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**ON THE LEASE RATE, THE CONVENIENCE YIELD  
AND SPECULATIVE EFFECTS IN THE GOLD  
FUTURES MARKET**

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# Contents

<b>List of Tables</b>	<b>v</b>
<b>List of Figures</b>	<b>xv</b>
<b>Abstract</b>	<b>xxiii</b>
<b>Résumé</b>	<b>xxiv</b>
<b>Acknowledgements</b>	<b>xxv</b>
<b>Introduction</b>	<b>1</b>
<b>1 Does Speculative Activity Affect the Price of Futures Contracts?</b>	<b>5</b>
<b>2 On Speculative Pressure and its Possible Effects</b>	<b>12</b>
<b>3 Central Banks and the Gold Leasing Market</b>	<b>17</b>
<b>4 Data and Summary Statistics</b>	<b>22</b>

<b>5</b>	<b>Inventory Effects</b>	<b>38</b>
5.1	Does the GOFO Rate Affect Inventory Levels? . . . . .	38
5.2	Changes in GOFO and Changes in Inventory . . . . .	42
5.3	Inventory, Convenience Yield and the Lease Rate . . . . .	44
5.4	The Effect of Lease Rates on Inventory Withdrawals . . . . .	52
<b>6</b>	<b>The Effect of Speculative Pressure on Returns</b>	<b>55</b>
<b>7</b>	<b>Price Differences Between Forward and Futures Contracts</b>	<b>59</b>
7.1	Mispricing and Speculative Pressure . . . . .	59
<b>8</b>	<b>The Growth Rate of Gold Forward vs. Gold Futures Contracts</b>	<b>73</b>
8.1	The Linear Filtering Problem . . . . .	77
8.2	Kalman Filter and Estimation Results . . . . .	79
<b>9</b>	<b>Transaction Costs and Profitability of Trading Strategies</b>	<b>84</b>
<b>10</b>	<b>Conclusion</b>	<b>92</b>

# List of Tables

## 4.1 SUMMARY STATISTICS FOR MARKET PRESSURE

<b>VARIABLES</b> The table presents summary statistics for the discretionary inventory level along with speculative, hedging and small trader pressures for the years 1996-2009. Discretionary inventory is recorded weekly and on Wednesdays using the average of the previous week as the Wednesday observation. Using an ARIMA(0,1,0) model, we remove the stochastic trend to obtain a series of innovations. These are then studentized to construct the discretionary inventory series as described in Dincerler et al. (2005). The market pressures series are recorded with weekly frequency on the Tuesday of every week. Speculative pressure is the most volatile of all pressures series, while small trader pressure is the most consistent, suggesting substantial differences in the positions of the respective trader categories. . . . .	23
--	----

4.2	<p><b>RESULTS OF AUGMENTED DICKEY-FULLER (ADF) UNIT ROOT TESTS ON INVENTORY AND MARKET PRESSURES</b></p> <p>The table shows the augmented Dickey-Fuller and KPSS test statistic values for all market pressures and discretionary inventory over the time period from 1986 to 2009. The test regression was specified to contain a constant but no deterministic trend. As indicated by the test results, the null hypothesis of the presence of a unit root cannot be rejected for all pressures considered. We therefore conclude that the series are unit root non-stationary. For the discretionary inventory series, the ADF statistic rejects the null hypothesis of non-stationarity. However, the KPSS test results suggests rejection of the null hypothesis of stationarity, albeit weakly, for the inventory series. . . . .</p>	26
4.3	<p><b>SUMMARY STATISTICS FOR THE FUTURES RETURNS SERIES OVER THE PERIOD FROM 1996 - 2009</b></p> <p>The table shows the summary statistics for the first, third, sixth and twelfth nearby futures contracts for the COMEX gold contract. Observations are weekly in frequency and have been made into a continuous returns series using the method of de Roon et al. (2000). . . . .</p>	28

4.4	<p><b>SUMMARY STATISTICS FOR THE MARKET RATES (LIBOR, GOFO, LEASE) FOR THE PERIOD 1996 - 2009</b> The table shows summary statistics for the LIBOR, GOFO and derived lease rates for tenors of 1, 3, 6 and 12 years for the period spanning 1996 - 2009. The LIBOR and lease rates exhibit increasing mean value with increasing tenor. The exception is the GOFO rate, which demonstrates a decreasing mean value with increasing tenor. The LIBOR series have the highest standard deviations, followed by the GOFO rate series and the derived lease rate series exhibit the smallest values of standard deviation for all series. Significant differences between minimum and maximum values can be observed for all rate series. . . . .</p>	30
4.5	<p><b>COINTEGRATION TEST RESULTS FOR LIBOR AND GOFO RATES OF 1, 3, 6 AND 12 MONTH TENOR</b> The table shows the results of the Phillips-Ouliaris test for cointegration between the bivariate LIBOR and GOFO time series. There is evidence for a cointegrating relationship if the value of the test statistic exceeds the critical value at the 5% level of significance. For 1, 3 and 6 month tenors we cannot reject the hypothesis that the LIBOR and GOFO rates are cointegrated. The results for the 12 month rates suggest that at this maturity duration, the LIBOR and GOFO rates are not cointegrated. . . . .</p>	34

**5.1 RESULTS OF THE MOVING BLOCK BOOTSTRAP OF THE GOFO RATE ON LEVEL OF DISCRETIONARY INVENTORY AND LEVEL OF DISCRETIONARY INVENTORY SQUARED** Displayed are the nonparametric moving block bootstrap results for the regression model specified as  $GOF(i)_t = \beta_1 Inv_t + \beta_2 Inv_t^2 + \varepsilon_t$ . Despite the suggestions of the second-order polynomial fits, the results of the bootstrapping suggest that there is no significant relationship between the GOFO rate and either the level of discretionary inventory or the squared discretionary inventory level. The results indicate there are neither level nor non-linear inventory effects on the GOFO rate. Furthermore, these results are consistent across all tenors. . . . . 41

**5.2 RESULTS OF UNIT ROOT TESTS ON 1, 3, 6 AND 12 MONTH GOFO TENORS** The table shows the results of testing the 1, 3, 6 and 12 month tenor GOFO rate time series. We used three separate unit root tests: the Augmented Dickey-Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and the Phillips-Perron (PP) test. The ADF and PP tests examine the null hypothesis that the series being tested has a unit root (against the alternative of stationarity). The KPSS test evaluates the null hypothesis that the series is level or trend stationary. The table provides the value of the test statistic and the associated 5% critical values in the case of the ADF and KPSS tests. The PP test shows the ADF regression coefficient along with the  $p$ -value of the test. . . . . 43



