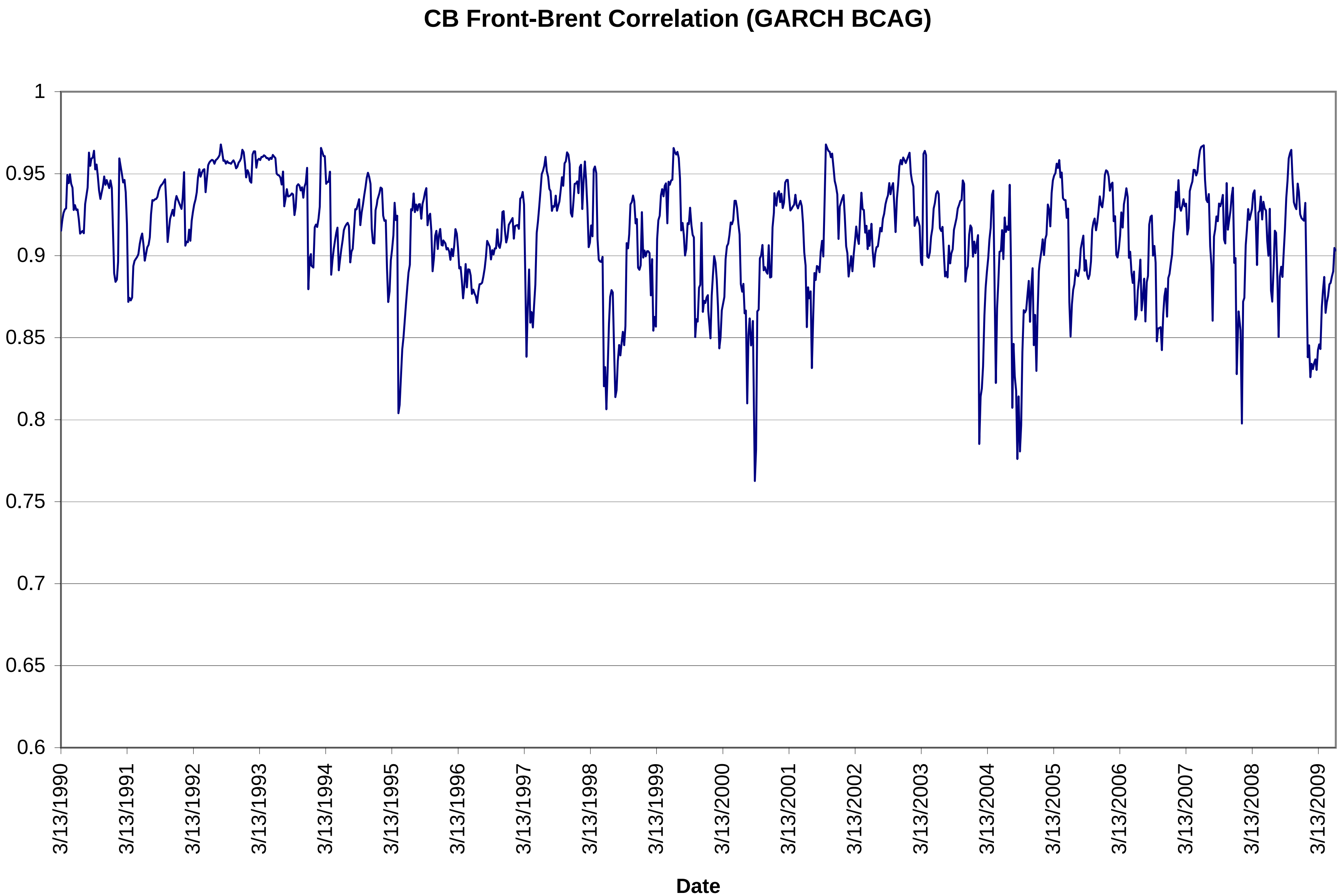
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

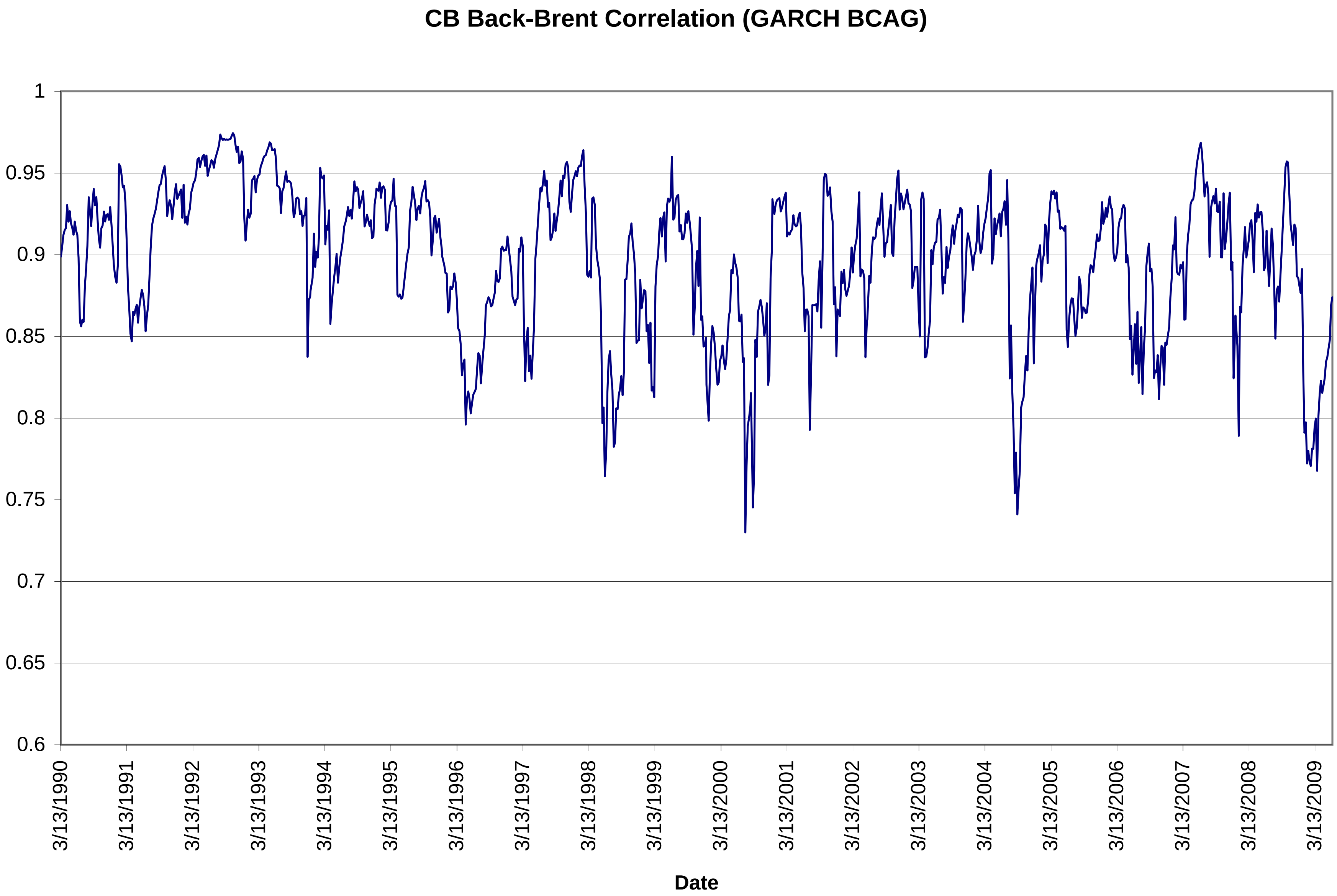

CL Back-MARS Correlation (BCAG)
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
8/10/1999
12/10/1999
4/10/2000
8/10/2000
12/10/2000
4/10/2001
8/10/2001
12/10/2001
4/10/2002
8/10/2002
12/10/2002
4/10/2003
8/10/2003
12/10/2003
4/10/2004
8/10/2004
12/10/2004
4/10/2005
8/10/2005
12/10/2005
4/10/2006
8/10/2006
12/10/2006
4/10/2007
8/10/2007
12/10/2007
4/10/2008
8/10/2008
12/10/2008
4/10/2009


