South African Political Unrest, Oil Prices, and the Time Varying Risk Premium in the Gold Futures Market

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Popular opinion asserts that South African politics and oil prices are major exogenous forces that move the gold market. Recent political tension in South Africa and its possible fallout in the gold market is of particular concern because South Africa produces a significant share of the world's supply of gold. The problem is that political tension may have an adverse effect upon South Africa's gold production which could lead to significant price fluctuations in the gold market. This article indexes political unrest in South Africa and demonstrates that it is possible to incorporate empirical measures of political unrest that provide insight to movements in the spot and futures prices in the gold market. This is an important step in bringing the econometric work in asset pricing closer to the reality of market forces that determine prices.

The link between oil and gold is not as obvious. Demand for gold is thought to fluctuate with the price of oil. There are at least two avenues through which this happens. First, rising oil prices are viewed as inflationary. The demand for gold as an inflation hedge increases with oil prices. Second, fluctuations in the demand for gold by oil exporting countries are identified as a source linking oil and gold prices. As oil revenues fluctuate, the demand for gold by oil exporters fluctuates in order to smooth consumption and/or government expenditures. The purpose of this article is to empirically estimate a time varying risk premium in the gold futures market and identify factors that may contribute to such a risk premium.

THEORETICAL FRAMEWORK

As Fama and French (1985) discuss, there are two popular theories of commodity futures markets. The theory of storage has been popularized by Working (1948), Brennan

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(1958), and Telser (1958); and the risk premium theory by Cootner (1960), Dusak (1973), Breeden (1980), and Hazuka (1984). The theory of storage explains the difference between the current spot and futures price as being due to: (a) interest forgone in storing the commodity: (b) warehousing costs; and (c) a convenience yield from holding inventory. Risk premium theory explains the difference between the current spot and the futures price as being equal to the expected change in the spot price plus a risk premium.

In the gold market, inventory convenience yields are likely to be small and storage costs are relatively small compared to the market value of the commodity. Any deviation between the current spot and futures price of gold will then be closely related to the rate of interest. Fama and French present evidence that the interest rate explains a substantial fraction of the movement in the deviation between the current spot and futures price of gold. Salant and Henderson (1978) maintain that speculators are acting on the basis of an expected future gold price. Opportunities for profitable speculation are eliminated when the current spot price of gold (S_t) equals the discounted present value of the expected future price ($E\,(S_{t+1})$) as $S_t = E(S_{t+1})/(1 + r_t)$, or:

$$E(S_{t+1}) = (1 + r_t)S_t = S^*_{t+1} \tag{1}$$

where r is the risk-adjusted return.

According to the risk premium theory, the futures price at time t for delivery 1 period forward (F_t^{t+1}) should be equal to the expected future spot price plus a time varying risk premium π_t:

$$F_t^{t+1} = E(S_{t+1}) + \pi_t. \tag{2}$$

Substituting for $E(S_{t+1})$ yields:

$$F_t^{t+1} = S^*_{t+1} + \pi_t \tag{3}$$

A goal of this research is to identify determinants of the risk premium in terms of economic phenomena.

South African political unrest or oil price movements can affect gold market participants' perception of the future and may lead to a change in the premium being attached to futures price quotations.[1] As with other assets, returns from gold markets display clusters of volatility as new information affects price expectations.[2] Political unrest and oil price movements will move the market as they change the realized or expected supply and demand for gold. Consider first the link between oil and gold. As an international reserve asset free of national control, gold plays an important role in the international reserve portfolio of several countries, most notably the OPEC nations. If an event leads to expectations of official gold purchases, the expected future price rises. If the price of oil rises, with an inelastic demand, the revenue to oil exporters will also rise. A revision in oil exporter revenue may have important implications for the price of gold. Suppose that gold is a larger component of the asset portfolio of the oil exporters than other nations and the oil exporters buy gold in proportion to their wealth. As oil revenues rise, one expects the demand for gold to rise from oil exporters, and the price of gold to rise accordingly. If the oil price falls, just the opposite effect is expected.

In the case of South African political events, a national strike or revolution could curtail gold exports in the short run and lead to a temporary rise in price. Any events today

[1]A recent article by Neal (1989) also addresses a similar issue to determine the informational content of several determinants of gold prices. In particular, the author links gold prices to inflation, interest rates, price of oil, expected grain imports by the Soviet Union, and stock prices of South African gold mining companies.