**5.3 COEFFICIENT ESTIMATES FOR THE REGRESSION OF CHANGE IN GOFO ON INVENTORY WITHDRAWALS**

The table presents the coefficient estimates of a GLS regression estimated using maximum likelihood for the model  $\Delta GOFO_t(i) = \alpha + \beta_1 \Delta Inv_t + \beta_2 \Delta Inv_t^2 + \varepsilon_t$ . The results in the table show that there is no coefficient on inventory withdrawals that is statistically significant at the <5% level. The coefficient for inventory withdrawals squared is not significant at the 5% across all tenors. . . . . 45

**5.4 RESULTS OF THE REGRESSION OF INVENTORY LEVEL ON PAST 3 MONTH LEASE RATE AND LAGGED INVENTORY LEVEL OVER THE PERIOD 1996-2009**

Shown are the results of the regression  $Inv_t = \beta_1 Lease_{t-1} + \beta_2 Inv_{t-1} + \varepsilon_t$ , which is specified in order to investigate the effect of lagged lease rates on the level of discretionary gold inventory. The lag-1 level of inventory was included to capture any remaining autocorrelation. Across all maturities, the coefficient of lagged inventory remains positive, consistent but statistically insignificant suggesting there is no carry-over inventory effect. Notably, the effect of the lagged lease rate diminishes with increasing lease rate duration. This suggests that short-term leasing has a more pronounced effect on current inventory levels. The negative coefficient implies that short-term lease repayments, in the form of physical bullion, act to reduce the current inventory level.

Signif. codes: 0 '\*\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 . . . . . 49

**5.5 RESULTS OF THE LEASE REGRESSION INCLUDING SPECULATIVE PRESSURE OVER THE PERIOD**

**1996-2009**

The table shows the coefficient estimates and associated regression statistics for the regression model:  $Inv_t = \alpha + \beta_1 Lease(i)_{t-1} + \beta_2 Inv_{t-1} + \beta_3 i_{t-1} + \varepsilon_t$ . By controlling for speculative pressure, we note that the effect of the lease rate on discretionary inventory level is now very weak and significant at just under the 10% level of significance for the 1 month rate tenor. This suggests that speculative pressure increases inventory levels counteracting the negative effect of lease repayments.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 . . . . . 51

**5.6 RESULTS OF THE REGRESSION OF WITHDRAWALS ON CHANGES IN THE LEASE RATE OVER THE PE-**

**RIOD 1996-2009**

The table shows the regression output for the model:  $\Delta Inv_t = \beta_1 \Delta Lease(i)_t + \beta_2 \Delta Inv_{t-1} + \varepsilon_t$ . This examines the effect of the lease rate on inventory withdrawals, while controlling for past inventory withdrawals. The estimation results for the coefficient of lagged inventory withdrawals suggest that there is a consistent level of withdrawals that acts to diminish withdrawals at time  $t$ . The coefficient  $\beta_2$  remains nearly constant in value, negative and statistically significant across all lease rates. In addition, we observe that the lease rate is a statistically insignificant factor in explaining gold stock withdrawals.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 . . . . . 54

**6.1 RESULTS FOR THE REGRESSION OF RETURNS ON SPECULATIVE PRESSURE FOR THE YEARS 1996 -**

**2009** The table contains the estimation statistics of the regression model:  $r_{i,t} = \alpha + \beta_1 r_{i,t-1} + \beta_2 r_t^{SNP500} + \beta_3 p_t + \varepsilon_t$ . The results demonstrate that current returns are not related to past returns. Additionally, we note that gold futures returns are positively, but insignificantly related to returns on the S&P 500 index. Additionally, we note that the level of speculative pressure is positively and significantly related to futures returns, suggesting that increased speculation leads to slightly higher returns, although the coefficient,  $\beta_3$  is rather small in magnitude, being on the order of 0.008.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 . . . . . 56

**6.2 ROBUSTNESS CHECK FOR THE REGRESSION OF RETURNS ON SPECULATIVE PRESSURE AND PRICE PRESSURE FOR THE YEARS 1996 - 2009**

The table shows the results of a robust specification of the returns regression model given by the following equation:  $r_{i,t} = \alpha + \beta_1 r_{i,t-1} + \beta_2 r_t^{SNP500} + \beta_3 \frac{t}{\sigma(t)} + \beta_4 \frac{\Delta t}{\sigma(\Delta t)} + \varepsilon_t$ . In this regression, we include both a speculative pressure term and a price pressure term, specified as the change in speculative pressure from time  $t - 1$  to time  $t$ . We divide both series by their respective standard deviation in order to compare them effectively. Results show that, after controlling for price pressure, the effect of speculative pressure on returns is mitigated. While still significant at the 1% level, the value of the speculative pressure coefficient,  $\beta_3$ , is considerably reduced. However, we note that the speculative pressure effect does remain statistically significant at the <5% level across all returns series and increases with the maturity horizon. This is consistent with our previous findings that speculators may be induced to speculate long term as their increased risk-aversion for long-term bets resulting in higher futures contract risk-premiums.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 . . . . . 58

7.1	<b>SUMMARY STATISTICS FOR THE 1, 3, 6 AND 12 MONTH MISPRICING SERIES FOR THE YEARS 1996 - 2009</b>	The table shows summary statistics for the mispricing series of the log-difference of observed futures prices and theoretical forward contract prices. Separate statistics are given for 1, 3, 6 and 12 month contract maturities. Although the 1 month contract exhibits a small degree of under-pricing of futures relative to forwards, we observe and increasingly positive mean in the 3, 6 and 12 month series, suggesting that, for these contracts, futures are over-priced, on average, relative to forwards. . . .	62
7.2	<b>VAR(2) MODEL ESTIMATION RESULTS</b>	The table shows the OLS estimated coefficients along with their standard errors for the VAR(2) model defined in equation (7.5). . . . .	68
8.1	<b>KALMAN FILTER ESTIMATION RESULTS</b>	Parameter vector optimisation results from the log-likelihood maximization. Parameters $\lambda$ , $\alpha$ , $ h_3 $ and $ h_{12} $ are not statistically significant. The remaining parameters are significant at the $< 1\%$ level. . . . .	80

## 9.1 GOLD FUTURES TRANSACTION COST ESTIMATES

**BY YEAR** The table shows transaction costs estimated using the method in Lesmond et al. (1999). Costs were estimated on a year-by-year basis using a full year of daily returns data based on the linear dependent variable (LDV) model. In the table,  $\alpha_1$  and  $\alpha_2$  represent the proportional transaction costs for selling and buying, respectively. Round trip transaction costs are estimated by subtracting  $\alpha_1$  from  $\alpha_2$ . The coefficients were estimated by maximizing the log-likelihood function given in Lesmond et al. (1999). . . . . 90