CL Front-LLS Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

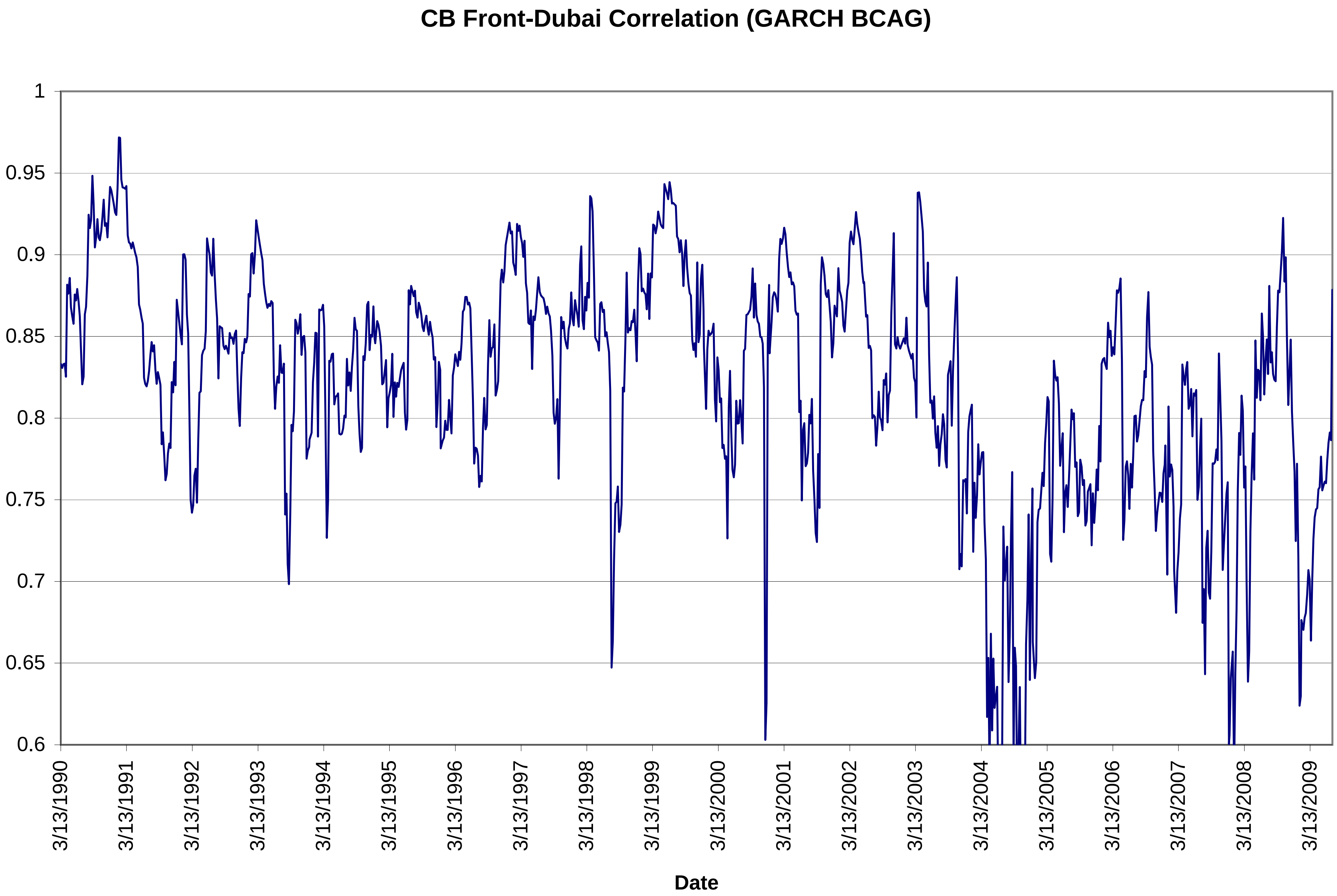

CL Back-LLS Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date


CL Front-MARS Correlation (BCAG)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8/10/1999
12/10/1999
4/10/2000
8/10/2000
12/10/2000
4/10/2001
8/10/2001
12/10/2001
4/10/2002
8/10/2002
12/10/2002
4/10/2003
8/10/2003
12/10/2003
4/10/2004
8/10/2004
12/10/2004
4/10/2005
8/10/2005
12/10/2005
4/10/2006
8/10/2006
12/10/2006
4/10/2007
8/10/2007
12/10/2007
4/10/2008
8/10/2008
12/10/2008
4/10/2009
Date

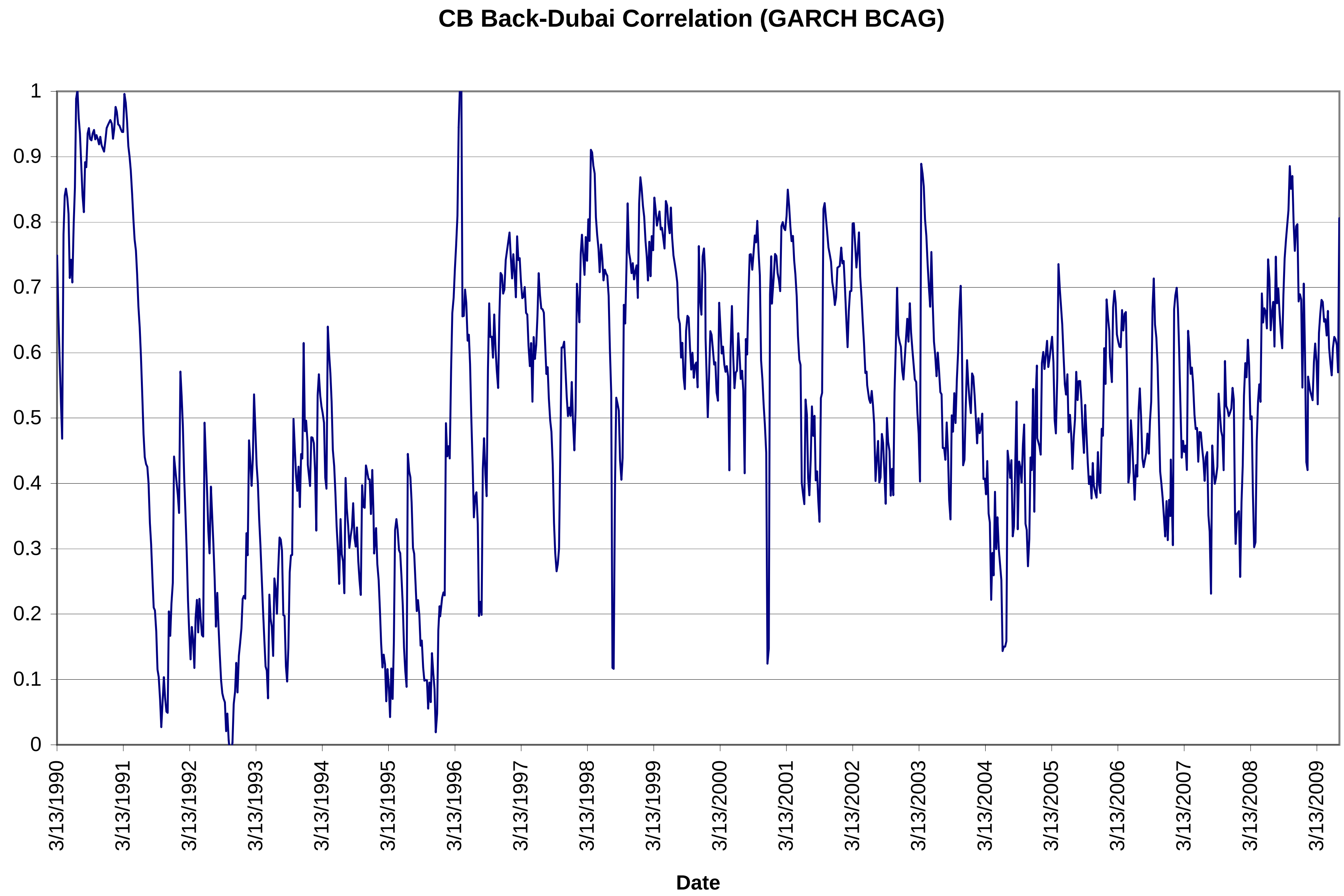

CB Front-Brent Correlation (GARCH BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

