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Abstract

Traditionally, analysts and traders have expected to see a stable, reasonably predictable, relationship between the price (and thus the rate of return) of gold and silver. Both these metals retain important industrial, commercial and investment uses. Recent research has cast some doubt on this assumption. We find that while over the 1990's the relationship may well have been more unstable, when a longer timeframe is examined the relationship is stable but weakening. This we hypothesise is due to the changing nature of the demand patterns for gold versus silver.

Introduction

This study examines the dynamic relationship between gold and silver over the 1978-2002 period. This period covers a very extensive range of economic conditions, political change in major producers and increased sophistication in asset markets generally. It includes, at the start of the period, covers the attempted cornering of the silver market by the Hunt Brothers. Thus, prima facia we would not expect to necessarily see a stable relationship between gold and silver.

Gold and silver have historically been seen as close substitutes for one another, both being precious metals that can be used to back currency and both having been used as currency. There is significant evidence (see for example Shishko (1977), Money, Affleck-Graves and Carter (1982), Sherman (1982),Landa and Irwin (1987) Aggarwal and Sonen (1988), Johnson and Soenen (1997), Egan and Peters (2001), Draper, Faff and Hillier (2002) and Adrangi, Chatrath and Raffiee (2003)) that these metals can play a useful role in diversifying risk, as well as being an attractive investment in their own right, Thus, one might expect that the prices share similar dynamics. More recently the focus has switched to collectibles made from these metals: see for instance Kane (1984), Koford and Tschoegl (1998) & Roehner (2001).

However, there are also economic fundamentals that may act to drive the prices of gold and silver apart. While both are used extensively in industrial processes, there are significant differences between these uses. Silver is extremely reflective, a good conductor of electricity and has extensive use in optics and photography. Gold's industrial uses are fewer, with the majority of demand coming from the jewellery and dental markets as well as being driven by Central Bank reserve demand (official sector gold). Recently, Dooley, Isard and Taylor (1995), Christie-David (2000) and Adrangi, Chatrath et al. (2003) have examined the relationship between macroeconomic variables and these assets, concluding that while they share a similar set of drivers they each also have important unique macroeconomic drivers.

Previous Research

Testing for the existence and stability of the gold-silver relationship is not new. Ciner (2001) cites the long held belief that the price ratio should be 1:16 in favour of gold. More recently, studies have used cointegration methods to examine the relationship. Unlike these previous studies we examine this relationship both for the cash and the future markets. A finding that there existed such a relationship would be of significance for traders, as it would imply a certain degree of mutual predictability and thus raise the potential for trading profits. However, it would also imply that as the assets shared a common longterm relationship the benefits of including both gold and silver in a portfolio would be considerably reduced.

Portfolio diversification across assets is justified only if there are gains from it. With increasing integration of asset markets, the diversification benefits will tend to decline as the correlations become increasingly positive and strengthen. Significant evidence has accreted for equity and bond markets finding that diversification benefits are non-constant and may be least available when they are most needed. The effect of cointegration is to reduce portfolio benefits as the two assets share a long-term stable relationship. Thus, in assessing the benefits of gold and silver as potential portfolio diversifiers an examination of cointegration is required. There have been an increasing number of papers that have examined this.

The most recent of these include Wahab, Cohn and Lashgari (1994), Escribano and Granger (1998), Ciner (2001) and most recently Adrangi, Chatrath et al. (2003).

Wahab, Cohn et al. (1994) use cash and futures data, on a daily frequency and find that cointegration does exist, but that there were no profitable arbitrage opportunities between these markets. Examining monthly cash data, Escribano and Granger (1998) find that a cointegrating relationship between gold and silver from 1971 to 1995. They split their dataset at 1990 and find that the relationship was weaker in the latter part of the dataset, indicating that the markets were separating. Ciner (2001) examines daily data on futures on gold and silver from the Tokyo Commodities Exchange, over the 1992-1998 period. He finds that over that period there was no evidence of cointegration. Thus, the indication would appear o be that while there may have been a stable relationship at one time this has disappeared in the 1990's. By contrast, Adrangi, Chatrath et al. (2003) use a multivariate approach, and find that a stable longrun relationship exists not only between these metals but also between them and macroeconomic variables. Thus, the evidence of Ciner (2001) appears anomalous.

All of these papers however can be critiqued on the *static* nature of their analyses. With the exception of Escribano and Granger (1998) there is no examination of whether or how the relationship changes over time. In particular, there is no examination of the issue of integration over different time periods. This note attempts to fill that gap.