# List of Figures

- 3.1 **THE NEGATIVE INTEREST-ADJUSTED BASIS AND THE LEASE RATE** The figure shows the negative interest-adjusted basis in dark grey and the corresponding lease rate for tenors of 1, 3, 6, and 12 months in black. A linear trend has been removed from both series. Agreement between the plotted lease rate and the calculated adjusted basis increases with increasing lease tenor. 20
- 4.1 **PERCENT OF TOTAL OPEN INTEREST (TOI) BY MARKET POSITION FOR THE YEARS 1996 - 2009** The figure shows the percent of total open interest for the various market positions. This includes non-commercial, commercial and small trader (i.e. non-reporting) open interest. Both non-commercial and small trader open interest is increasing over the sample period while commercial open interest is declining. This suggests an increase in activity by speculators and a scaling back of participation by hedgers. . . . . 25

4.2	<p><b>TERM STRUCTURE OF THE LIBOR, GOFO AND DERIVED LEASE RATES FOR THE YEARS 1996 - 2009</b> The figure shows the LIBOR, GOFO and corresponding derived lease rate for tenors of 1, 3, 6 and 12 months. The lease rate is obtained by subtracting the GOFO rate from the prevailing LIBOR rate. The lease rate is the rate at which a central bank will lend gold, while the GOFO rate represents the rate a central bank is willing to pay on a loan secured using gold as collateral. . . . .</p>	32
4.3	<p><b>DYNAMIC CONDITIONAL CORRELATIONS BETWEEN THE LIBOR AND GOFO RATES FOR 1, 3, 6 AND 12 MONTH TENORS</b> The figure shows the results of the estimates of the dynamic conditional correlation (DCC) between the LIBOR and GOFO rates for tenors of 1, 3, 6 and 12 months. The correlations were estimated using the Engle and Kroner (1995) multivariate BEKK model with a GARCH(1,1) specification. Intermittent periods of strong decoupling of the conditional correlation between the GOFO and LIBOR rate can be observed. . . . .</p>	36



## 5.1 **RELATIONSHIP BETWEEN THE GOLD FORWARD OFFERED (GOFO) RATE AND THE DISCRETIONARY INVENTORY LEVEL FOR THE YEARS 1996-2009.**

The first row of the figure shows the relationship between the GOFO rate and the level of discretionary inventory for tenors of 1 and 3 months. The second row shows the corresponding relationship between the GOFO rate and discretionary inventory level for tenors of 6 and 12 months. The black line is a second-order polynomial fit to the data.

We can see that the fitted lines for the various tenors are all concave up, although this is difficult to discern for the 1 month tenor. They are also asymmetric about the zero level of discretionary inventory. While the asymmetry of the fitted curves is visible, with increasing GOFO tenor, the asymmetry is much more pronounced. More specifically, the degree of asymmetry increases with increasing tenor. That is, the GOFO rate appears to be higher during periods of high and low discretionary inventory levels. A linear trend has been removed from both the inventory and GOFO series. . . . . 39

## 5.2 **RELATIONSHIP BETWEEN THE DERIVED LEASE RATE, THE NEGATIVE INTEREST-ADJUSTED BASIS AND DISCRETIONARY INVENTORY LEVEL FOR THE YEARS 1996 - 2009**

The scatter plots illustrate the relationship between the lease rate and the level of discretionary inventory. For all lease durations we notice that the lease rate tends toward zero with increasing level of inventory. This is consistent with the idea that the lease rate can be considered as an observable form of the convenience yield of gold. Furthermore, data point dispersion increases with increasing lease rate tenor suggesting that short-term leasing will have a more pronounced effect on inventory levels. The black line is a second-order polynomial fit to the data and is consistent with the shape of the convenience yield curve as discussed in Fama and French (1988). We note the similarity between the observable and inferred forms of the convenience yield as represented by the lease rate and interest-adjusted basis, respectively. However, increased dispersion and proliferation of data points less than zero present in the interest-adjusted basis series suggests that inference of the convenience yield directly from weekly price data may result in important inaccuracies.

47

**7.1 PLOTS OF RELATIVE FUTURES CONTRACT MIS-PRICING BY YEAR FOR VARIOUS FUTURES CONTRACT MATURITIES** The figure shows the degree of relative mispricing between gold forward and gold futures contracts for maturities of 1, 3, 6 and 12 months. As contract maturity increases, we note an increasing amount of underpricing of forward contracts relative to future contracts. Furthermore, the degree of underpricing seems to be increasing in more recent years. This may be indicative of risk-averse speculators demanding higher risk premiums for contracts of longer maturity. 63

**7.2 PLOTS OF RELATIVE FUTURES CONTRACT MIS-PRICING VS. THE LEVEL OF SPECULATIVE PRESSURE FOR VARIOUS FUTURES CONTRACT MATURITIES** The figure shows the mispricing between gold forward and futures contracts against the level of market speculative pressure. The black line is a least squares regression fit to the sample data. The slope becomes increasingly positive with increasing time to maturity of the contracts. If risk-averse speculators require higher risk-premiums to act as counter-parties to long-term futures contracts. This behaviour would manifest itself in future prices that increasingly exceed forward prices leading to positive price differences and, subsequently, an upward sloping regression line. 65

7.3	<p><b>THE IMPULSE RESPONSE OF THE SPECULATIVE PRESSURE FROM AN ORTHOGONAL SHOCK IN THE AMOUNT OF MISPRICING.</b> Plots of the impulse response functions for the VAR(2) model estimated using weekly observations of the speculative pressure and futures/forward mispricing. Shown are the responses of speculative pressure to an innovation in the mispricing. The sample period is from January 1996 to October 2009. Dashed lines indicate the 95% confidence interval. . . . .</p>	70
7.4	<p><b>THE IMPULSE RESPONSE OF THE DEGREE OF MISPRICING FROM AN ORTHOGONAL SHOCK IN SPECULATIVE PRESSURE.</b> Plots of the impulse response functions for the VAR(2) model estimated using weekly observations of the speculative pressure and futures/forward mispricing. Shown are the responses of the 1, 3, 6 and 12 month mispricing series to an innovation in the speculative pressure. The sample period is from January 1996 to October 2009. Dashed lines indicate the 95% confidence interval. . . . .</p>	71
8.1	<p><b>COMPARISON BETWEEN MARKET-QUOTED 3M GOFO RATE AND KALMAN ESTIMATED <math>t</math> GROWTH RATE</b></p> <p>The figure shows a comparison between the market quoted 3 month GOFO rate and the asset growth rate estimated using the Kalman filter. Starting in approximately February 2003 and ending in the latter half of 2007, there is an observable separation between the GOFO rate and the filtered value. . . . .</p>	82