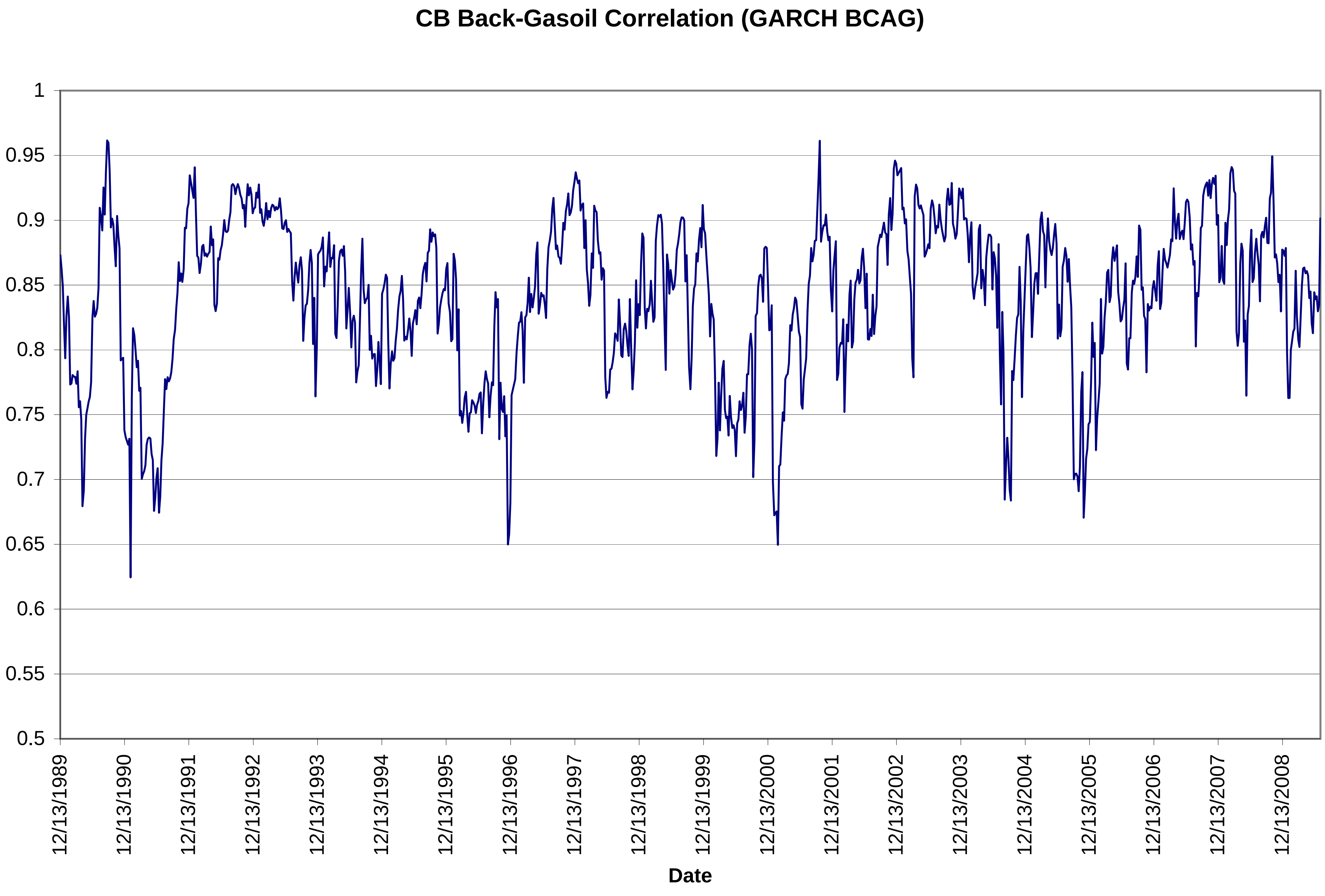


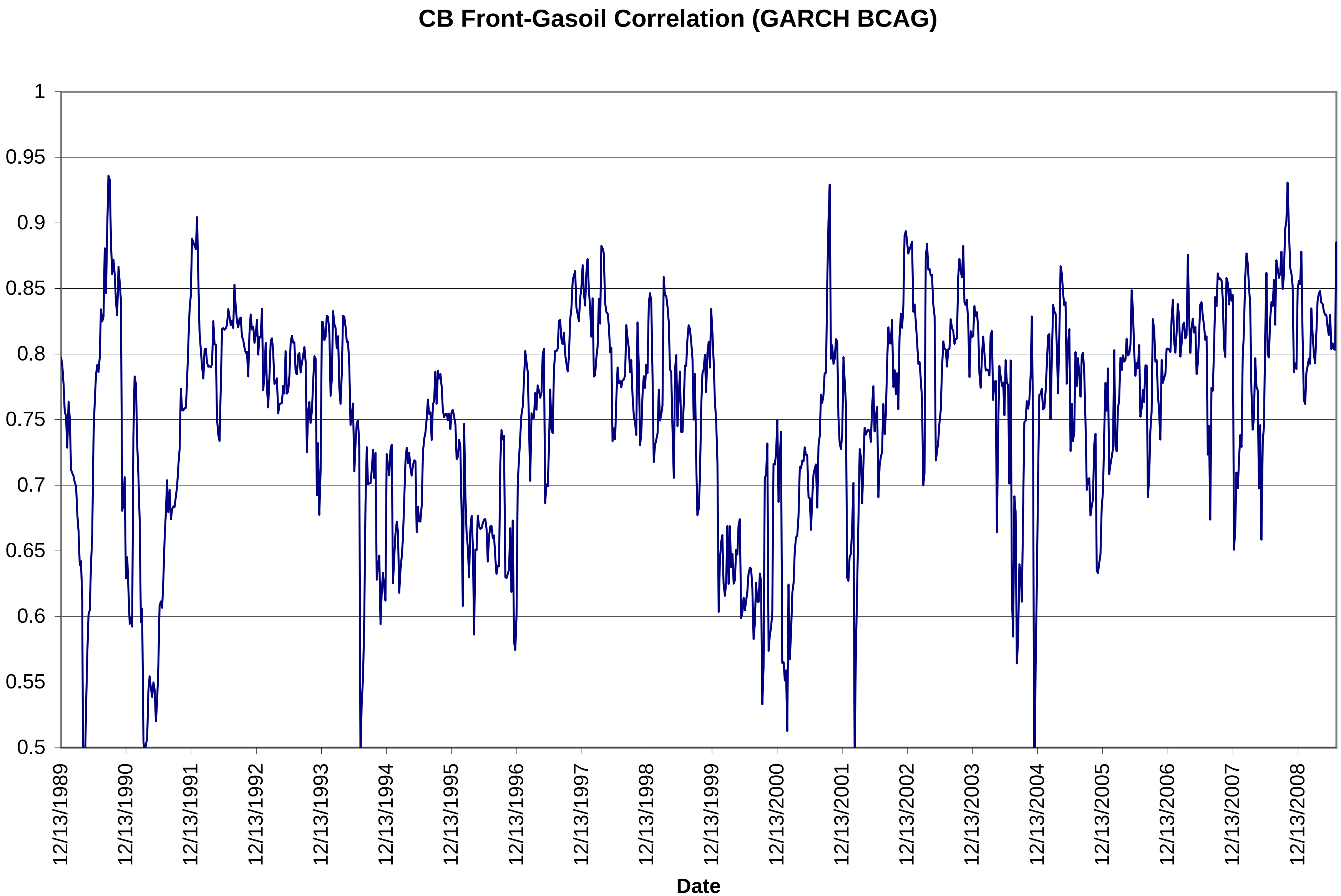
CB Back-Brent Correlation (GARCH BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

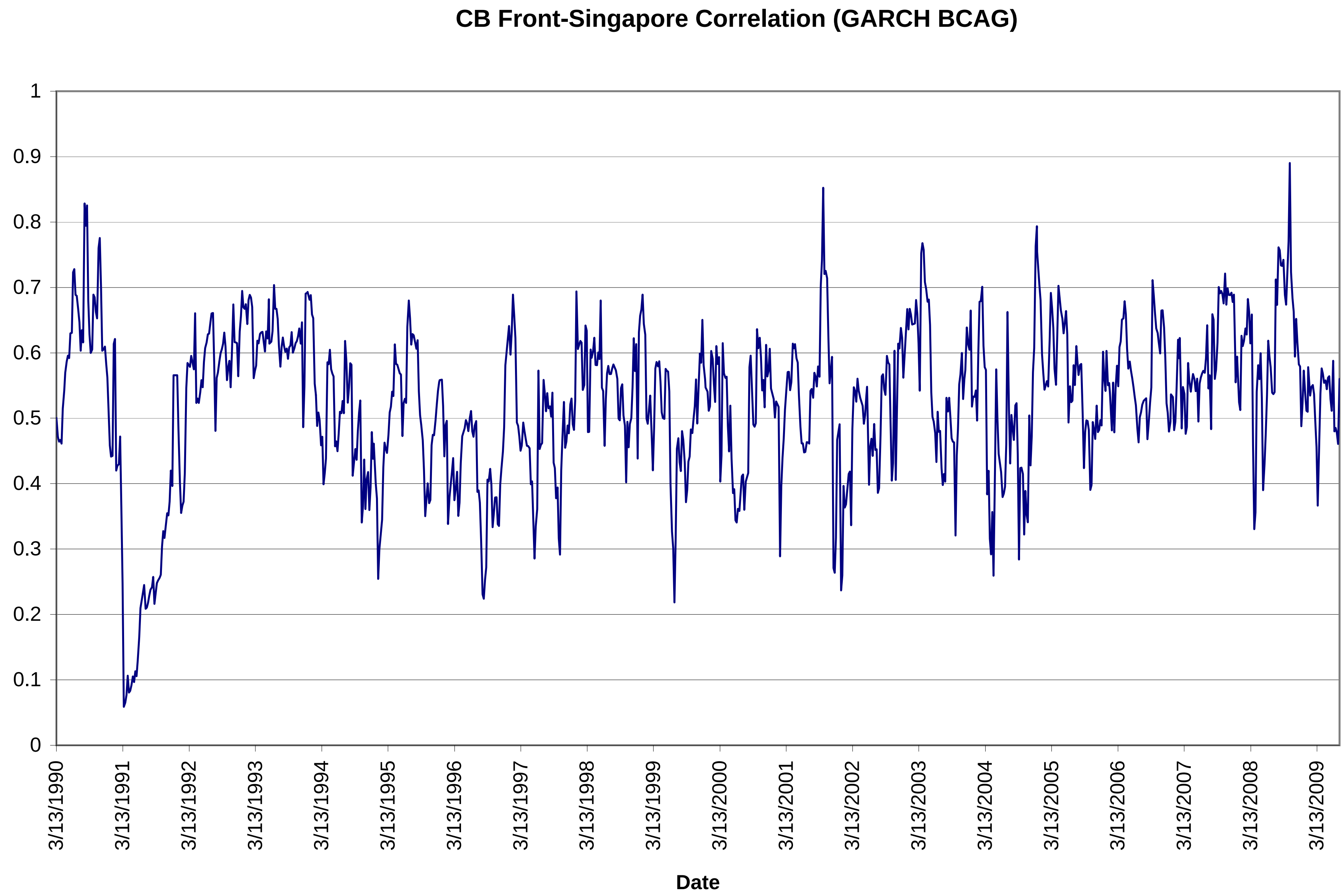


CB Front-Dubai Correlation (GARCH BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date


CB Back-Dubai Correlation (GARCH BCAG)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