Data and Analysis

Data

The data used here are Friday closing prices, from COMEX (now part of the New York Mercantile Exchange) for cash and futures. The dataset runs from start of

January 1978 to end-november 2002, giving a total of 1237 data points.[1] The futures data are front month with roll-on-expiration. We examine 4 series: Cash Gold, *GC*; Cash Silver, *SC*; Gold Future, *GF*; and Silver Future, *SF*. Figure 1 and Figure 2 show the evolution of these series. All series have a unit root, as shown by the ADF tests reported in Table 1. This indicates a degree of mean reversion – the data are stable.

In all cases the lag selection was by means of the BIC.

Table 1 : Unit Root Tests

Series	ADF t-test	ADF Z-test	ADF Joint Test of Constant & Unit Root
GC (4 lags)	-3.13	-17.02	4.96
SC (16 lags)	-3.27	-25.22	5.36
GF (8 lags)	-2.97	-15.78	4.47
SF (8 lags)	-3.40	-26.75	5.77
1% Critical Value	-3.43	-20.7	6.43
5% Critical Value	-2.86	-14.1	4.59

Thus, unit roots being present in the levels we can proceed to an examination of any possible cointegration relationships. The method chosen is that of dynamic cointegration analysis, introduced by Hansen and Johansen (1992). In essence, this involves estimation of the by now well understood Johansen (1988) & Johansen and Juselius (1990) multivariate cointegration approach (hereafter JJ) over various windows. In essence the JJ approach involves the determination of the rank of a matrix of cointegrating vectors.

Methodology

[1] The data were sourced from Norman's Historical Data (http://www.normanshistoricaldata.com/index.htm).

To illustrate, for a given lag length l, and assuming no deterministic components, we can write a Vector Autoregression (VAR) representation of the series[2] in levels as:

$$\mathbf{E}_t = \mathbf{A}_1\mathbf{E}_{t-1} + \mathbf{A}_2\mathbf{E}_{t-2} + ...\mathbf{A}_l\mathbf{E}_{t-l+} + \mu_t, \mu_t \approx N(0,\Sigma) \qquad 1.$$

where **E** represents a (*n*x*1)* vector of stock equity indices, **A** an (*n*x*n*) matrix of coefficients. We can represent this relationship more generally in Vector Error Correction (VECM) format as:

$$\Delta\mathbf{E}_t = \Gamma_1\Delta\mathbf{E}_{t-1} + \Gamma_2\Delta\mathbf{E}_{t-2} + ...\Gamma_{l-1}\Delta\mathbf{E}_{t-l+1} + \Pi\Delta\mathbf{E}_{t-l} + \mu_t; \Gamma_i = \sum_{i=1}^{l-1} - \mathbf{A}_i; \Pi = \mathrm{I}_n + \Gamma_{l-i}. \qquad 2.$$

What the JJ technique endeavours to ascertain is the rank, *r*, of Π. This gives the number of stable cointegrating vectors in the system, as Π can be demonstrated to be equivalent to $\Pi = \alpha\beta'$ where β' is the vector of cointegrating relationships and α a matrix associated with the equilibrium errors $\beta'\mathbf{E}_t$.

More details of the approach used here can be found in Barari and Sengupta (2002). They describe the process whereby the investigator plots over time the values of selected test statistics from the JJ approach. In the JJ approach two major statistics of interest are generated. The first is the λ_{trace} statistic, which is a test of the general question of whether there exist one or more cointegrating vectors. An alternative test statistic is the λ_{max} statistic, which allows testing of the precise number of cointegrating vectors. This approach is in essence a visual application of the recursive cointegration

[2] In all cases the JJ approach is estimated on a VAR in levels. One issue that arises then is the appropriate lag structure of the VAR. In this case, using a variety of approaches including the BIC and the AIC, as well as the General-to-simple approach , a lag of 2 (2 weeks) was suggested

approach of Hansen and Johansen (1992) that has also been applied in a somewhat different form by Rangvid (2001) and Pascual (2003).

Two types of windows are available. The first can be termed *Global* analysis, where the JJ methodology is applied to an initial subset of the data. Additional data are then added to the system and the JJ approach reestimated. Thus we see from this the evolution of the cointegrating vectors and the λ_{max} and λ_{trace} statistics over time. In this paper the initial estimation is over the first ten years of the data, 500 weeks. Each subsequent cointegration analysis then adds 10 weeks data to the analysis.

