

Futures Maturity and Hedging Effectiveness: The Case of Oil Futures

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Abstract

This paper examines the effect of the maturity of the futures contract used as the hedging instrument on the effectiveness of futures hedging. For this purpose, daily and monthly data on the WTI crude oil futures and spot prices are used to work out the hedge ratios and the measures of hedging effectiveness resulting from using the near-month contract and those resulting from the use of a more distant (six-month) contract. The results show that futures hedging is more effective when the near-month contract is used. They also reveal that hedge ratios are lower for near-month hedging. Some explanations are presented for these findings.

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Introduction

The objective of this paper is to examine the relation between hedging effectiveness and the maturity of the contract used as the hedging instrument for a fixed hedging horizon while using two different data frequencies. Specifically, we address the following question: if the hedging horizon is six months, would hedging be more effective with a futures contract that matches the hedging horizon or a rollover of near-month contracts throughout the hedging window? As a robustness check we use both daily and monthly data to calculate the hedge ratio and to carry out the analyses. For the same purpose we use one-period differencing and k -period differencing, where k is set to be equal to the hedging horizon. This exercise will also expose some frequently arising issues in the hedging literature, such as the relations between the hedge ratio and the hedging horizon and between data frequency and hedging effectiveness. In addition, we address whether or not the expected lower volatility of the longer-dated hedging instrument will outweigh the expected higher correlation between spot prices and near-month futures prices. We must mention at the outset that we employ a six-month hedging horizon to illustrate these issues, but there is nothing special about this choice. It is simply a convenient construction for the data set used in this study.

The literature on futures hedging, particularly the strand of this literature dealing with the estimation of the hedge ratio, has frequently addressed the interrelated issues of hedging horizon, data frequency, maturity of the futures contract used as the hedging instrument, and hedging effectiveness. For example, Lee et al. (1987) found that if the near-month contract is used as the hedging instrument, the hedge ratio will be higher

than it would be if a contract with a longer maturity is used for this purpose. Another issue is the relation between the frequency of the data used to estimate the hedge ratio and the hedging horizon, particularly the question of whether or not the data frequency should be equal to the hedging horizon. Malliaris and Urrutia (1991) used weekly data to estimate the optimal hedge ratio and found hedging to be more effective when the hedging horizon was equal to the frequency of the data. Also by using weekly data, Benet (1992) found that shorter hedging horizons produced more effective hedging. However, Chen et al. (2003) stress the potential problem of matching the length of the hedging horizon with data frequency, which leads to the loss of data observations. Geppert (1995) suggested the use of k -period differencing to circumvent this problem.

Methodology

The optimal hedge ratio is measured as the slope coefficient in a regression of the rate of return on the unhedged (spot) position on the rate of return on the hedging instrument. If s_t and f_t are the logarithms of the spot and futures prices, then the underlying regression is

$$\Delta s_t = \mathbf{a} + h\Delta f_t + \mathbf{e}_t \quad (1)$$

where h is the hedge ratio. If k -period differencing is used, then the hedge ratio is estimated from the equation

$$\Delta_k s_t = \mathbf{a}' + h'\Delta_k f_t + \mathbf{e}'_t \quad (2)$$

where $\Delta_k s_t = s_t - s_{t-k}$ and $\Delta_k f_t = f_t - f_{t-k}$.

Citing Myers and Thompson (1989), Chen et al (2003, p 443) note that the use of conventional OLS estimation implies the use of unconditional sample moments to estimate the optimal hedge ratio rather than their conditional alternatives. However, they further note that should Δs_t and Δf_t follow a random walk, the optimal hedge ratio estimated by OLS will be identical to the hedge ratio estimated from conditional moments. Furthermore, Moosa (2003a) has shown that the use of alternative models and methods to estimate the hedge ratio does not make any significant difference for hedging effectiveness (see also Moosa, 2003b). In any case, our objective here is not to measure the hedging effectiveness associated with different estimates of the hedge ratio but rather to examine the relation between hedging effectiveness and the maturity of the futures contracts, using the same method to calculate the hedge ratio.