[2]This does not mean that systematic speculative profits can be made by exploiting the information. For more on this issue, see Agarwal and Soenen (1988) and Neal (1989).

which raise the probability of a supply disruption would be reflected in a higher expected price of gold. Suppose that at any point in time there is a market forecast of the price next period should a supply disruption in South Africa occur: S^d_{t+1}. If there is no interruption in the flow supply from South Africa, the price is expected to be S^n_{t+1}. If δ_t represents the probability of the supply disruption, then

$$S^*_{t+1} = \delta_t S^d_{t+1} + (1 - \delta_t) S^n_{t+1}.$$

For periods when the supply disruption is not realized, the actual percentage increase in the spot price of gold will be less than r_t. This is seen by rewriting eq. (1) as:

$$(1 + r_t) S_t = \delta_t S^d_{t+1} + (1 - \delta_t) S^n_{t+1}. \tag{4}$$

Since $S^d_{t+1} > S^n_{t+1}$, it is true that:

$$[\delta_t S^d_{t+1} + (1 - \delta_t) S^n_{t+1}] > S^n_{t+1}.$$

Speculators in period t require that the expected price in period $t + 1$ exceed S_t by the rate of interest; yet if the supply disruption is not realized in period $t + 1$, then S^n_{t+1} is established and the market price of gold has grown at less than the rate of interest. This result is not evidence of any inefficiency in the market and is analogous to the "peso problem."[3] The seemingly low rate of growth of the gold price is a market outcome in response to the asymmetric uncertainty regarding the future price of gold. With a positive probability of the price rising to S^d_{t+1}, the realized return in periods where the supply disruption does not occur is not required to equal the risk-adjusted rate of interest. Speculators and gold miners accept this lower return when there exists a positive δ of realizing S^d_{t+1}. Changes in δ should be associated with a change in the current and expected spot price as well as the risk premium. The greater the magnitude of potential forecast errors in the gold price, the greater the risk premium on futures trading.

To this point, δ has been linked to the probability of supply disruptions in South Africa. Alternatively, one can argue that there is a market forecast of a higher spot price due to future oil exporter gold purchases, where S^p_{t+1} is the price that exists if the purchases occur. This expected price could be said to exist with probability Φ, while S^n_{t+1} would exist if there is no change in oil exporter gold purchases. This framework is analogous to the South African political uncertainty just discussed, where a change in Φ may shift the spot and futures price along with the risk premium. The greater the potential magnitude of a spot price forecast error, the greater the risk premium. An attempt to model both of the alternatives in the empirical work follows.

AN EMPIRICAL MODEL OF RISK

It has recently become popular to treat risk as a term that arises from the probability distribution of errors in predicting some variable.[4] The conditional variance of the forecast errors is usually chosen as the appropriate moment of the probability density function for applied research.

Since its introduction by Engle (1982), the ARCH and more recently the GARCH (see footnote 5) modelling procedures have been incorporated by a number of authors to estimate a time varying risk premium involving autoregression and heteroscedasticity in

[3]Krasker (1980) argues that when there is a small probability of an event which would cause a large change in the market price, empirical tests using available data may give the appearance of inefficiencies when, in fact, none exist.

[4]See Frankel (1988) or Pagan and Ullah (1987) for reviews and critiques of such approaches.

commodity prices, foreign exchange rates, stock returns and interest rates. Studies using goods prices include articles by Engle (1983), Engle and Kraft (1983), Engle, Granger, and Kraft (1984), and Granger, Robins, and Engle (1986). Commodity prices were modeled by Baillie (forthcoming). Studies on foreign exchange rates include articles by Baillie and Bollerslev (1989), Fama (1984), Domowitz and Hakkio (1985), Engle and Bollerslev (1986), Bollerslev (1987), Frankel (1988), and Hsieh (1988). Finally, Engle, Lilien, and Robins (1987), French, Schwert, and Stambaugh (1987), Baillie and Bollerslev (forthcoming), and Baillie and DeGennaro (1988) have applied the ARCH/GARCH technique to investigate the properties of interest rates and stock returns. The results of these studies have generally been supportive of the fact that standard OLS estimates of a time varying risk premium are unsatisfactory because the errors are not independent.