The second approach is a *rolling* one, where the data are divided into a number of non-overlapping samples (periods of 52 weeks in this paper) and the JJ approach then applied. Again this allows an interpretation of how the dynamics of the system evolve over time. A further advantage is that with the output being the two λ_{max} and λ_{trace} statistics as well as the number of cointegrating vectors, this renders it possible to graphically represent the evolution. Such approaches have been used in Barari and Sengupta (2002) and Aggrawal, Lucey and Muckley (2003) to demonstrate increased integration in equity markets. There is some debate over which of these approaches provides a better estimate of the true situation, with Pascual (2003) suggesting that in relatively small samples the rolling estimates are to be preferred. However, in the dataset here the number of data points is large by comparison to those papers he examines.

One issue that is important in examination of cointegrated systems is which statistic, λ_{max} or λ_{trace} to use. These have differing interpretations, and can give conflicting results. λ_{max} tests for r cointegrating vectors against the specific alternative of r+1 while λ_{trace} tests that the number of vectors is less than r. Enders (1995) suggests that in general λ_{max} is preferred when testing specific hypotheses. However, with two series there can be only at most one vector, so we present the λ_{trace}.

Results

The λ_{trace} statistic cointegrating vector is shown on a global basis in Figure 3 while Figure 4 shows it on a local basis. All statistics are rescaled to be shown as ratios to the critical values of 15.19 (95%) and 13.31 (90%).

In all cases in we see that the ratio of the global statistics are well in excess of 1, indicating that over the 1978-2002 period we can reject the null of no cointegration. A stable, long run relationship existed between gold and silver returns over the period examined, in both cash and futures markets. The ratio, and hence the probability of rejection, increases as time progresses, but even at the start, examining from the 1978-1998 period we can still reject. This rejection is not dependent on the choice of confidence interval. This result is in contrast to Ciner (2001), but reconfirms in a dynamic setting the findings of Wahab, Cohn et al. (1994) and Escribano and Granger (1998). Thus, we can conclude that the stable relationship between gold and silver found to prevail historically appears to have continued to the present day.

However, when we examine the local plots, formed by analysing non-overlapping 52 week datasets, a different picture emerges. In general the data indicate that we cannot reject the null of no cointegration. A number of periods emerge however when such rejection is possible. First of these is the 1979- early 1982 period, corresponding to the cornering of the silver market by the Hunt brothers, with a corresponding knock-on effect from silver to gold. Second, the 1983-1984 periods emerges as one of stabile relationships, as does the 1999-2001 periods. Explanations for these may involve the explosion in interest rates in the 1980's which corresponded to a rising market in these precious metals. In the 1999-2001 the Washington Central Bank gold agreement catapulted the price of gold. Other factors in this time period include the beginning of the bear market in equities and terrorist activities in the US.

It is interesting to note that Ciner (2001) examined (albeit on the Tokyo market) a period from Jan 1992 to December 1998. From our local plots we can see that this was a period when, with rare exceptions, we observe non-rejection of the null of no cointegration Thus his finding of non-cointegration is mirrored over this period. In the overall context however this period is unexceptional – at some time periods we will find cointegration, at others not. This may indicate that the results of Ciner (2001) are driven by the period under analysis.

We show in Figure 5 rolling 52-week correlation coefficients for both the cash and futures series. There is no case where the correlation coefficients are negative. Over the total period the correlation coefficients are .64 and 62 for cash and futures: the figures for average quarterly, semi annual and annual rolling correlations are .58/ .67, .59/.67 and .58/.67 respectively.

Conclusions

Overall our findings indicate that in the long run the stable relationship historically observed between gold and silver has been maintained. This relationship is, in general, strong and convincing. However, there are significant periods when it is weakened or broken. The use of dynamic cointegration methods allows for greater disaggregating of the temporal relationship. The evidence indicates that the longterm for the relationship appears to lie in a horizon greater than one year. For portfolio managers and investors the overall message is that while gold and silver, in general, offer little advantages when together in a portfolio due to their close relationship: this relationship is neither stable nor constant however and thus there may be potential at certain times to include both. In particular, as many funds etc are rebalanced annually, if not more frequently, and as we see that in most one year samples there is not a stable relationship, the case for the inclusion of both gold and silver in portfolios may still be defensible.