Once the hedge ratio is calculated, a hedged position (portfolio) is constructed to produce the rate of return R_H , which is given by

$$R_H = \Delta s_t - h\Delta f_t \quad (3)$$

Testing hedging effectiveness amounts to testing the equality of the variance of the hedged position and that of the unhedged position. The null hypothesis is

$$H_0 : \mathbf{s}^2(R_U) = \mathbf{s}^2(R_H) \quad (4)$$

against the alternative hypothesis

$$H_1 : \mathbf{s}^2(R_U) > \mathbf{s}^2(R_H) \quad (5)$$

where $R_U = \Delta s_t$ and $\mathbf{s}^2(\cdot)$ is the variance of the rate of return on the underlying position. The null is rejected if

$$VR = \frac{\mathbf{s}^2(R_U)}{\mathbf{s}^2(R_H)} > F(n-1, n-1) \quad (6)$$

where VR is the variance ratio and n is the sample size. This test can be complemented by the variance reduction, which is calculated as

$$VD = 1 - \frac{\mathbf{s}^2(R_H)}{\mathbf{s}^2(R_U)} \quad (7)$$

For the purpose of analysing our results, we elaborate on the preceding relations as follows: Let \mathbf{r} and $\mathbf{s}_{s,f}$ be the correlation coefficient between and the covariance of Δs and Δf , respectively. Also let \mathbf{s}_s^2 and \mathbf{s}_f^2 be their variances, respectively. Thus, we have

$$\mathbf{r} = \frac{\mathbf{s}_{s,f}}{\mathbf{s}_s \mathbf{s}_f} \quad (8)$$

$$h = \frac{\mathbf{s}_{s,f}}{\mathbf{s}_f^2} \quad (9)$$

$$VR = \frac{\mathbf{s}_s^2}{\mathbf{s}_s^2 + h^2 \mathbf{s}_f^2 - 2h \mathbf{s}_{s,f}} \quad (10)$$

$$VD = 1 - \frac{1}{VR} \quad (11)$$

From equation (8) we have

$$\mathbf{s}_{s,f} = \mathbf{r} \mathbf{s}_s \mathbf{s}_f \quad (12)$$

By substituting equation (12) into equation (9), we obtain

$$h = \frac{\mathbf{r} \mathbf{s}_s \mathbf{s}_f}{\mathbf{s}_f^2} = \mathbf{r} \left(\frac{\mathbf{s}_s}{\mathbf{s}_f} \right) \quad (13)$$

which shows the relation between the hedge ratio and the correlation coefficient. If $\mathbf{s}_s = \mathbf{s}_f$, then $h = \mathbf{r}$, and for constant variances, the hedge ratio is proportional to the correlation coefficient.

Combining equations (10) and (13) results in

$$VR = \frac{\mathbf{s}_s^2}{\mathbf{s}_s^2 + \mathbf{r}^2 \left(\frac{\mathbf{s}_s^2}{\mathbf{s}_f^2} \right) \mathbf{s}_f^2 - 2\mathbf{r} \left(\frac{\mathbf{s}_s}{\mathbf{s}_f} \right) \mathbf{r} \mathbf{s}_s \mathbf{s}_f} \quad (14)$$

which can be simplified to

$$VR = \frac{1}{1 - \mathbf{r}^2}. \quad (15)$$

Hence,

$$VD = 1 - \frac{1}{VR} = \mathbf{r}^2 \quad (16)$$

shows that variance reduction is equivalent to the coefficient of determination of the regression of Δs_t on Δf_t . Before discussing our results, we next describe the dataset employed.

Data

The market that we analyze is the crude oil market, and the futures contract that we use as the hedging instrument is for light, sweet crude oil that is listed on the New York Mercantile Exchange (NYMEX). The interest in this market is obvious, given the importance of oil in the global economy. The ability to hedge price risk effectively and efficiently is important to the continued smooth operation of this industry, which then facilitates smoother overall economic activity.