**8.2 ABSOLUTE DIFFERENCE BETWEEN THE 3 MONTH GOFO RATE AND THE KALMAN ESTIMATED ASSET GROWTH RATE.** Shown in the figure are the absolute differences between the Kalman filtered asset growth rate and the prevailing 3 month GOFO rate. The positive absolute difference between the two series can be observed beginning around February 2003. In addition, this difference appears to be consistently positive over the remainder of the sample period. . . . . 83

**9.1 POTENTIAL PROFIT OF THE GOLD REVERSE CASH AND CARRY TRADE (IN U.S. DOLLARS) OVER THE YEARS 1996 - 2009.** The plots show the potential profit of the reverse cash and carry trade for the gold market. This strategy consists of leasing gold from a central bank, selling the gold on the spot market and entering into a long futures contract. Proceeds from the sale are invested at the LIBOR rate and at maturity; the profit is calculated as the difference between the value (at maturity) of the money invested and the repurchase cost of the bullion at the futures price. Potential profitability of the reverse cash and carry is positive for the 1 month duration and becomes increasingly negative for the 3, 6 and 12 month trade durations. The 12 month trade is not profitable at all from 2001 until 2009. . . . . 85

**9.2 POTENTIAL PROFIT OF THE GOLD CASH AND CARRY TRADE (IN U.S. DOLLARS) OVER THE YEARS 1996**

**- 2009.** Figure 9.2 shows the potential profitability for the 1, 3, 6 and 12 month gold cash and carry trade. The strategy consists of obtaining a loan at the LIBOR rate in order to purchase a unit of gold, shorting a futures contract and holding the gold until maturity. For the duration of the strategy, the trader has the possibility to earn the lease rate on the gold bullion. At maturity, the gold is delivered, the position is dissolved and the investor earns a potential profit that is the difference between the loan repayment amount and the money received for bullion delivery. The 1 month duration trade is seen to be highly unprofitable. Conversely, the 3, 6 and 12 month trade durations are potentially profitable and profitability is seen to increase with increasing trade duration. . . . . 87

# Abstract

By examining the gold leasing market and employing data on the gold forward offered rate (GOFO) and derived lease rates, we propose that rather than using the interest-adjusted basis as a proxy for the convenience yield of gold, the convenience yield is better approximated by the derived gold lease rate. Additionally, using the interest-adjusted basis as opposed to the lease rate can lead to incorrect inferences pertaining to the convenience yield. Using the lease rate, we study the relationship between gold leasing and the level of COMEX discretionary inventory. The results suggest that the lease rate has an asymmetric relationship with the level of discretionary inventory, which we calculate using weekly inventory data obtained from the COMEX futures trading exchange. Linear regressions of the level of discretionary inventory on lagged lease rates reveal that lease rate tenors of 1, 3 and 6 months have a negative effect on the level of discretionary inventory. After controlling for speculative effects we find that for bullion leases exceeding one month in duration inventory levels are dominated by speculative effects rather than lease rates. Furthermore, this speculative activity acts to increase the amount of bullion available to the gold futures market by decreasing the repayment effect. Finally, we show that the presence of speculation in gold futures contracts can be associated with increased futures contract returns and that this effect increases with increased futures contract maturity. These results suggest that speculation plays a significant role in the COMEX gold futures market.

**Key words:** commitments of traders, gold futures market, convenience yield, gold leasing, speculative effects

# Résumé

À travers l'examen du marché de l'emprunt d'or et l'utilisation à la fois des données relatives aux taux à terme offerts sur ce marché (GOFO) et aux taux du leasing de l'or, nous suggérons l'adoption de ce dernier taux comme étant une << proxy >> pour quantifier le rendement de l'or. Une telle approche permet de remédier aux insuffisances d'une approximation par un ajustement du différentiel de taux (interest-adjusted basis). En effet, l'utilisation de ce dernier est sujette à des biais d'inférence aboutissant à une estimation erronée du rendement de l'actif en question. Dans ce contexte, il est naturel d'utiliser le taux le plus approprié, en l'occurrence le taux d'emprunt (lease rate) pour étudier la relation entre l'emprunt de l'or et le niveau d'inventaire du COMEX. Enfin, notre analyse révèle qu la présence de spéculateurs sur les marchés des contrats à terme est un facteur d'accroissement à la fois des rendements, mais aussi des maturités des contrats futures.

**Mots clés:** commitments of traders, marché à terme de l'or, convenience yield, gold leasing, effets spéculatifs



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This work, initiated on a comment made in passing, evolved to become a thorough and illuminating investigation into the gold market. Despite the ubiquity of gold, I never imagined just how little information I would find and thus how deep I would have to search and how far I would have to travel in order to complete this work. Due to the scale of such a task, it goes without saying that this work has been dependent on the help and support of numerous people. I would like to thank them for all their input and aid.

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*Pfaffenberg, Luxembourg*

*December 8, 2009.*

# Introduction

Human civilization is enamoured with gold. Besides its widespread usage as adornment, it also represents a precious and long-lasting store of value. But this is not a modern ideal. The use of gold as a store of value<sup>1</sup> and as the basis for a stable monetary system can be traced to ancient times. The first evidence of gold being used as currency dates to roughly 630 BCE in a region then known as Lydia. The coins of Lydia were minted from a naturally occurring alloy of gold and silver called electrum. In an attempt to stabilize the metal content of these ancient coins, the ruler of Lydia, Croesus, would manipulate the currency, actually reducing the gold content as discussed in Lewis (2007). This resulted in coins with a face value that exceeded the value of their gold composition. In order to maintain the artificial value of the coin, the government passed laws to control the minting of the coins. Perhaps somewhat unrecognizable to us now, this monopolistic system, in a more democratic form, would eventually form the basis of our modern monetary system.

Gold is unique among commodities in that nearly all the gold ever extracted is still thought to exist aboveground, for a distinguishing property of gold is that, unlike agricultural commodities, it does not degrade over time. Bullion can be stored almost indefinitely and requires very little maintenance. This particular attribute of gold leads to another important aspect of gold, namely the existence of vast aboveground inventories that dwarf annual gold mine production. These large inventories of gold can be quickly and easily brought to market to counter any excess demand or supply shocks that may arise. This is a

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<sup>1</sup>As opposed to stocks which represent a return on value.

remarkable feature that distinguishes the gold market from the typical non-precious metal<sup>2</sup> and agricultural commodity markets. For example, agricultural markets and inventories exhibit strong seasonality while the non-precious metals markets are sensitive to annual mine production, supply and demand shocks, and degradation over time. Because gold is such a unique commodity, more akin to a financial asset, conventional commodity price models based on the theory of storage fail to accurately represent the dynamics and stylized facts of the historical gold price see, for example, the papers by Casassus and Collin-Dufresne (2005), Schwartz (1997), Salant and Henderson (1978), and Fama and French (1988).