Begin by asserting that the risk premium proxy in the gold futures market (π^p) is a function of the conditional variance of the forecast error of the spot price:

$$\pi_t^p = \beta_1 \sigma_t^2 \tag{5}$$

where σ_t^2 is the conditional variance arising from the spot price forecast errors conditioned on information at the time the forecast is made (I_{t-1}):

$$S_t - S_t^* = \varepsilon_t \tag{6}$$

$$\varepsilon_t \,|\, I_{t-1} \sim N(O, \sigma_t^2) \tag{7}$$

The conditional variance function in (5) may be substituted for π_t in (3) to yield:

$$F_t^{t+1} - S_{t+1}^* = \beta_0 + \beta_1 \sigma_t^2 + u_t \tag{8}$$

where β_0 is expected to be zero and $u_t = (\pi_t - \beta_1 \sigma_t^2)$. The equation becomes stochastic because of the divergence between π_t and $\beta_1 \sigma_t^2$. The estimated σ_t^2 will be used to estimate the gold futures price equation. The model is specified in terms of excess returns of the realized spot price S_t above the expected spot price S_t^* and the risk premium $(F_t^{t+1} - S_{t+1}^*)$. In this setting the variables are stationary. Since σ_t^2 measures risk with error, OLS will yield inconsistent estimates. This is a standard errors in variables problem. Instrumental variables (IV) are used to obtain consistent estimates.

THE DATA

Gold futures price data were collected from COMEX and the *Wall Street Journal*. The futures settlement price of a contract 30 days prior to the last day of trading in a contract is then taken as a 30-day futures price (F_t^{t+1}). The corresponding spot market price (S_t) on the same day is used for the current spot price observation. This yields one observation per month for each variable, and there is no overlapping data problem. Data on the spot price of gold (S_t) are taken from the Data Resources, Inc. daily data tape. Interest rates are collected to match as closely as possible the gold market data. For each day t, the yield on a U.S. Treasury bill maturing in 30 days was gathered from the *Wall Street Journal*. The sample period runs from February 1975 to November 1988.

CONDITIONAL VARIANCE AND THE RISK PREMIUM

The data were examined for evidence of nonstationarity and ARCH distribution which would affect the choice of functional form and support the use of conditional variance as a proxy for risk. Nonstationarity was detected using the Phillips-Perron test for a unit root and the results are reported in Table I. The Phillips-Perron test estimates

Table I
PHILLIPS-PERRON UNIT ROOT TESTS ON MONTHLY SPOT AND FUTURES IN GOLD

Test Statistics	Estimated F or t Values S_t	S_t^*	F_t^{t+1}	$F_t^{t+1} - S_{t+1}^*$	Critical Value of F or t (at 1% level)
$t_{\alpha 1}$	.04	−.02	.02	−5.32*	−2.58[a]
$t_{\alpha 2}$	−1.48	−1.54	−1.50	−6.59*	−3.43[a]
F_1	1.32	1.38	1.34	52.40*	4.59
$t_{\alpha 4}$	−1.61	−1.62	−1.59	−7.84*	−3.96[a]
F_2	1.35	1.39	1.35	52.47*	4.68
F_3	1.05	1.07	1.04	34.98*	6.25
Number of Observations	162	162	162	162	

Note:

Phillips Perron Test:

$$Y_t = \alpha_1 Y_{t-1} + u_{1t} \quad \ldots (1)$$
$$Y_t = \mu_1 + \alpha_2 Y_{t-1} + u_{2t} \quad \ldots (2)$$
$$Y_t = \mu_2 + \alpha_3 T + \alpha_4 Y_{t-1} + u_{3t} \quad \ldots (3)$$

$t_{\alpha 1}$:	Test Statistics for H_0^1:		$\alpha_1 = 1$
$t_{\alpha 2}$:	Test statistics for H_0^2:		$\alpha_2 = 1$
F_1:	Test statistics for H_0^3:	$\mu_1 = 0$	$\alpha_2 = 1$
$t_{\alpha 4}$:	Test statistics for H_0^4:		$\alpha_4 = 1$
F_2:	Test statistics for H_0^5:	$\alpha_3 = 0$	$\alpha_4 = 1$
F_3:	Test statistics for H_0^6:	$\mu_2 = 0, \alpha_3 = 0,$	$\alpha_4 = 1$

Note: [a]t-statistics rather than F statistics.
*Denotes significant value of F or t.

equations (1), (2), and (3) listed in the footnote to Table I (see Phillips and Perron (1988) for the details on the estimation procedure and the distribution of the test statistics).