Figure 1 : Gold and Silver Cash Series

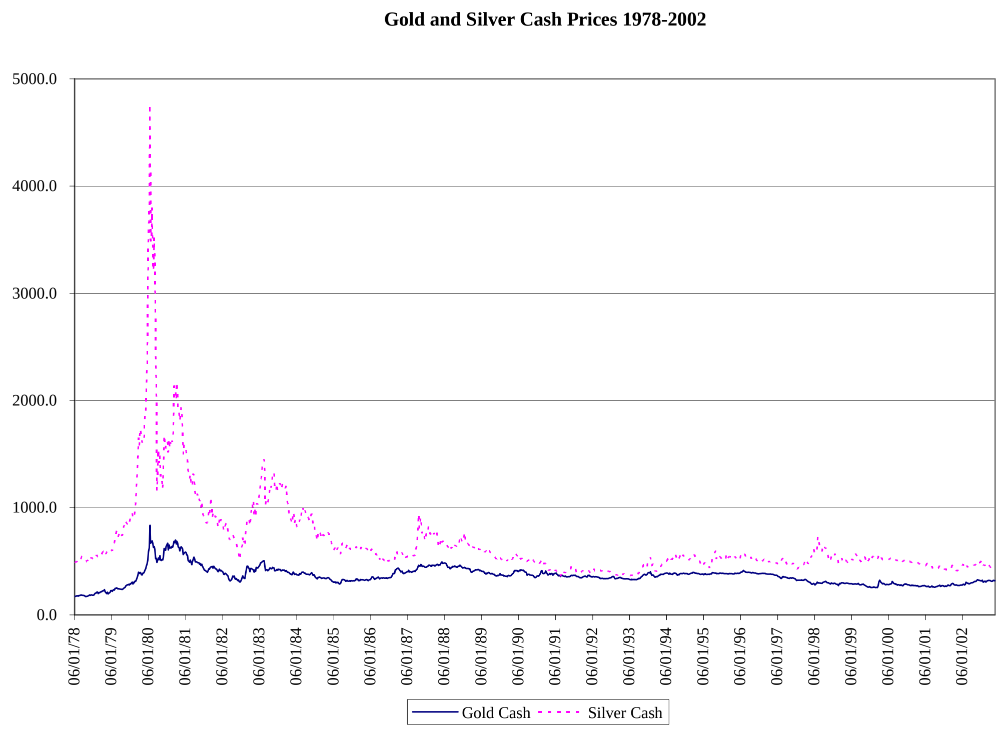


Figure 2 : Gold and Silver Futures Series