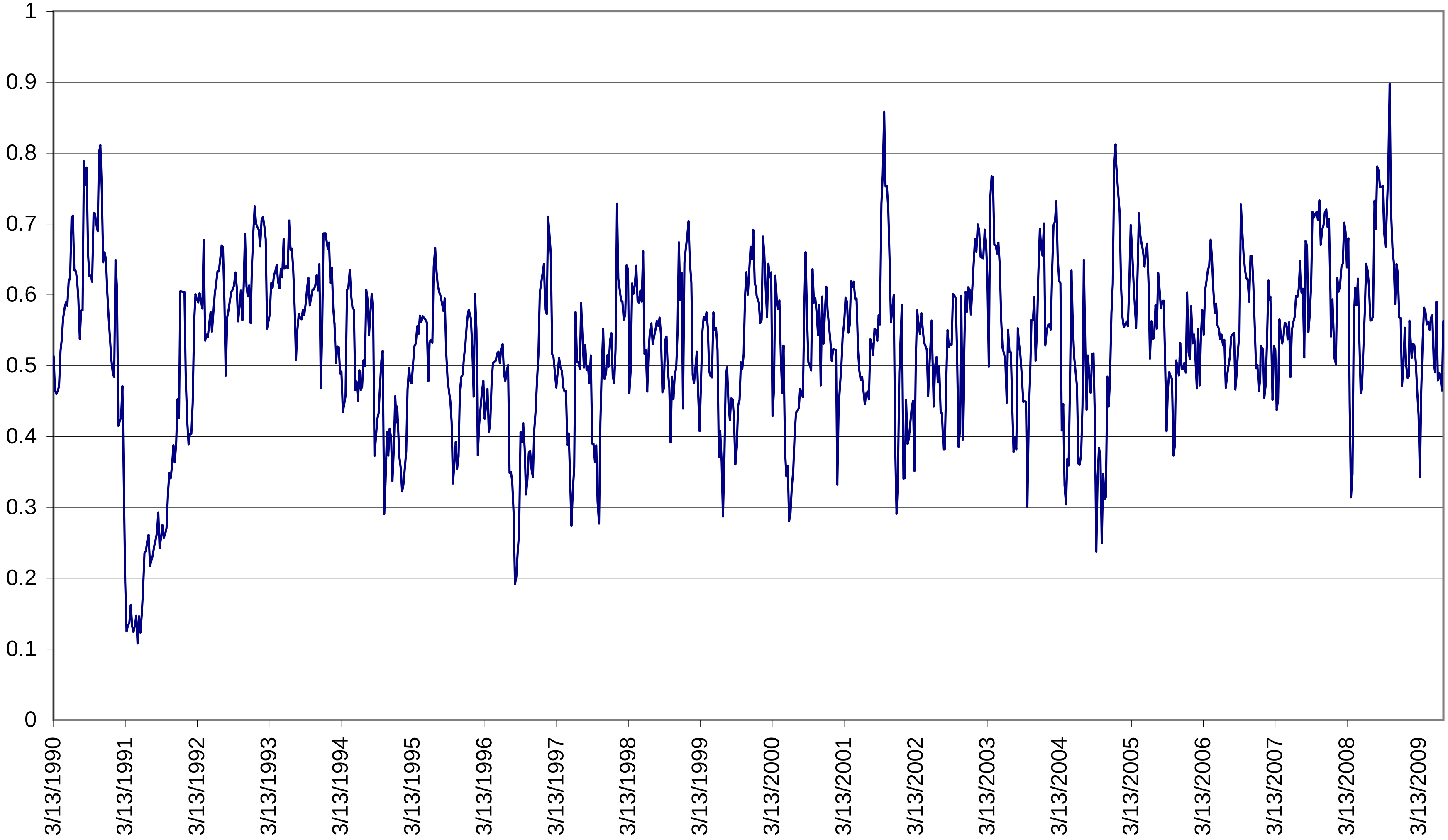

CB Back-Gasoil Correlation (GARCH BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
12/13/1989
12/13/1990
12/13/1991
12/13/1992
12/13/1993
12/13/1994
12/13/1995
12/13/1996
12/13/1997
12/13/1998
12/13/1999
12/13/2000
12/13/2001
12/13/2002
12/13/2003
12/13/2004
12/13/2005
12/13/2006
12/13/2007
12/13/2008
Date

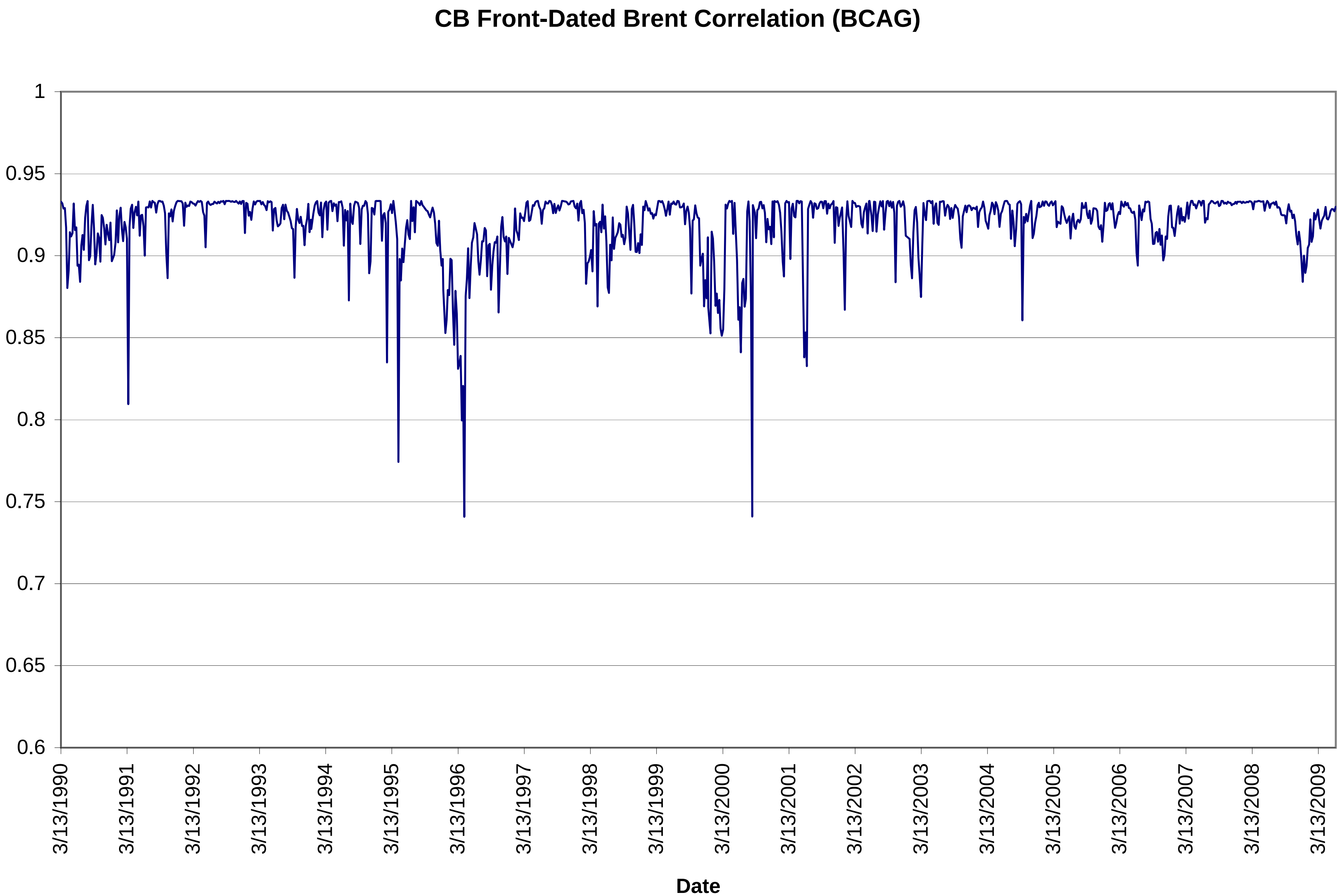

CB Front-Gasoil Correlation (GARCH BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
12/13/1989
12/13/1990
12/13/1991
12/13/1992
12/13/1993
12/13/1994
12/13/1995
12/13/1996
12/13/1997
12/13/1998
12/13/1999
12/13/2000
12/13/2001
12/13/2002
12/13/2003
12/13/2004
12/13/2005
12/13/2006
12/13/2007
12/13/2008
Date



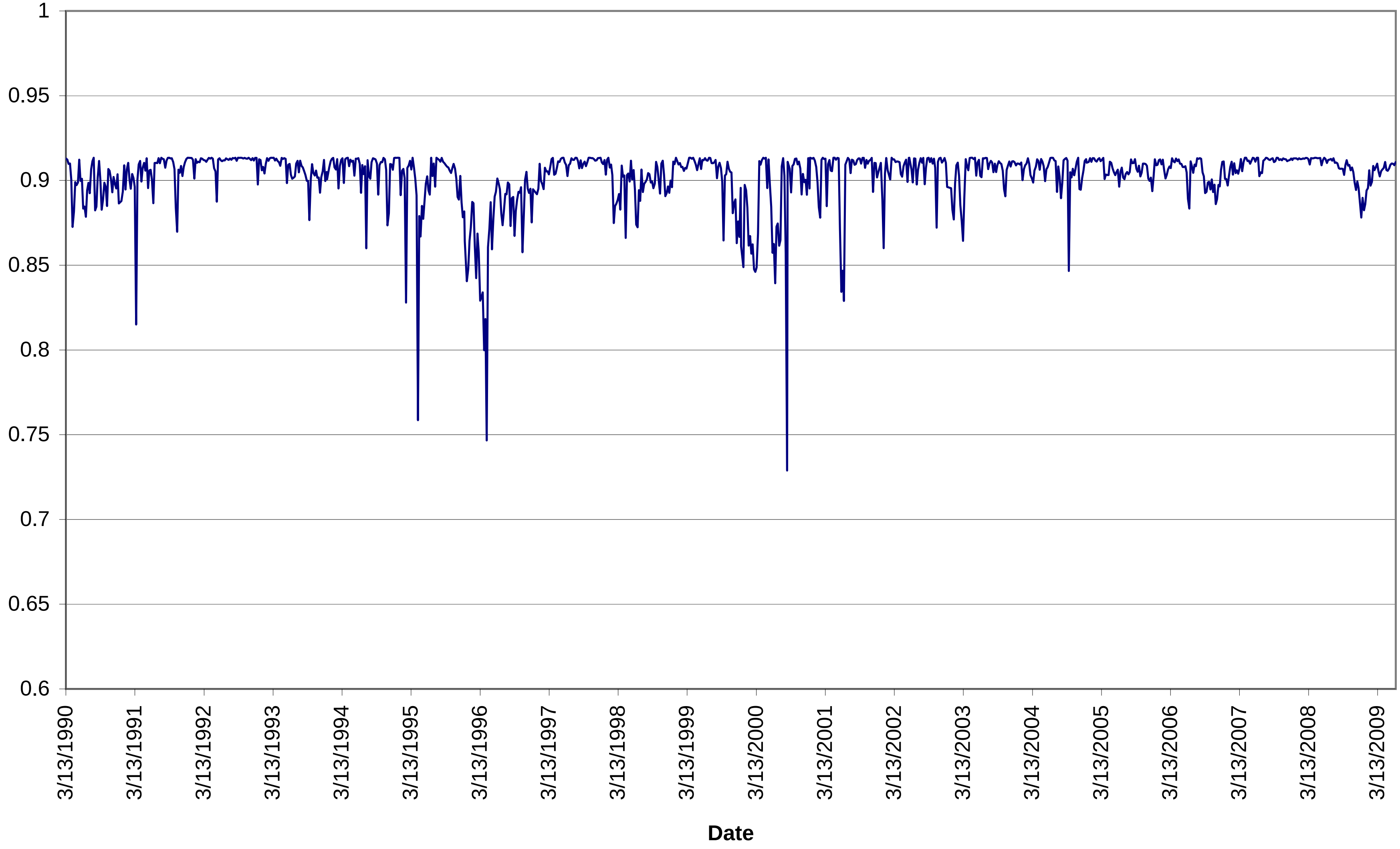
CB Front-Singapore Correlation (GARCH BCAG)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