Y represents the variable of interest, μ_1 and μ_2 are constants (drift terms), T is a deterministic time trend, α_1, α_2, α_3, and α_4 are parameters to be estimated, and μ_{1t}, μ_{2t} and μ_{3t} are residuals. The Phillips-Perron test for a unit root in a series is based on six test statistics and associated hypotheses given in the note to Table I. In eq. (1), the existence of a unit root is tested by the adjusted t-statistic ($t_{\alpha 1}$) for the hypothesis (H_0^1: $\alpha_1 = 1$). In eq. (2), two hypotheses are tested H_0^2: $\alpha_2 = 1$ and H_0^3: $\mu_1 = 0$ and $\alpha_2 = 1$. The test statistics for H_0^2 and H_0^3 are the adjusted t-statistic ($t_{\alpha 2}$) and the F-statistic (F_1), respectively. In eq. (3), three hypotheses are tested: H_0^4: $\alpha_4 = 1$, H_0^5: $\alpha_3 = 0$, $\alpha_4 = 1$ and H_0^6: $\mu_2 = 0$, $\alpha_3 = 0$ and $\alpha_4 = 1$. The test statistics are $t_{\alpha 4}$, F_2 and F_3, respectively. The estimated F and t-statistics are reported along with their critical values in the body of the table. All statistics indicate that the spot, the expected spot, and the futures price are nonstationary. The estimated statistics are less than the critical F or t values. The presence of a unit root in each case suggests that S_t, S_t^*, and F_t^{t+1} should not be used as dependent variables in the level form. The test statistics all indicate that the deviation of the futures price from the expected future spot price ($F_t^{t+1} - S_{t+1}^*$) is stationary.

The presence of the ARCH distribution was confirmed by an LM test (Engle's TR^2 equivalent where T refers to the number of observations and R^2 is the coefficient of determination for the regression) on the residuals of the regression equation given in

Table II. The LM test for an ARCH effect is based on the estimated TR^2 statistics (having a chi square distribution) which leads to rejection of the null hypothesis of no ARCH effect. The ARCH test determines if large changes in asset returns are followed by a large variance of returns and if small changes in returns are followed by small changes in the variance of returns. The procedure for estimating the TR^2 statistic involves OLS estimation of the equation in Table II then regressing the squared residuals on their past values. The TR^2 from the regression is examined to see if it is a significant value of chi square at the 5 percent level. Tests are conducted for first, second, and third order ARCH effects, and the estimated TR^2 exceeds the critical value for each. A third-order ARCH process maximizes the value of the TR^2 (and the likelihood function for the regression). So the evidence indicates that the spot price forecast errors follow an ARCH process. The time-varying conditional variance of the spot price forecast errors are used as a proxy for the risk associated with trading gold futures.

Incorporating the conditional variance of the ARCH model as the risk proxy, allows a test of the hypothesis that oil prices and South African political unrest are significant determinants of the risk premium. Specifically, this involves the conditional variance following a GARCH process like:[5]

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 \sigma_{t-1}^2 + \beta_3 \mathrm{POIL}_t + \beta_4 \mathrm{SA} \tag{9}$$

where POIL and SA variables are added to the test the hypothesis that the conditional variance of the spot price forecast error varies with changes in oil prices and South African political unrest. Monthly data on the oil price are defined as the dollar cost per barrel to refineries as collected by the U.S. Department of Energy. As indicators of South African political unrest, monthly data were gathered on the number of deaths in South Africa due to political violence, the number of demonstrations, and the number of political arrests as reported in the *New York Times*.[6]

Table II
ENGLE'S ARCH TEST (TR^2 EQUIVALENT)

$$\begin{aligned} dS_t &= \alpha_0 + \alpha_1 dS_t^* + \varepsilon_t \\ &= 1.24 + .1359\, dS_t^* \\ &\qquad\quad (1.82) \\ F &= 3.31 \\ R^2 &= .0139 \\ D - W &= 2.1347 \end{aligned}$$

Order	TR^2	Critical X^2 (5% level)
1	6.08	3.84
2	18.40	5.99
3	42.27	7.82

Note: *d* refers to first difference.

[5]A GARCH (p, q) model differs from ARCH (q) by the inclusion of the lagged conditional variance term (σ_{t-1}^2) as an explanatory variable in the conditional variance equation. In that respect a GARCH model is similar to an ARMA (q) model because the conditional variance in eq. (9) is an ARMA process. For example, eq. (9) would be a pure ARCH if $\beta_2 = 0$.

[6]Unit root tests on SA variables indicate that all are stationary. The oil price appears to be nonstationary at first glance, but futher analysis indicates that the null hypothesis of a unit root can be rejected if the large breaks in the series that occurred in the 1970s and 1980s are taken into account. It seems that the oil price is stationary with breaks in structure. Perron (1988) discusses this issue in more detail.