We employ futures prices obtained from the NYMEX and spot prices sourced from the US DOE EIA website. The time period covered was 2 January 1998 to 29 April 2005. The construction of the futures series requires establishing a decision rule for *splicing* the futures price when a contract nears maturity. Different researchers and database providers employ different decision rules for constructing such series; consequently, it is useful to explain the procedure that we used to construct our data set.

Our primary interest is to examine prices that reflect the focus of market activity. As one contract nears maturity, the market focus shifts toward the next-near contract. Moreover, as the maturing contract gets very near to the last trading day, the trading volume shrinks along with the open interest, and the price can become very volatile with the shrinking liquidity. The market focus is revealed to have shifted by observing increased trading volume and open interest in the next-to-near-month contract. The decision to be made is when to shift from the near-month prices to the next-to-near-month prices.

The decision rule employed in our study conditions the timing for the transition to the next-near-month contract on both the trading volume and the open interest. Let us denote the trading volume as V_i and the open interest as O_i , where $i = 1$ or 2 , representing the near-month and next-near-month contracts. The transition from the near-month price to the next-to-near-month price then occurs when $V_2 > V_1$ and $O_2 > O_1$. The validity of both of these conditions is taken to be an indication that the focus of the market has shifted from the near-month contract to the next-to-near-month contract. It may be useful to note that once the above condition is first

satisfied, it does not reverse until the next-to-near month contract becomes the near-month contract, following the cessation of trade on the maturing contract.

The futures price series for the near-month rolling hedge is then the price series constructed according to our decision rule. The price series for the six-month rolling hedge is constructed so as to observe the price series for a contract that matures in six months by following that specific contract throughout the period. For example, if the hedger is making a six-month hedging decision on the first day of April, he or she would like to hedge with a contract that matures on the last day of September. If a contract existed with a delivery date of 30 September, our six-month futures price series would capture the price of the 30 September contract on 1 April, following that contract price through to maturity.

We do not have contracts that mature on the 30th day of any month. The NYMEX crude oil futures contract matures on the third business day prior to the 25th of the month prior to the delivery month (with adjustments for holidays and weekends). We also make use of the observation that the most heavily traded months tend to be June and December, with the exception of the near-month contracts. Since our data series begins on 2 January 1998, we construct a six-month rolling hedge with delivery months of June and December.

An example may be useful. The price series begins on 2 January 1998, which makes the futures contract price for this series the price for the June 1998 delivery. On that date, the near-month contract will be the February 1998 delivery, with the next-to-near-delivery contract being March 1998, and so on. The six-month series captures

the June 1998 futures price until the transition condition is satisfied, at which date we roll into the December 1998 contract, and so on. At the time of transition, both series will contain the same futures prices. However, at the transition, the near-month rolling series will shift into the July 1998 contract rather than the December 1998 contract.

The spot price, taken from the US DOE EIA website, is the spot price reported for the WTI crude oil. This is the crude oil stream for which the NYMEX crude oil futures contract was originally designed. While other crude oils are now deliverable against the NYMEX contract, it is still typically referred to as the WTI contract. Hence, we would expect there to be a close relation between the spot price and the futures price. In this case, the commodity underlying the futures contract is virtually identical to the spot commodity. Therefore, very little basis risk would be present.