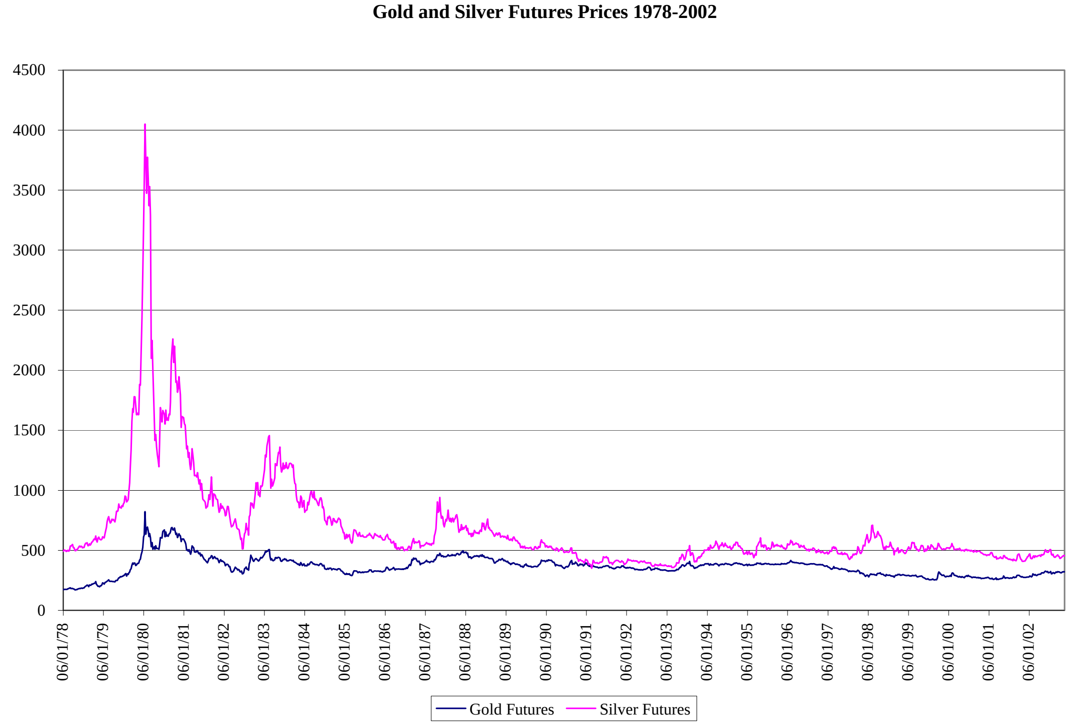
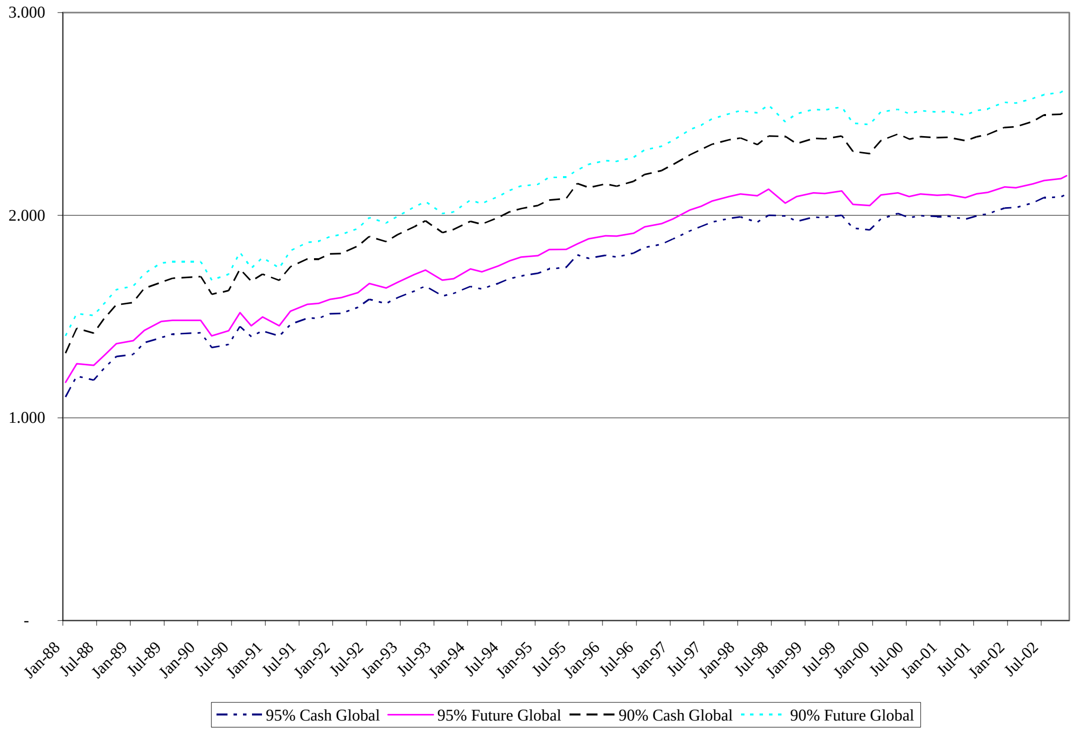
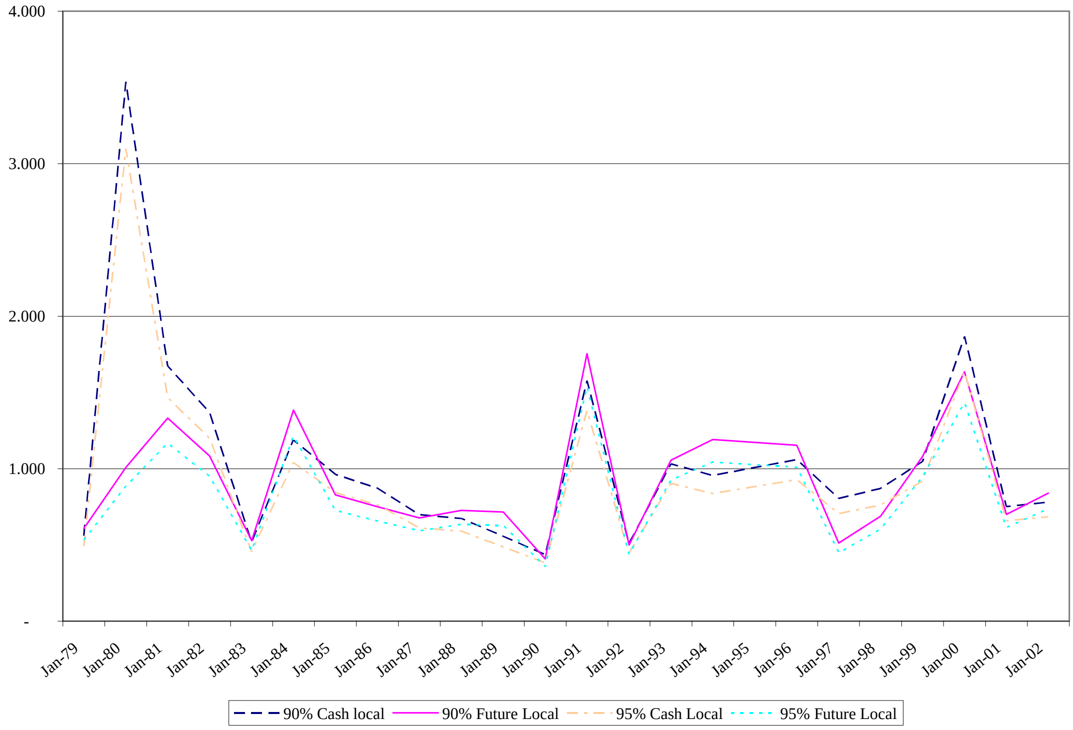