Table III
ESTIMATION OF A GARCH (1,1) MODEL

$$dS_t = -2.71 + .14\, dS_t^* + 1.20\, \sigma_t^2$$
$$(-.71) \quad (46.54)^* \quad (146.94)^*$$
$$\sigma_t^2 = .00001 + .00002\, \varepsilon_{t-1}^2 + .005\, \sigma_{t-1}^2$$
$$(.00) \quad (8.62)^* \quad (6.54)^*$$
$$+ 19.72\, \text{Poil}_t + .005\, \text{Death}_t$$
$$(51.22)^* \quad (.92)$$
$$+ .08\, \text{Demo}_t + .05\, \text{Arrest}_t$$
$$(3.37)^* \quad (45.89)^*$$
$$-2 \log L = 50127.94$$

t statistics in parentheses.
*Significant at the 1 percent level.

Estimates of the GARCH model are reported in Table III. The oil price (POIL) and two of the South African political variables: demonstrations and political arrests are all significant determinants of the conditional variance of the spot price forecast errors. This supports the hypothesis that oil prices and the South African political situation are related to the distribution of spot price forecast errors. The results also suggest that deaths due to political violence are not significant determinants of the risk premium in gold futures. The term σ_t^2 (the ARCH-in-Mean) is significant and positive in the spot price equation. The coefficients of the ARCH (ε_{t-1}^2) and the GARCH (σ_{t-1}^2) terms in the conditional variance equation indicate that GARCH modelling of the time varying risk premium is appropriate. The coefficients are both positive and significant at the 1 percent level. The final link in the story requires estimating the futures price as a function of the expected spot price and the conditional variance of the spot price forecast error as a risk premium term σ_t^2 contained in the futures price.

The σ_t^2 is now used to estimate the risk premium equation ($F_t^{t+1} - S^*_{t+1}$). Since σ_t^2 measures risk in the market with error, two-stage least squares (2SLS) was used to incorporate the σ_t^2 in the risk premium equation. The instruments for σ_t^2 are three lagged values of the variables appearing in the GARCH model. The estimation results are reported in Table IV. The estimated risk term coefficient in Table IV indicates that the conditional variance of the spot price forecast errors is a significant determinant of the excess returns in the gold market. The standard interpretation would be that the product of σ_t^2 and its coefficient represents the time varying risk premium in the futures market. It is interesting to note that an increase in the risk associated with trading gold is associated with a larger negative risk premium. Both the expected spot and futures prices increase, but the increase in the expected spot price exceeds the increase in the futures

Table IV
2SLS ESTIMATION OF THE RISK PREMIUM IN THE GOLD FUTURES MARKET

$$F_t^{t+1} - S_{t+1}^* = 2.26 - .013\sigma_t^2$$
$$(1.71) \quad (-4.42)^*$$
$$F = 19.56^*$$
$$R^2 = .1033$$

t statistics in parentheses.
*Significant at the 1 percent level.

price. This suggests that there is a systematic negative bias built into the futures price as a predictor of spot prices so the negative risk premium will lead to the futures price underpredicting spot prices.

The results are consistent with the existence of a time-varying risk premium in the gold futures price and that the perceived risk will vary with political unrest in South Africa and changes in the price of oil. We should expect F_t^{t+1} to be a biased predictor of S_{t+1}, with the magnitude of the bias varying with changes in the South African political situation and oil prices.

SUMMARY AND CONCLUSIONS

Gold futures and spot price data are studied for evidence of a risk premium. The time varying risk premium contained in the futures price is assumed to be a function of the conditional variance of spot price forecast errors. A GARCH parameterization is used to estimate the conditional variance. The variance series is then used as a measure of risk in the futures price equation. Since the estimated conditional variance may differ from the true risk variable, an instrumental variables estimator is used to provide consistent estimates of the risk premium effect in the futures price equation. The estimation results yield the following inferences: (1) South African political unrest and oil price changes are significant determinants of the conditional variance of spot price forecast errors and (2) There is evidence of a significant time varying risk premium in the gold futures price that depends on the conditional variance of recent spot price forecast errors. As a result, the futures price is a biased estimate of the expected future spot price.

Practitioners and scholars all believe that political factors are important in determining spot and futures prices, but such factors are generally put in the residual in econometric models. This research incorporates quantitative measures of political unrest in econometric models of asset price determination. The results reveal the very significant impact of South African political unrest in the gold market. Future work in asset price modelling should increasingly explore the use of empirical proxies for political factors that can move the markets.

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