The gold market of today is a much different market than the gold market of 10 years ago. The New York Commodity Exchange (COMEX), is witnessing historically low lease rates, decreasing hedging activity and steadily rising non-commercial open interest. For a market that was once dominated by commercial<sup>3</sup> futures contracts, this is a fundamental change in the *status quo*. This ever-increasing percentage of non-commercial open interest results from the increased activities of two new classes of gold investor: gold exchange traded funds (ETF) and non-commercial speculators. With their recent proliferation and rising influence, ETFs are playing an ever more prominent and escalating role in the complex dynamics that now affect the price of gold. Speculators are also betting on the gold price in increasing numbers as commodities become commonplace in investment portfolios. This is an unprecedented shift in the composition of gold investors. The gold market, once the domain of an eclectic group colloquially known as “gold bugs”, is now readily accessible by any investor looking to put money into gold bullion. Historically, central banks and bullion banks were the primary gold trading agents, but with gold investment demand increasing and trades being facilitated by electronic trading platforms, non-traditional investors are seeking to put their capital into gold. The rapidly changing role of gold from monetary reserve to investment asset is exerting unique pressures on the gold market that

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<sup>2</sup>Copper or zinc, for example.

<sup>3</sup>As opposed to non-commercial positions.

could completely change how gold is traded on the commodity exchange. We may, in fact, come to eventually perceive gold as a financial investment rather than a commodity in the traditional sense.

Before the increase in investor interest and the creation of ETFs, central banks and bullion banks were among the largest operators in the gold futures market. Indeed, prior to the Washington Agreement on Gold sales in 1999, central banks bought and sold significant quantities of gold thereby either directly or indirectly affecting the price of bullion. This idea that central bank sales could impact the price of gold was studied more specifically in a paper by Salant and Henderson (1978). In their work, Salant and Henderson found that the risk of a future government gold auction served to depress the price of gold yet, under some circumstances, it could also pressure the price of gold to rise (in percentage terms) at a rate that exceeded the real rate of interest. These results lead Salant and Henderson to suggest that the Hotelling (1931) model of exhaustible resources is unable to properly describe gold price movements. Specifically, it is not capable of predicting the observed increases in the gold price that occur at rates exceeding the prevailing rate of interest. Salant et al. suggested this may be due to the non-negligible, and increasing, costs of gold extraction and, additionally, the fact that governments may sell some portion of their gold stock to the private sector, thereby rendering the exact government inventory of gold uncertain. Thus we seem to be left with an incomplete story. Specifically, the full mechanism of gold price formation is not well-understood. This is complicated by a noticeable and distinct absence of literature focused on gold. we argue that additional factors, as of yet unaccounted for in the literature, may also play a role in bullion price formation. In fact, an interesting aspect of this argument is that speculators, who are not constrained by extraction or storage costs, may be able to constrain the price of gold and prevent it from rising, in percentage terms, at a rate exceeding the rate of interest. To our knowledge, no satisfactory or comprehensive analysis of this finding has been treated in the literature to date and could suggest that the presence and influence of speculative behaviour in the gold market influences price. With

this work we hop to contribute an original and in-depth examination of the bullion market and the factors influencing the price of gold. To this end, we first turn our attention to the possible influences that speculative activities may have on the bullion markets.

# Chapter 1

## Does Speculative Activity Affect the Price of Futures Contracts?

The question is ubiquitous in the financial press. Everyday the financial media reports that speculators are playing a role in the latest commodity price increases and this sentiment is not restricted to any particular commodity market. Rather remarkably, the issue has a long history in the literature: Machlup (1969) had published "*Speculations on Gold Speculation*"! However, to some observers, the net effect of speculative activity in commodities markets appears difficult to gauge. A certain number of analysts and individuals even believe that excessive levels of speculation exert a negative influence on markets by driving up the price of commodities. For example, as recently as 2006, the United States Senate commissioned a report on the speculative activity occurring in the oil and gas markets<sup>1</sup> Although the report was inconclusive regarding the exact extent and level of harmful speculation, the recommendations were clear: provide the Commodity Futures Trading Commission (CFTC) with stricter oversight and control of the futures market. In regard to the potential impact on the financial markets, the senate report immediately raises several

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<sup>1</sup>*The Role of Market Speculation in Rising Oil and Gas Prices: A Need to Put the Cop Back on the Beat.* Staff report prepared by the Permanent Subcommittee on Investigations of the Committee on Homeland Security and Governmental Affairs, United States Senate, June 27, 2006.

important questions. Are these controls necessary? Is speculation actually having a tangible effect on commodity prices? And, if so, by what mechanism does speculation influence price? In the analysis that follows, we endeavour to contribute to this debate.

In his theory of normal backwardation, Keynes (1930) proposed the explanation that speculators act as the market counterpart to hedgers and thus they play a necessary and important service in the day-to-day operation of the commodity markets. According to this theory, speculators are an essential participant in commodity markets. In order to reduce their risk, hedgers take long positions in the underlying commodity. Consequently, there is a need for a category of traders willing to take the associated long futures contract positions<sup>2</sup>. This class of traders is referred to as the speculators. In this Keynesian world, the incentive to take on hedgers' risk is that speculators require that the futures price be less than the expected future spot price at the contract maturity. This implies that futures prices are downward-biased expectations of future spot prices, the bias being interpreted as a risk-premium. The debate over the existence of this risk-premium has a lengthy tradition in the financial literature and continues to this day.

Kaldor (1939) was one of the first authors to examine the effects of market speculation on economic stability. In defining speculation as:

*"...the purchase (or sale) of goods with a view to re-sale (re-purchase) at a later date, where the motive behind such action is the expectation of a change in the relevant prices relatively to the ruling price and not a gain accruing through their use, or any kind of transformation effected in them or their transfer between different markets."*

Kaldor argued that there exists a range of price oscillations such that within this range, speculation acts to stabilize prices. Kaldor further argued that this price range varies in size and level across markets and exhibits a spill over effect on supply and demand, and

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<sup>2</sup>i.e. the counterparty



hence inventory stocks, across commodity markets. The resulting asymmetric responses in stock levels across markets, he argues, lead to price stability in commodity markets. This cross-market stock variability is thus a possible mechanism by which speculators can affect market dynamics, and highlights the importance of inventories in influencing commodity markets.