Empirical Results

The empirical results are presented in Table 1 and Table 2 using, respectively, first differences and 6-month differences to calculate the hedge ratios and the associated statistics. The first item reported in Table 1 is “correlation with spot,” which is the correlation coefficient between the rates of return on the spot and futures positions (the first log differences of the spot and futures prices, Δs_t and Δf_t), calculated as in equation (8). Table 1 reports the variance of the futures rate of return measured as the first log difference of the underlying futures price, Δf_t . The hedge ratio is calculated by using equation (1) or, equivalently, equation (12). The variance of the portfolio (the hedged position) is the variance of R_H , which means that the variance ratio (VR) against spot is $\mathbf{s}^2(R_H)/\mathbf{s}^2(R_U)$, where $R_U = \Delta s_t$. “VR against the hedge” is the ratio of the variance of the portfolio when the six-month hedge is used over the

variance of the portfolio when the near-month hedge is used. In both cases, the variance reduction, VD , is calculated from equation (7) or equation (16).

The same items are reported in Table 2, but in this case the calculations are based on six-month differences, such that the lag length (k) is 6 when monthly data are used and 125 when daily data are used. Correlation with the spot price in this case is the correlation between $\Delta_k s$ and $\Delta_k f$, where $\Delta_k x = x_t - x_{t-k}$. Likewise, the variance is $\mathbf{s}^2(\Delta_k f)$. The hedge ratio reported in Table 2 is derived from a regression of $\Delta_k s$ on $\Delta_k f$ (equation 2) or, alternatively, from equation (12), recalculating \mathbf{r} , \mathbf{s}_s and \mathbf{s}_f on the basis of $\Delta_k s$ and $\Delta_k f$ rather than Δs and Δf . All of the other reported items are calculated analogously.

Examining the results reported in Table 1 and Table 2, we observe the following:

1. Hedge ratios are lower for near-month hedging than for six-month hedging.
2. Some hedge ratios are greater than one.
3. Near-month hedging is more effective than six-month hedging.
4. Hedging effectiveness seems to be higher across the board when six-month differencing is used.

The first of these observations is in direct contrast with the results of Lee et al (1987) who found that higher hedge ratios are associated with near-month hedging. However, it is possible to explain our results by resorting to Samuelson's (1965) finding that distant maturity futures contracts are less volatile than near maturities. Evidence for the so-called "maturity effect" has been provided by Anderson (1985), Milonas (1986), Fama and French (1988), Serletis (1992), and by Moosa and Bollen (2001).

The Samuelson result has intuitive appeal. As futures contracts approach maturity, they tend to respond more strongly to new information about expected market conditions, such as available inventories and the supply-demand balance. Conversely, information about market conditions for distant futures contracts is more uncertain, which makes the process less responsive to new information.

If this is the case, then the variance (standard deviation) of the distant contracts should be expected to be smaller than those for near-month contracts. Given that the hedge ratio is $h = \mathbf{r}(\mathbf{s}_s / \mathbf{s}_f)$, and denoting \mathbf{s}_f^i as the standard deviation of the i^{th} -month contract, then (according to Samuelson) $\mathbf{s}_f^i > \mathbf{s}_f^j \quad \forall i < j$. Therefore, for given \mathbf{r} and \mathbf{s}_s , we should have $h_i < h_j$, where h_i (h_j) is the hedge ratio associated with the i^{th} (j^{th})-month contract. This result implies that the hedge ratio that is applicable to the near-month hedge will be smaller than that for the six-month-contract hedge. The Samuelson-based result obtained here appears to be inconsistent with the findings of Lee et al. (1987) who argued that the “hedge ratio increases as the maturity is approached”, which means that “if we use the nearest to maturity futures contracts to hedge, then the [MV] hedge ratio will be larger compared to the one obtained using futures contracts with a longer maturity.”

Let us now turn to the second finding that some hedge ratios are greater than one. It is typically expected that the hedge ratio (particularly for near-month hedging) will be less than one, implying that the optimal hedge ratio will be smaller than the so-called naïve hedge ratio of equivalent futures and spot positions. From the definition of the optimal hedge ratio (equation 13), however, we see that whether the hedge ratio

exceeds one or not is dependent on the ratio of the standard deviations. Cecchetti, et al. (1988, p 624) note that if the futures price has the same or higher price volatility than the spot price (as is typically the case), the hedge ratio can be no greater than the correlation between them, which will be less than one. If, however, the volatility of the futures price is less than that for the spot price, an optimal hedge ratio exceeding one is possible. This is relevant because, as noted above, distant-maturity futures are expected to have lower volatility than the near contracts, which are also likely to be more closely correlated with the spot prices.