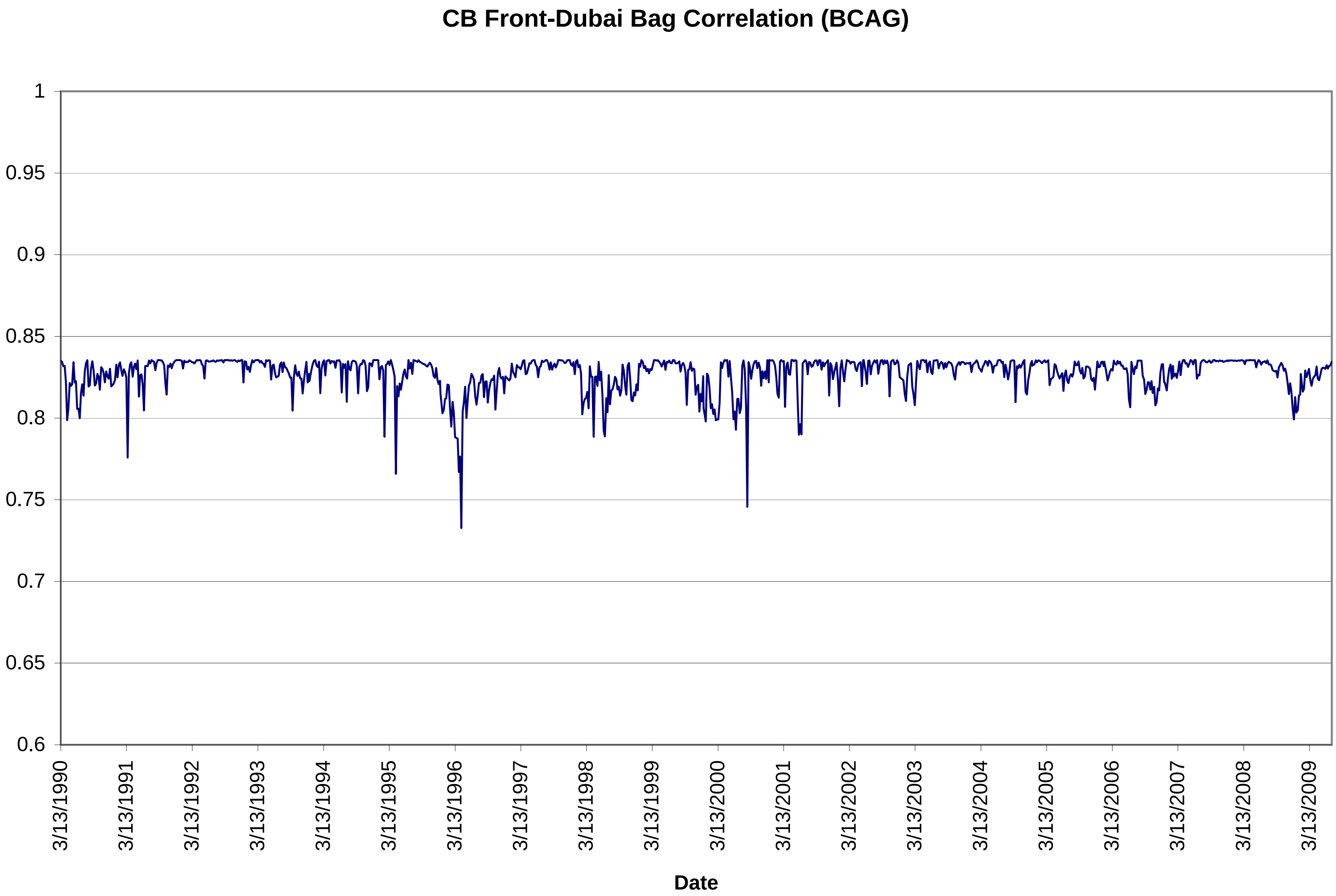
CB Back-Singapore Correlation (GARCH BCAG)

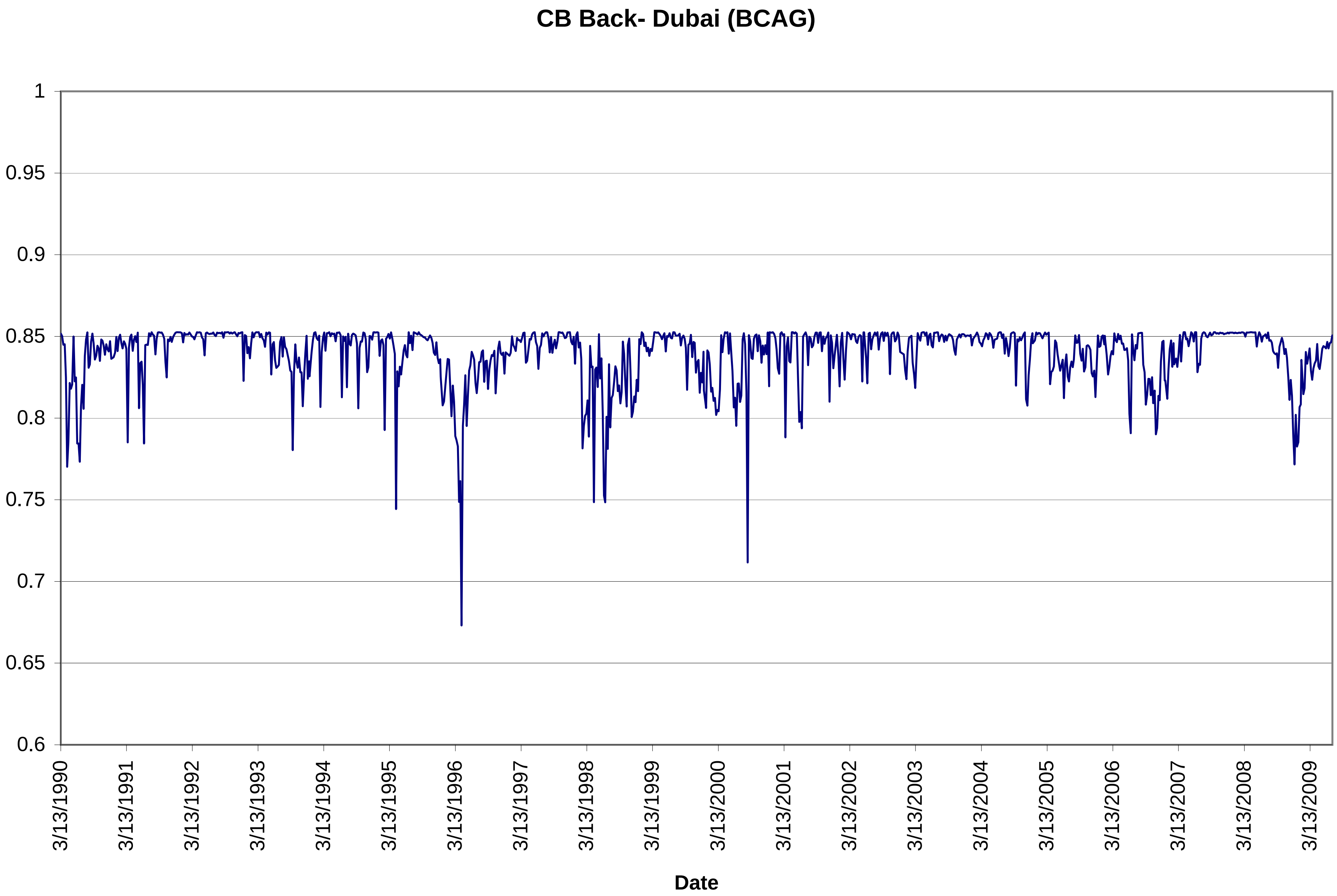



CB Front-Dated Brent Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

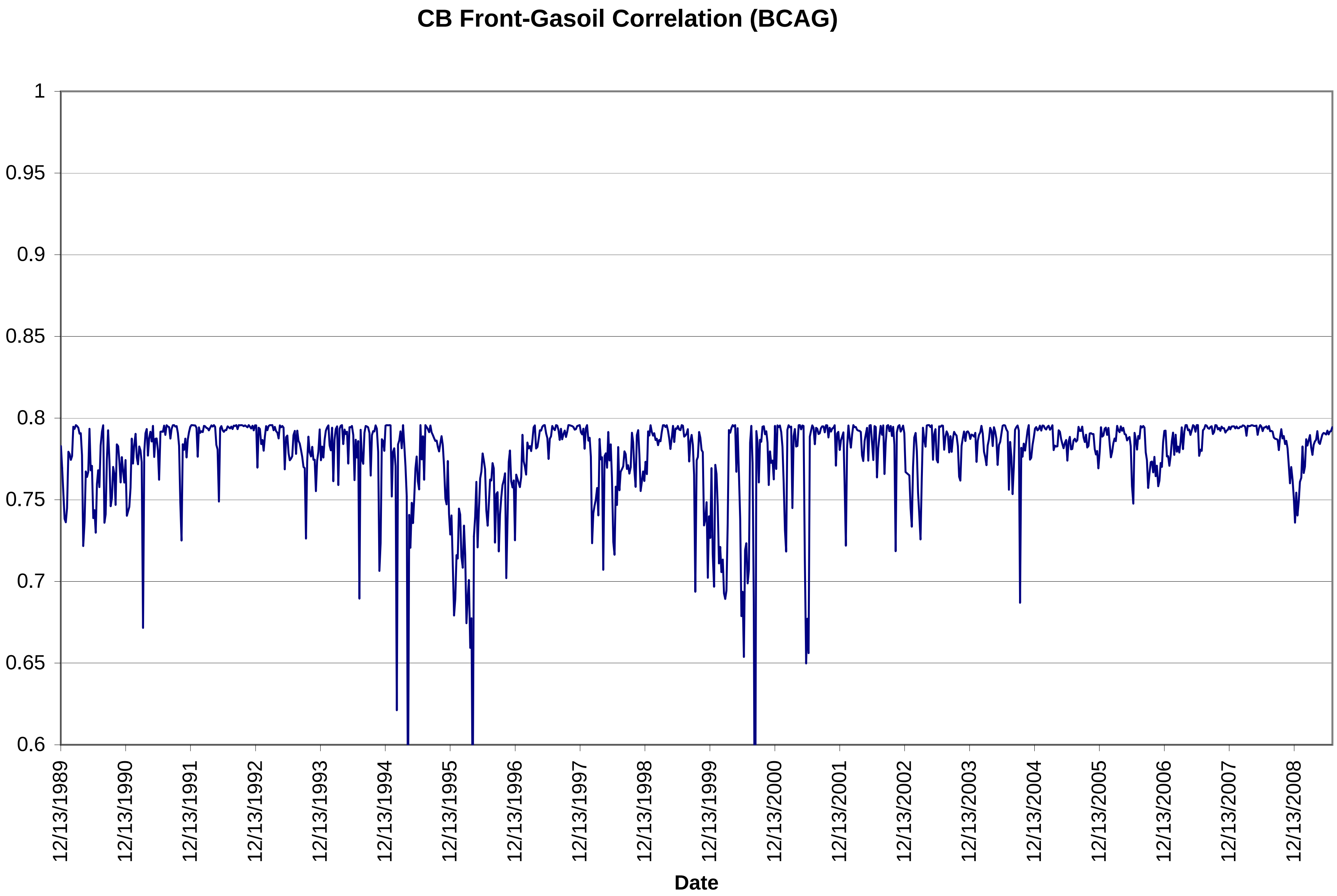
CB Back-Dated Brent Correlation (BCAG)