In a relatively early paper, Working (1953) tried to distinguish the respective importance of the roles of speculation and hedging in the commodity markets, suggesting that evidence gathered at the time favoured the view of speculation following hedging or, put in another way, the speculators went to where the hedgers were. In fact, Working suggested that the then traditional view of hedging as an activity meant to offset risk may not have been accurate. He stated that a more accurate depiction of hedging in commodity futures is that it is an activity involving:

*“...the purchase or sale of futures in conjunction with another commitment, usually in the expectation of a favourable change in the relation between spot and futures prices.”*

Working’s definition thus portrays hedging as an activity akin to speculation as defined by Kaldor. Working goes on to suggest that one way through which speculation can induce price changes is if large-scale mismanagement of stocks<sup>3</sup> takes place in a futures market highly utilized for hedging. The gold futures market has, historically, been such a market. To study speculative effects, Working proposed to quantify “excessive” price fluctuations in a commodity by measuring the amount of fluctuation in price occurring in excess of price fluctuations that could be attributed to unpredictable changes in economic fundamentals. However, his numerical evidence was weak and Working was forced to concede that the evidence in favour of speculative effects on futures prices was at best anecdotal but this was due more to a lack of appropriate data than anything else.

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<sup>3</sup>Such stocks are referred to by Kaldor as “speculative stocks”.

Houthakker (1957) was among the first authors to introduce the use of trader commitment data to the study of market speculators. Although his work was concerned with the estimation of the profits and losses of speculators, it served to illustrate that open interest commitment data could be successfully employed to study the effects of speculation in the futures market. The work of Houthakker lays the groundwork for our methodology.

In this paper we restrict our study of speculation to the gold futures market for several reasons. A key one is that gold, unlike other commodities, behaves more as an asset than a true commodity. For example, gold in central bank inventories can be leased in order to earn a return, yet this differs from the concept of convenience yield developed in the theory of storage. Reinforcing this point, authors such as Casassus and Collin-Dufresne (2005) find that the long-run mean of the convenience yield of gold is nearly indistinguishable from zero. According to Solt and Swanson (1981), a key difference between gold and other financial assets is that gold is an asset with an inherent value whereas other financial assets represent contingent claims.

Another characteristic of the gold price is that it lacks a seasonal component that could potentially mask speculative effects. Agricultural and energy commodities exhibit strong seasonal patterns in relation to weather, whereas evidence for seasonality in the gold market is weak. Lucey and Tully (2006) find weak evidence of a Monday effect in gold futures trading but report no conclusive evidence of a long-term seasonal price behaviour. Similarly, Tschoegl (1987) finds no evidence of a monthly seasonal effect in gold futures over the period from January 1975 to December 1984 despite having employed three different definitions of seasonality.

As a result of its physical properties, almost all the gold ever mined survives in vast aboveground inventories. Owing to this durability, gold does not deteriorate over time and, consequently, financial institutions hold large stocks of gold that do not suffer from depreciation or spoilage; its value being tied to the spot price. Gold inventory levels are therefore quite stable and do not run any significant risk of sudden, unexpected changes.

Indeed, as described in Salant and Henderson (1978), any large governmental sales of gold are announced in advance. As we have argued, speculators may affect the rate of increase of the gold price. In studying the efficiency of the gold and silver markets, Solt and Swanson (1981) reach a similar conclusion, arguing that trading in gold and silver is, perhaps, more of a speculative, rather than an investment, activity.

Prior work on the effects of speculation in metals markets was carried out by Kocagil (1997). Kocagil tested the hypothesis that increased speculation in the metals futures markets acts to stabilize spot price volatility. He developed a rational expectations model that included producers (short hedgers), inventory holders consumers and producers. He defined the speculative intensity as the sensitivity of open futures positions to the spread between the futures and expected spot price. His results suggested a rejection of the above hypothesis, indicating that speculation increases spot price volatility and thus has a destabilizing effect on price.

In a paper studying commodity futures price volatility, Fama and French (1987) considered the role that volatility plays in the dynamics of commodity futures. Using futures spreads, they demonstrated that the conditional variance of futures prices increased with the current price of the commodity. In addition, they showed that the basis variation of gold futures prices was almost completely explained by the interest rate. Further evidence of the importance of volatility over convenience yield in metals futures prices comes from Fama and French (1988). Using regressions, they showed that there was little support for the theory of storage in explaining the price movements of the precious metals. Their explanation for this finding was that the low storage costs of the precious metals relative to their inherent value results in limitations on the variance of convenience yields and, consequently, in the interest-adjusted basis. As a result, it is possible that the low storage costs of gold depress convenience yields to near zero which is consistent with the finding of Fama and French (1988) that spot and forward prices for gold exhibit a near one-to-one variation.

All these sentiments were shared by Gehr and Martell (1994) who interviewed traders

in order to assess the impact of derivative usage on the spot price of gold. It is clear that gold market liquidity has been significantly increased as a result of extensive derivative trading. Such a well-developed derivatives market would make a welcoming environment for the operation of speculative agents. However, further research is required in order to corroborate such findings.

One early analysis of the economics of gold prices was given by Abken (1980). Abken's analysis of gold price movements is based on the idea that price movements can be explained as a consequence of rational behaviour by economic agents participating in a speculative market. The intuition is that the only return that gold yields is that return resulting from an anticipated increase in the future price of gold. Because rational agents are profit maximizing, they will store a quantity of gold whose storage costs are such that the anticipated appreciation of the gold price will offset any marginal costs associated with the storage of gold. Abken further argues that rational agent behaviour during times of uncertainty will lead to excess demand for gold as a store of value, thereby driving up the spot price and causing stored gold to be brought to market. This will act to restore equilibrium in the market so that the anticipated price increase no longer exceeds the interest rate. Using linear regressions, Abken tries to identify the factors responsible for gold price movements, specifically percentage monthly changes in the spot price of gold. He considers yield rates on one month-maturity Treasury Bills, lagged spot prices and lagged futures prices for the period of January 1973 to December 1979 for the former and September 1975 to December 1979 for the latter. However, one problem facing Abken is a lack of data. For example, his regressions involving the futures prices contain a total of 18 observations. This manifests itself as a weakness in the results. He finds that the coefficients on lagged percentages price changes are non-significantly different from zero, while the coefficients for the current interest rate are significant at the 90 percent level of confidence. He reports a value of 0.039 for the regressions on interest rate and past price changes. His regressions on past futures prices show little improvement in explanatory power and exhibit that the spot price

behaviour of gold cannot solely depend upon lagged values of the futures prices.

In the next two chapters we introduce the quantities and variables that will be central to our empirical analysis: speculative pressure and the interest rates quoted in the gold market.

We will see that these quantities play a critical role in the formation of gold prices.

## **Chapter 2**

# **On Speculative Pressure and its Possible Effects**

The gold futures market has undergone significant change in the last two decades. Currently, the market is dominated by non-commercial long futures contracts and is now witnessing strictly positive speculative pressure over extended periods of time. This is a significant break from the historical precedent of high levels of hedging activity.