Indeed, it is just this relation between standard deviations and correlation coefficients that leads to employing optimal hedging estimation, rather than employing the naïve hedge. One representation of basis risk is $\sigma_f \neq \sigma_s$, suggesting the potential for unexpected deviations (and perhaps large ones) between the two series. While we would expect the correlation between the spot price series and the futures price series for more distant-maturity futures contracts to be less than that for the correlation between spot price and the near-month contract price, the expected fall in the standard deviation for the distant contract relative to the near contract provides an offsetting effect. Thus, while the hedge ratio for the near-month contract may be expected to be less than one, if the ratio of standard deviations increases faster than the decline in correlation as i increases, we may also observe optimal hedge ratios greater than one.

Observations 3 and 4 can be explained in terms of the crucial dependence of the hedging effectiveness on the correlation coefficient between spot and futures prices (returns). The intricate relation between correlation and hedging effectiveness lies in the heart of the Garbade-Silber (1983) model (see supportive evidence in Moosa,

2002). According to Garbade and Silber, the ability of the futures market to perform the risk transfer function is measured by the elasticity of arbitrage between the physical commodity and the corresponding futures contract, and it is this elasticity that determines the correlation of price changes. This is because the higher the elasticity, the more rapidly arbitrage will bring the two markets in line with each other, producing highly correlated price changes and facilitating the risk transfer function.

The dependence of hedging effectiveness on correlation can be gleaned from equations (15) and (16). By differentiating the two equations with respect to the correlation coefficient, we obtain

$$\frac{d}{d\mathbf{r}}(VR) = \frac{2\mathbf{r}}{(1-\mathbf{r}^2)^2} > 0 \quad (15)$$

and

$$\frac{d}{d\mathbf{r}}(VD) = 2\mathbf{r} > 0 \quad (16)$$

which also means that

$$\frac{d(VD)}{d(VR)} = \frac{1}{(VR)^2} > 0 \quad (17)$$

These equations show positive nonlinear dependence, as also displayed in Figures 1-3. We can see that initially the variance ratio moves very slowly with the increase in correlation, but it accelerates quickly at high correlations. What is important here is that it requires relatively high correlation for the VR to get over its critical value and produce effective hedging. In Figure 2, we can see that the variance reduction also exhibits positive nonlinear dependence on correlation. It follows that variance

reduction depends on the variance ratio as shown in Figure 3. For example, a variance ratio of around 50 produces a variance reduction of about 98 per cent, after which it barely moves as the variance ratio increases. In all of this, of course, the number of observations plays an important role because it partly determines the critical value of the variance ratio.

The crucial dependence of hedging effectiveness on correlation explains why near-month hedging is more effective than six-month hedging, irrespective of the data frequency and the level of differencing. In all cases, the correlation of the spot price with the near-month futures price is higher than the correlation with the six-month futures price, and this is why near-month hedging is more effective. We must mention, however, that six-month hedging is effective (producing statistically significant *VR*) in all cases, but it is less effective (in terms of variance reduction) than near-month hedging. The item “*VD* (against hedge)” shows that near-month hedging is capable of removing a significant amount of the risk left by the use of six-month hedging. It is also interesting to observe how a small increase in correlation brings about a big risk reduction.

Concluding Remarks

The empirical results in this paper reveal that futures hedging is more effective when the near-month contract, rather than a distant contract, is used for hedging a spot position on crude oil. This result is explained in terms of the higher correlation between spot prices and near-month futures prices than that with more distant futures prices. This outcome suggests that the lower volatility of the futures price for the horizon-matching instrument does not outweigh the higher correlation between the

spot price and the near-month contract futures price. The relation between hedging effectiveness and correlation lies in the heart of the Garbade-Silber (1983) model. The results also revealed that hedge ratios are lower for near-month hedging, which is explained in terms of the Samuelson (1965) findings about the volatility of contracts with short and long maturities. An explanation was also put forward for why the hedge ratio may be greater than one.