CB Front-Dubai Bag Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date



CB Back- Dubai (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date


CB Front-Gasoil Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
12/13/1989
12/13/1990
12/13/1991
12/13/1992
12/13/1993
12/13/1994
12/13/1995
12/13/1996
12/13/1997
12/13/1998
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12/13/2000
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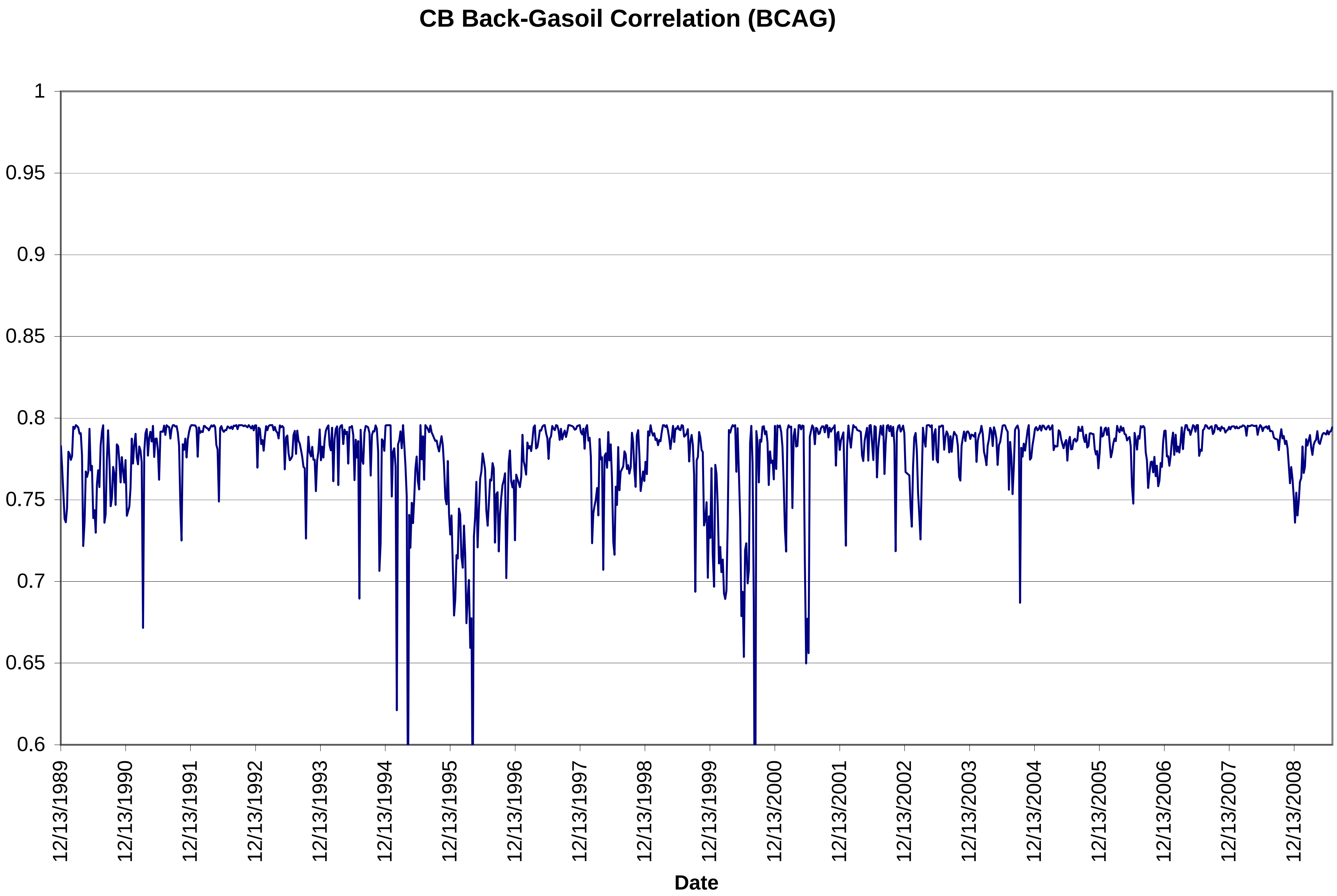
12/13/2006
12/13/2007
12/13/2008
Date