Keynes' theory of normal backwardation implies that the net supply of commercial futures contracts, or hedging pressure, affects the equilibrium futures price path, thereby leading to a rise (or fall) in futures prices over time. This equilibrium trend can be interpreted as the risk-premium. When hedgers take long positions, the equilibrium achieved is such that futures prices tend to decrease over time. Conversely, in a market where short hedging dominates, futures prices tend to increase over time.

Not all market agents can freely diversify their portfolios and, as a result, a price bias is created. In a Keynesian world, producers will hedge their short positions by taking a corresponding long futures position in the commodity or physical. The resulting net supply of futures contracts, termed the hedging pressure, creates a downward pressure on the expected future spot price at maturity. This downward pressure appears as a bias and is

termed normal backwardation.

Speculators are another type of market agent that takes long positions in futures markets. They are assumed to be risk-averse and in order to enter into the long futures position, they require a premium as compensation for the risk that they bear. In this manner they are compensated by a positive expected profit, the aforementioned risk-premium. However, speculators are not the only agents that will enter into long futures positions. Producers facing inventory problems may also take long futures positions. Combined, both producers' and speculators' long positions can result in an upward bias, or contango, in futures prices. This situation can be particularly acute when inventories are more variable than prices. It is evident then, that upward or downward bias in prices can result from aggregate long or short futures positions.

Optimal hedging to speculation ratios and the existence of risk-premiums are two important topics in the study of futures markets. In reviewing the Keynesian idea of normal backwardation, Hirschleifer (1990) studied the effects of hedging pressure on futures price formation. It is known that both consumers and producers hedge in the futures market and that the hedging activity of the respective groups is counteractive. Under the assumption of substantial setup costs, Hirschleifer developed a model of the futures market that accounts for the non-participation of consumers. He showed that producer hedging would dominate consumer hedging under significant costs, thereby restoring the downward bias in futures prices. In other words, consumers become discouraged by short-hedging and increase their long futures positions. Consequently, he shows that futures hedging is dependent on trading costs that are not symmetric between consumers and producers and these asymmetries arise from the different hedging incentives between the two groups.

In support of the hedging pressure hypothesis, Bessembinder (1992) found that returns in the foreign exchange and agricultural commodity markets vary with the net holdings of hedgers, thus adding further evidence that hedging pressure influences risk-premiums. Using cross-sectional commodity data along with trader position data, Bessembinder showed

that hedging pressure has explanatory power for risk premiums. More specifically, he found that unconditional futures returns have mean returns that do not differ significantly from zero. Conversely, when those returns are conditioned on hedging pressure, he reported that mean futures returns are significantly different than zero. He extended the results of Hirschleifer with the finding that hedging pressure may have a much broader scope; it extends beyond the commodity market and into the foreign exchange futures markets.

In recent work on hedging effects, de Roon, Nijman and Veld (2000) modeled the returns on a portfolio consisting of non-marketable risks, investment assets and futures contracts. Such a model allows for a relationship between the risk-premium and the hedging pressure, which is calculated using bi-monthly observations of trader positions taken from the CFTC position data. Their model is constructed such that hedging pressure arises from risks that agents either do not, or cannot, hedge as a result of market frictions or transaction costs. Under such assumptions, de Roon et al. show that hedging pressure leads to price bias. They also find that returns are influenced by hedging pressure, but not just hedging pressure in the commodity's own market, but rather across commodity markets.

By controlling for price pressure, measured as a change in hedging pressure, de Roon et al. show that hedging pressure is responsible for the formation of price bias in futures prices. Additionally, they find that hedging pressure influences not just futures returns, but returns on the underlying asset of the futures contract.

To understand how speculative agents can affect the gold futures market, we examine the open interest data from the Commodity Futures Trading Commission (CFTC) Commitment of Traders (CoT) report. The CoT report contains open interest data regarding the various trading positions of the futures market for gold<sup>1</sup>. The open interest data is separated

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<sup>1</sup>In the CFTC CoT report, there are multiple categories of data. We are interested in commercial and non-commercial (all) data. The category denoted by "other" is not utilized in this paper but contains information regarding the remaining futures contracts. In short, this category contains traders not categorized as either "long" or "short" under the CFTC reporting framework. Specifically, we use non-commercial long, short and spread (all), commercial long and short (all) and non-reporting long and short (all). We also use the data for total open interest (all).



into various categories that represent the possible trading positions. These are subsequently decomposed into various reporting categories themselves. The primary distinction is between reportable and non-reportable positions. Reportable positions can be further partitioned into commercial and non-commercial positions. According to CFTC regulations, commercial positions consist of those market positions used primarily for hedging<sup>2</sup>. We thus identify commercial open interest with hedging activity. Conversely, non-commercial positions are identified with speculative activity. This category includes positions taken by speculative institutions like hedge funds, for example. The classification is not rigorous, however, as some commercial positions may be speculative in nature while some non-commercial positions may be associated with hedging activity<sup>3</sup>. It is therefore important to be aware that some cross-position contamination may be present in the open interest data. Nonetheless, these classifications can be further subdivided into long, short and in the case of the non-commercial data, spread positions. These data comprise a subset of the total open interest. Aggregate activity by hedge funds and other institutions can increase the speculative activity, resulting in a net positive number of long futures contracts in comparison to short futures contracts. Subsequently, it is possible to calculate a measure of the excess of long contracts over short contracts. To quantify the speculative activity in the gold futures market we define the speculative pressure as the analogue to the hedging pressure of de Roon et al. (2000). The speculative pressure,  $\pi_t$ , is given by Equation (2.1):

$$\pi_t = \frac{NC_t^{long,all} - NC_t^{short,all}}{NC_t^{long,all} + NC_t^{short,all} + 2NC_t^{spread,all}} \quad (2.1)$$

The speculative pressure can be considered a measure as to whether the market can be characterized as either net long speculation or net short hedging if the open interest of

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<sup>2</sup>We refer to the definition of a “hedging transaction” as specified in the CFTC Electronic Code of Federal Regulations (e-CFR) section 1221(b)(2)(A). This definition details a “hedging transaction” to be “any transaction that a taxpayer enters into in the normal course of the taxpayer’s trade or business primarily[for various risk management activities]”.

<sup>3</sup>For example, we know that banks sometimes hedge because they have an OTC contract with a customer who may be hedging or speculating. Consequently, this blurs the distinction between hedgers and speculators and results in noisy speculator (i.e. non-commercial) data.

reporting speculative long open interest<sup>4</sup> exceeds (or is less than) speculative short open interest. This interpretation is backed by the work of Hirshleifer (1990) who identifies hedging pressure with the supply of futures contracts. Hirshleifer states that high values of hedging pressure result in a decrease in futures prices in comparison to the expected future spot price. The result of this property is the existence of a downward bias that is present in futures prices.