While we did not directly address the issue, one last remark concerning transaction costs may be useful. If a near-month hedge is employed, transactions costs will be higher than if a six-month hedge is used even in the absence of dynamic rebalancing. For a single six-month cycle, with no rebalancing, a hedger has to engage in twelve transactions if a near-month contract is employed, compared with two transactions for a six-month contract. If transaction costs are modest, and/or if discounts are given based on frequency of trades, this difference may not be sufficient to alter the decision to use near-month hedging instead of six-month hedging, but costs associated with increased transactions cannot be ignored out of hand.

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Table 1: Hedge Ratios and Effectiveness (First Differences)

	Monthly Data		Daily Data	
	Near Month	Six Month	Near Month	Six Month
Correlation with Spot	0.99	0.89	0.84	0.78
Variance	0.01022	0.00751	0.000592	0.000453
Hedge Ratio	0.99	1.03	0.93	0.98
Variance of Portfolio	0.000058	0.00219	0.000219	0.000290
<i>VR</i> (against spot)	175.86*	4.66*	3.34*	2.52*
<i>VD</i> (against spot)	99.4	78.5	70.0	60.3
<i>VR</i> (against hedge)	37.75*	--	1.32*	--
<i>VD</i> (against hedge)	97.35	--	24.24	--

* Significant at the 5% level. The critical values for the F statistics are 1.08 for the monthly data and 1.44 for the daily data. The variance of Δs_t is 0.000732 for daily data and 0.01020 for monthly data.

Table 2: Hedge Ratios and Effectiveness (Six-Month Differences)

	Monthly Data		Daily Data	
	Near Month	Six Month	Near Month	Six Month
<u>Six-Month Differences</u>				
Correlation with Spot	0.99	0.96	0.99	0.97
Variance	0.034	0.027	0.042	0.034
Hedge Ratio	0.99	1.08	1.01	1.09
Variance of Portfolio	0.00032	0.0030	0.000738	0.00304
<i>VR</i> (against spot)	106.25*	11.33*	59.76*	14.50*
<i>VD</i> (against spot)	99.01	91.17	98.33	93.10
<i>VR</i> (against hedge)	9.37*	--	4.11*	--
<i>VD</i> (against hedge)	89.33	--	75.67	--

* Significant at the 5% level. The critical values for the F statistics are 1.08 for the monthly data and 1.44 for the daily data. The variance of Δs_{t-k} is 0.0441 for daily data and 0.034 for monthly data.