Figure 3 : Global Plots



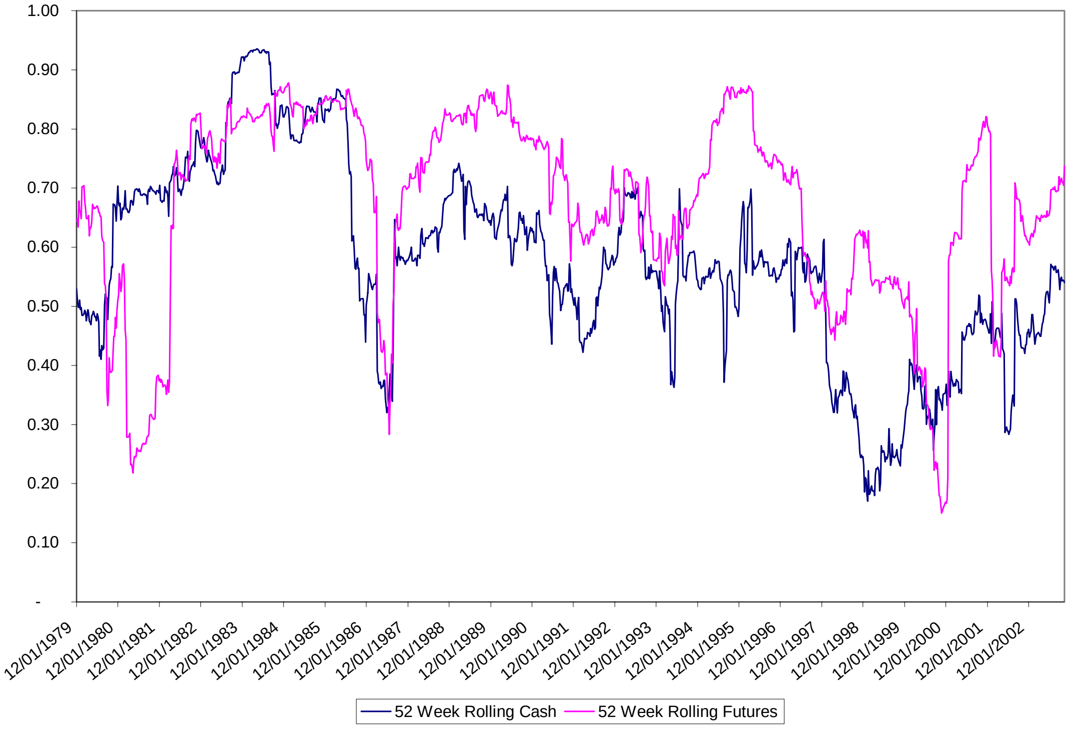
This chart shows the ratio of the calculated statistic to the 90 and 95% critical values. The statistic is calculated on a recursive basis, starting January 1978 and initially ending January 1988. Thereafter the statistic is recalculated by adding 10 observations each period successively.

Figure 4 : Local Plots



This chart shows the ratio of the calculated statistic to the 90 and 95% critical values. The statistic is calculated on a rolling basis, where each observation is calculated over 52 non-overlapping observations.

Figure 5: 52 Week Rolling Correlations



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