CB Back-Gasoil Correlation (BCAG)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
12/13/1989
12/13/1990
12/13/1991
12/13/1992
12/13/1993
12/13/1994
12/13/1995
12/13/1996
12/13/1997
12/13/1998
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12/13/2000
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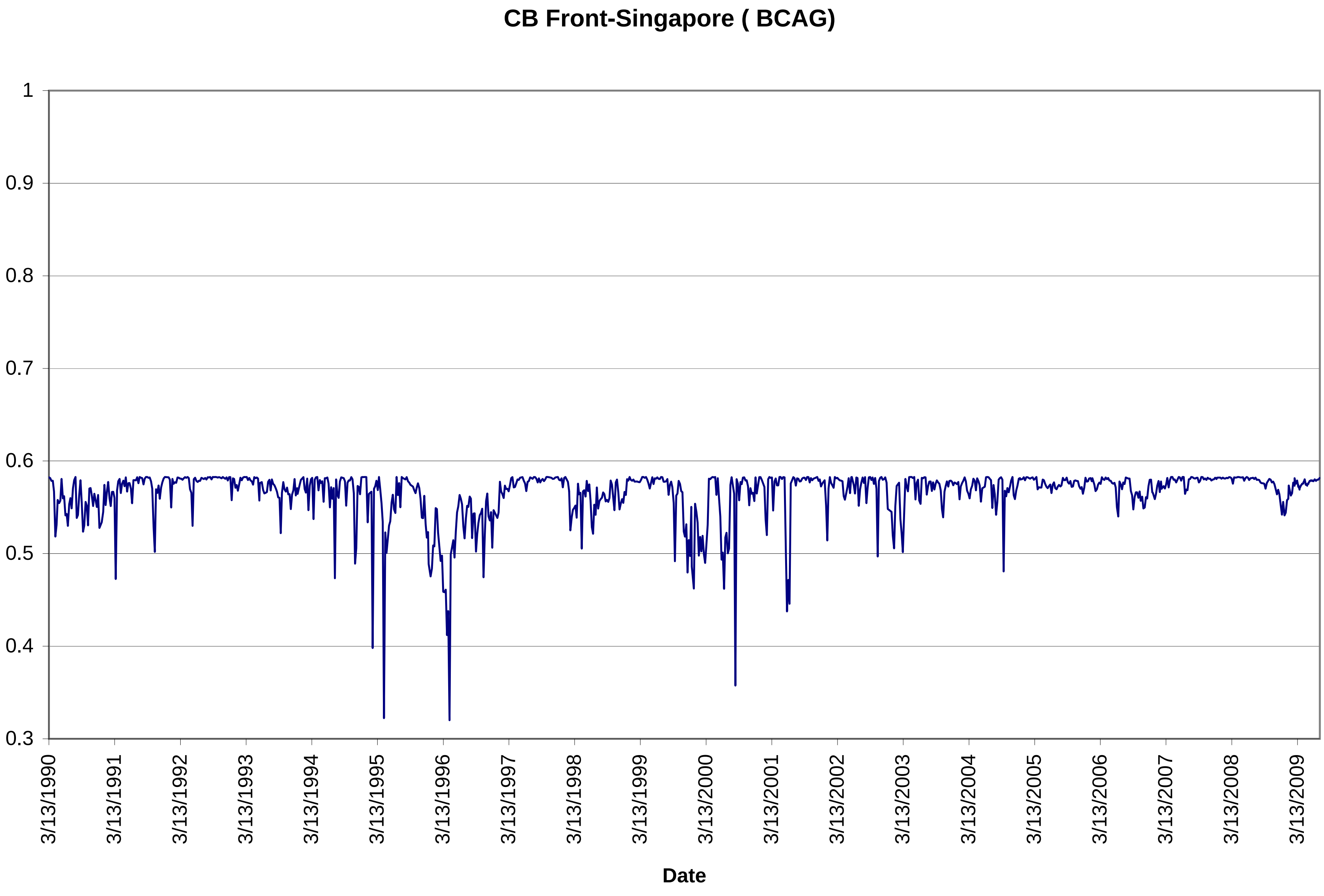
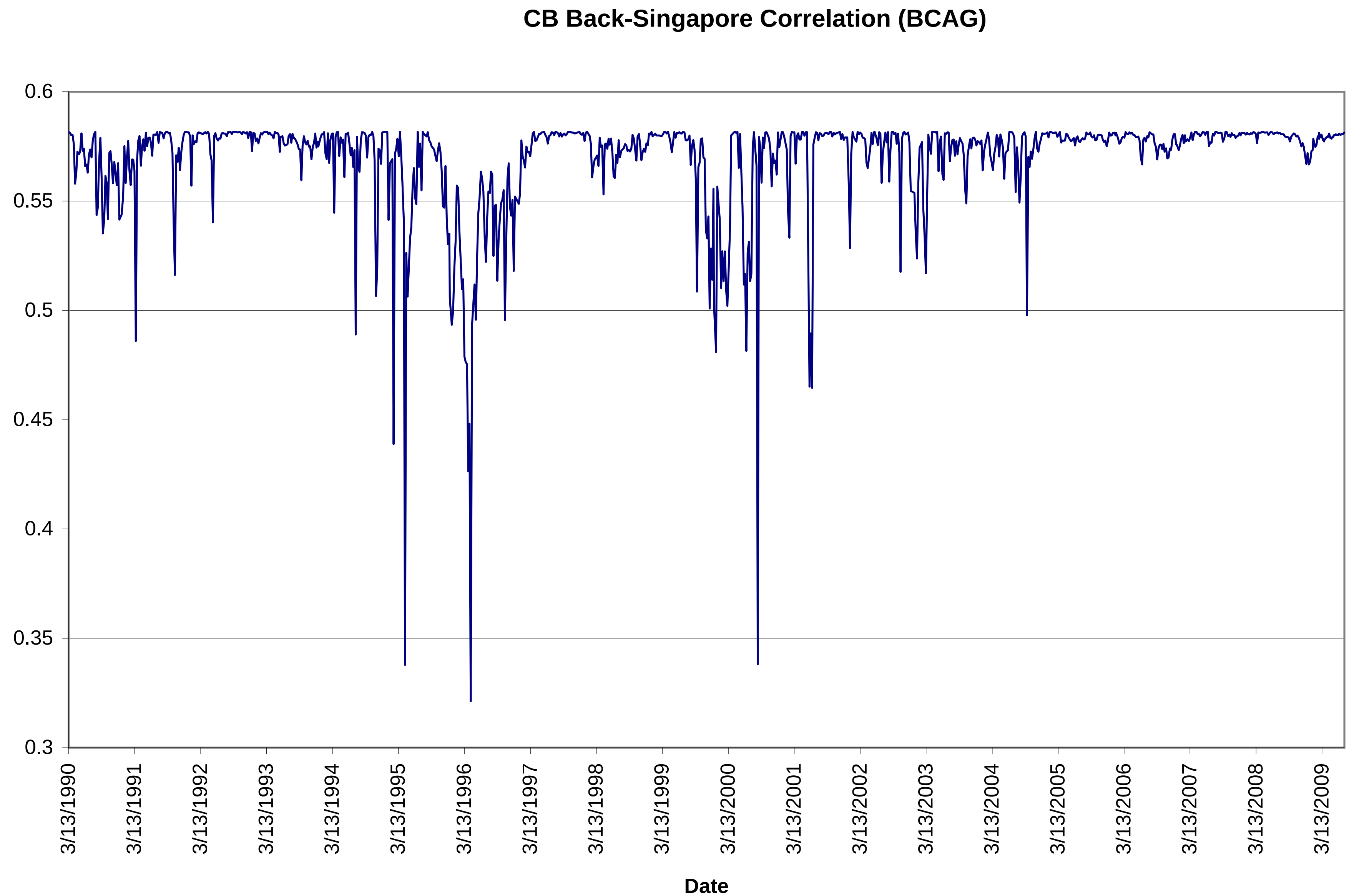
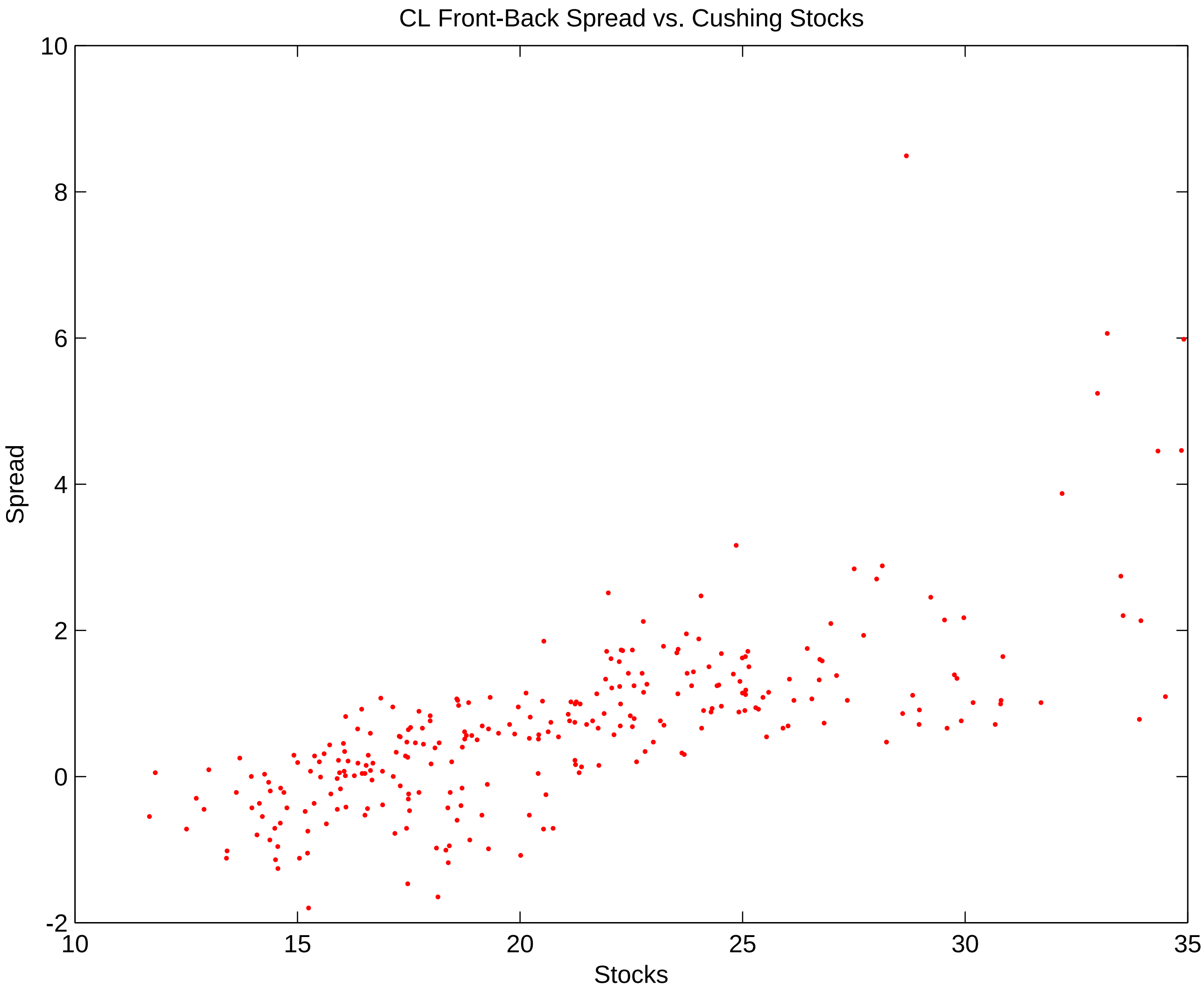
12/13/2003
12/13/2004
12/13/2005
12/13/2006
12/13/2007
12/13/2008
Date

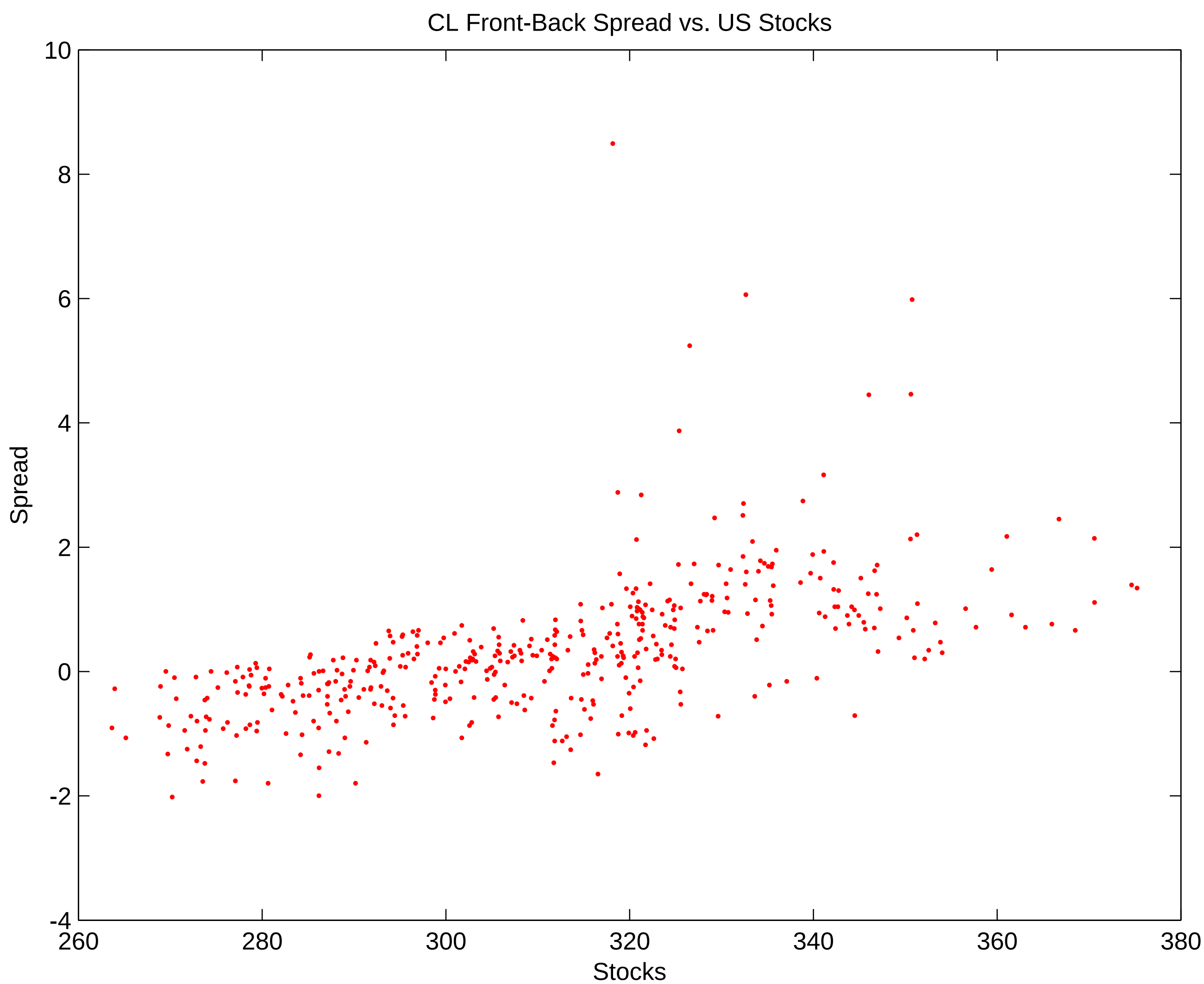

CB Front-Singapore (BCAG)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date