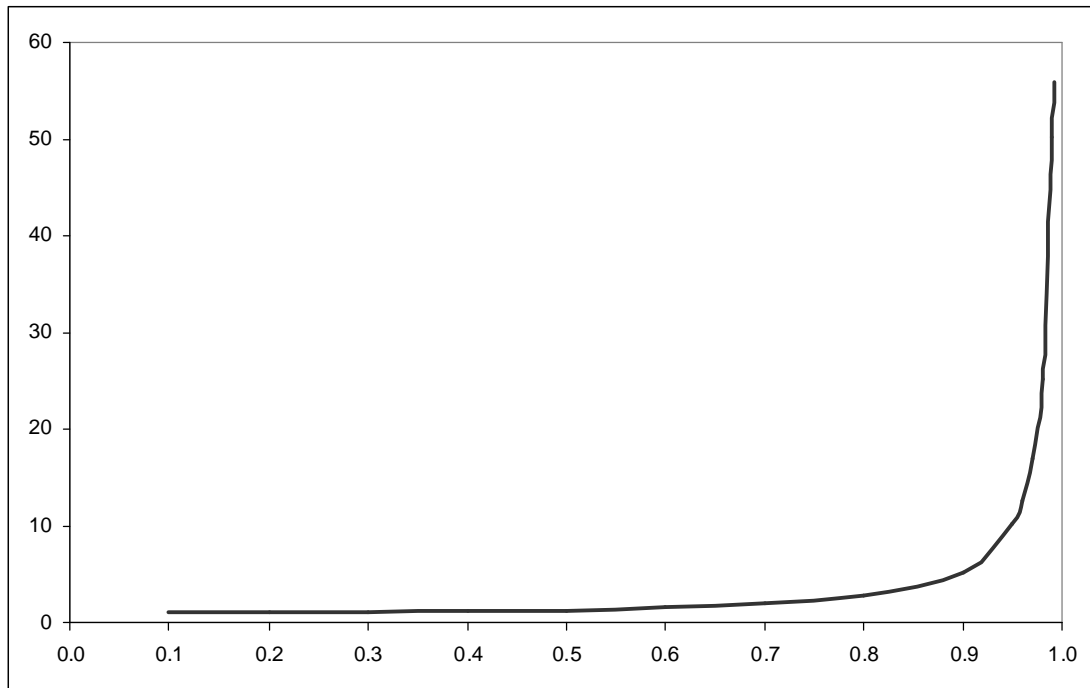
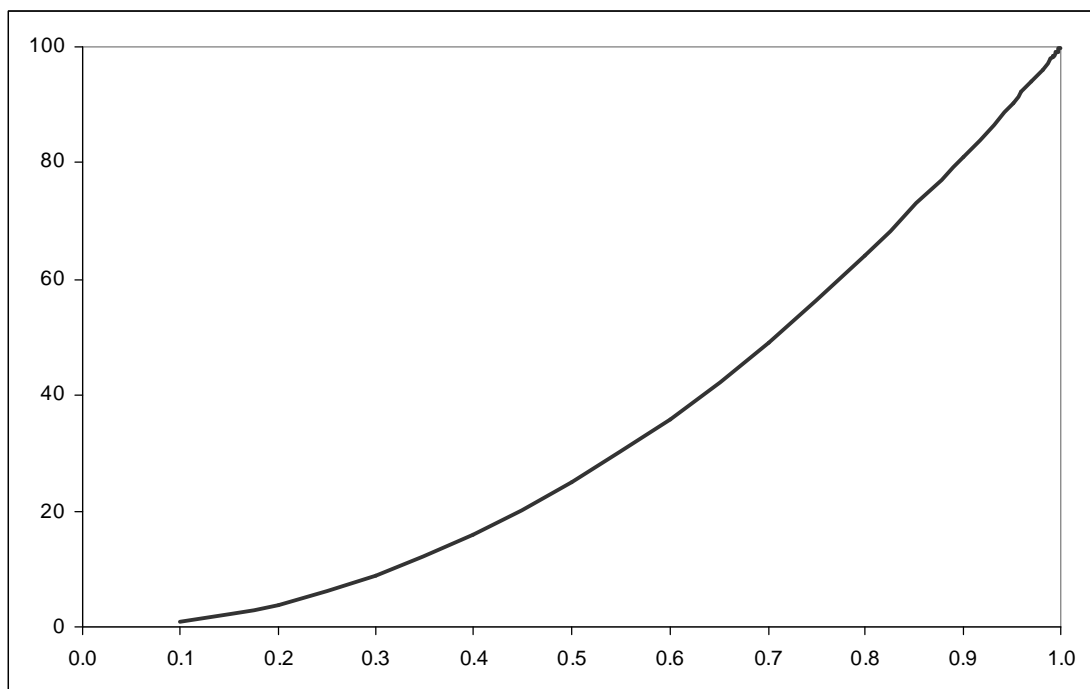
Figure 1: VR as a Function of the Correlation Coefficient**Figure 2: VD as a Function of the Correlation Coefficient**

Figure 3: VD as a Function of VR 