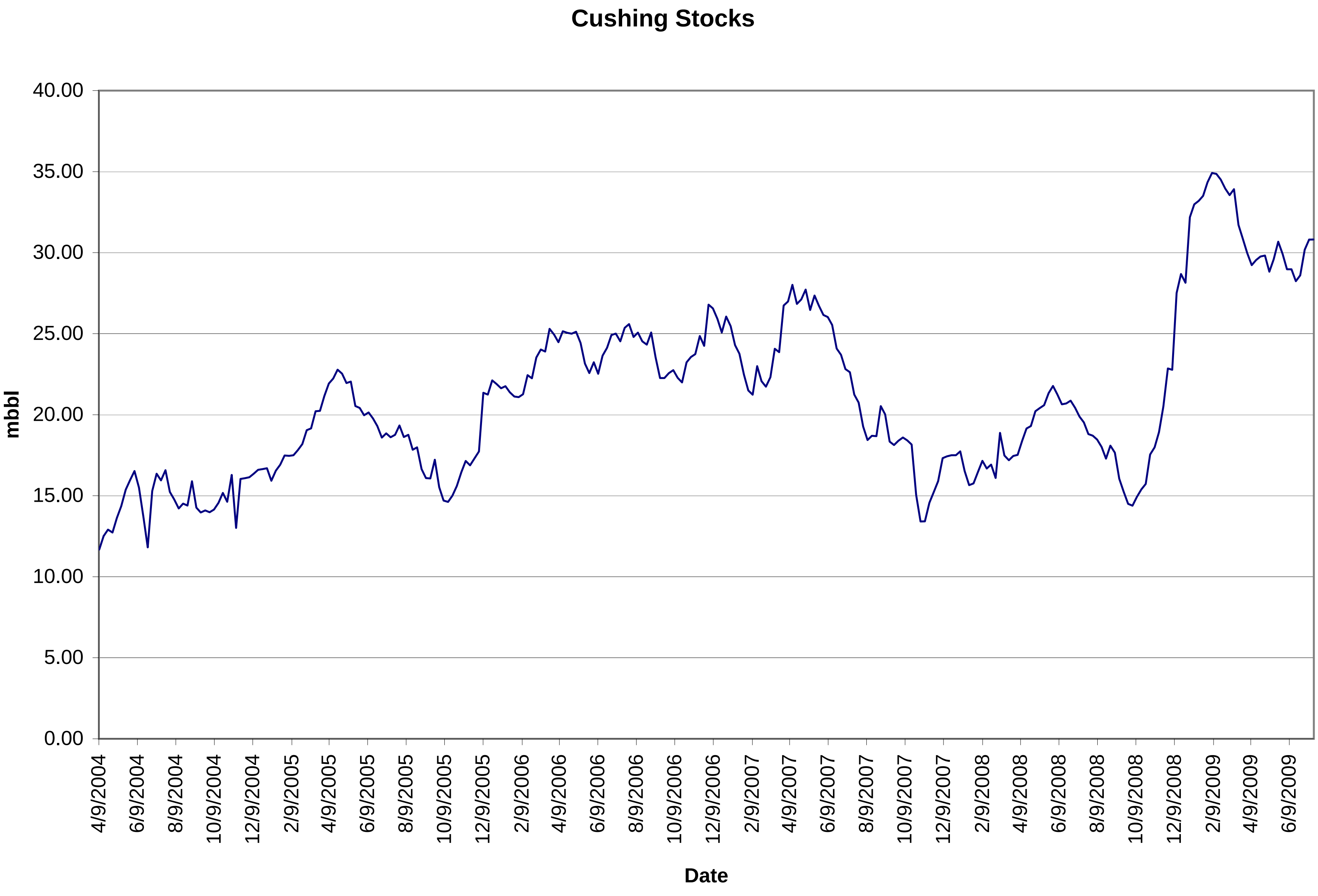


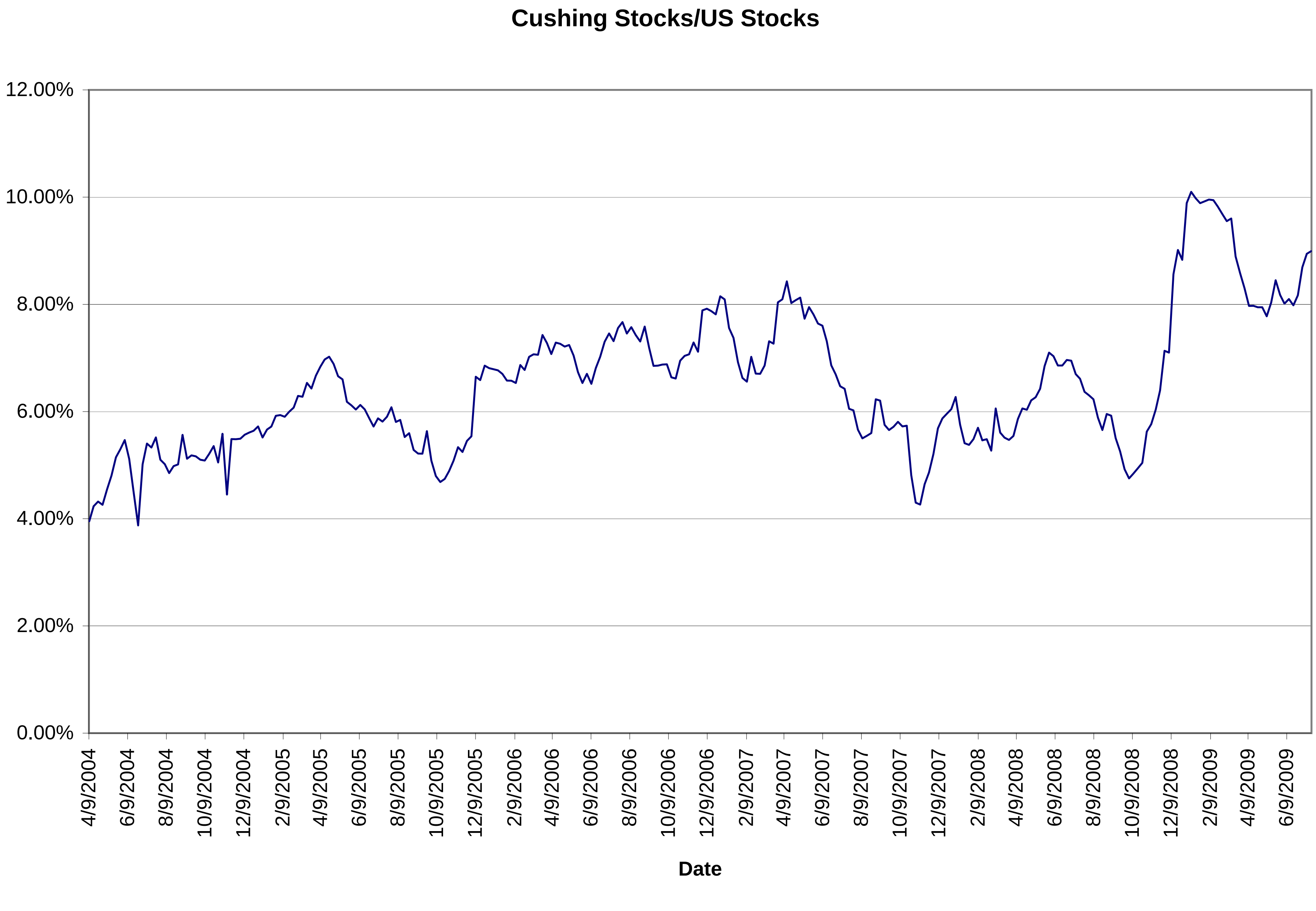
CB Back-Singapore Correlation (BCAG)
0.6
0.55
0.5
0.45
0.4
0.35
0.3
3/13/1990
3/13/1991
3/13/1992
3/13/1993
3/13/1994
3/13/1995
3/13/1996
3/13/1997
3/13/1998
3/13/1999
3/13/2000
3/13/2001
3/13/2002
3/13/2003
3/13/2004
3/13/2005
3/13/2006
3/13/2007
3/13/2008
3/13/2009
Date



CL Front-Back Spread vs. Cushing Stocks
Spread
Stocks
10
8
6
4
2
0
-2
10
15
20
25
30
35


CL Front-Back Spread vs. US Stocks
Spread
Stocks
10
8
6
4
2
0
-2
-4
260
280
300
320
340
360
380


Cushing Stocks
mbbl
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
4/9/2004
6/9/2004
8/9/2004
10/9/2004
12/9/2004
2/9/2005
4/9/2005
6/9/2005
8/9/2005
10/9/2005
12/9/2005
2/9/2006
4/9/2006
6/9/2006
8/9/2006
10/9/2006
12/9/2006
2/9/2007
4/9/2007
6/9/2007
8/9/2007
10/9/2007
12/9/2007
2/9/2008
4/9/2008
6/9/2008
8/9/2008
10/9/2008
12/9/2008
2/9/2009
4/9/2009
6/9/2009
Date



Cushing Stocks/US Stocks
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
4/9/2004
6/9/2004
8/9/2004
10/9/2004
12/9/2004
2/9/2005
4/9/2005
6/9/2005
8/9/2005
10/9/2005
12/9/2005
2/9/2006
4/9/2006
6/9/2006
8/9/2006
10/9/2006
12/9/2006
2/9/2007
4/9/2007
6/9/2007
8/9/2007
10/9/2007
12/9/2007
2/9/2008
4/9/2008
6/9/2008
8/9/2008
10/9/2008
12/9/2008
2/9/2009
4/9/2009
6/9/2009
Date