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<sup>4</sup>i.e. non-commercial long open interest

## Chapter 3

# Central Banks and the Gold Leasing Market

For most of its existence, the gold futures market was used for the gold carry trade<sup>1</sup>. The carry trade was facilitated by central banks wishing to earn a return on their bullion inventories. This trade involved borrowing gold from the inventories of central banks that were interested in generating a return on their bullion inventories and consisted of either leasing or swapping gold in exchange for a fee. The gold could be leased at a relatively low rate from the central bank and then sold quickly on the spot market. The proceeds from such a sale could then be invested at the London Interbank Offer Rate (LIBOR) or in Treasury bills. Because the lease rates charged by the central banks were less than the LIBOR rate, if the gold spot price did not move significantly then, on average, this was a profitable trading strategy; the leasing institution essentially being able to earn the Gold Forward Offered (GOFO) rate. This rate is the rate at which a dealer is prepared to lend gold on a swap against U.S. dollars. However, since late 2001, the profitability of the short-maturity carry trade has diminished. Rising gold prices have increased risk and diminished the trade's

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<sup>1</sup>See "textitBullish on Bullion" by Peter Madigan, Risk, February 1, 2008.

profitability as a result of increasing repayment costs<sup>2</sup>. Consequently, the prevalence of the gold carry trade is predicated on two factors; the rate at which the central bank is willing to swap or lease gold and whether or not the gold price is increasing.

To gain insight into this aspect of the gold market, we will consider how a central bank can proactively use gold to enhance the yield on their bullion inventories. A central bank can lease gold to the market using two methods. The first is by simply leasing bullion to another institution. The second method is essentially a swap whereby gold is exchanged for U.S. dollars. The leasing of gold by central banks is relatively straightforward as a transaction. The rate at which gold is leased is derived from the difference between the LIBOR and GOFO rates and is given by Equation (3.1):

$$lease = LIBOR - GOFO \quad (3.1)$$

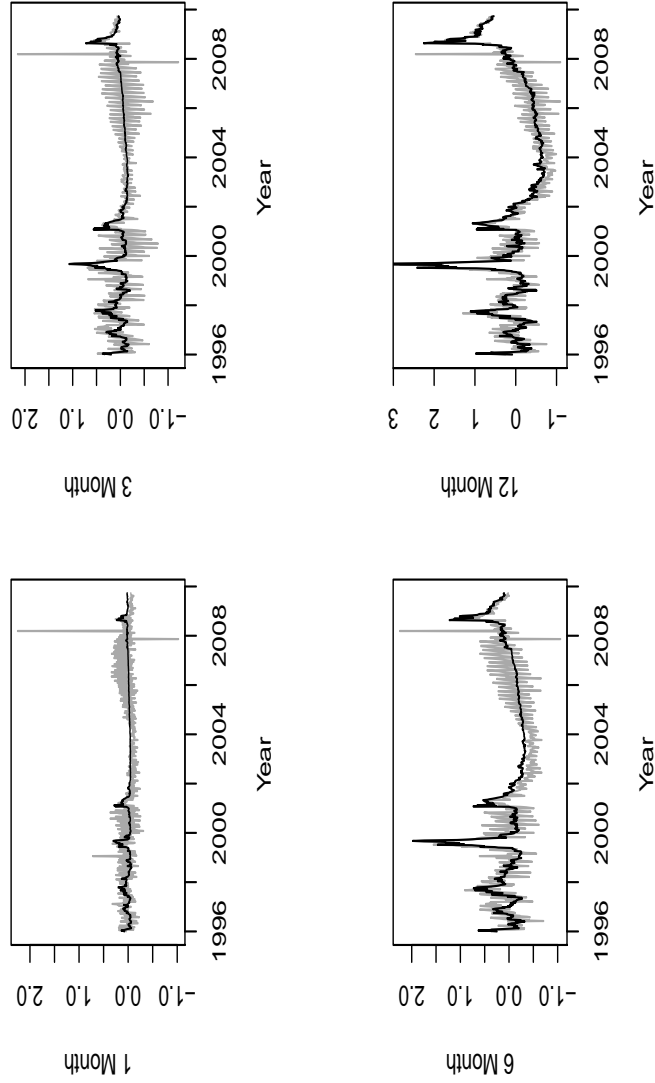
This is considered a derived rate since it is not set independently, but rather it arises from the difference between the market quoted LIBOR and GOFO rates. A leasing transaction would involve a central bank transferring ownership of the gold to the leasing institution. The leasing institution could then sell the gold on the spot market and invest the proceeds at, say, the LIBOR rate or could use the physical bullion to assist with producer hedging. The central bank would charge the borrower the lease rate, as given by Equation (3.1), for the duration of the loan. At a later date, the leasing institution, or borrower, would buy back or simply return the gold and pay the central bank the original loan plus the lease rate as interest. Because lease rates are less than the LIBOR rate, and if the price of gold remains favourable, the leasing bank is able to generate a profit using this transaction while the central bank earns the difference between the LIBOR and GOFO on its idle gold inventories.

The second type of transaction involves a swap, but it is actually less a swap than it is a sale and repurchase agreement. In a gold swap, a central bank is willing to exchange

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<sup>2</sup>The gold carry trade is profitable when gold prices are either stable or decreasing.

its gold bullion for cash. As with the leasing transaction, the ownership title of the gold is transferred to the leasing institution through an actual sale, but with the added condition that the central bank agrees to repurchase the gold from the borrower at some forward date. In selling the gold to the borrower, the central bank receives U.S. dollars and, consequently, in addition to agreeing to a repurchase, the central bank also pays interest to the leasing institution at the GOFO rate. The GOFO is thus the interest rate charged on a loan denominated in dollars and using gold as collateral. Once in their possession, the borrower is free to sell the gold on the spot market and invest the proceeds as before or to simply hold the bullion and earn the secure GOFO rate. It makes sense, therefore, to think of the GOFO rate as the rate at which the spot price rises relative to the futures price. Consequently, the lease rate can be thought of as a proxy for the convenience yield. For example, Figure (3.1) shows a plot of the lease rate and the negative interest-adjusted basis, as calculated using the definition published in Fama and French (1988), for the 3, 6 and 12 month maturities. During a gold swap, the central bank pays GOFO to the borrower. Since the GOFO rate is less than the LIBOR, the advantage for the central bank is that it exchanged gold for cash reserves that can be invested at a rate that exceeds the GOFO. The difference between the investment at LIBOR and the payment of GOFO is the lease rate. Once again, the central bank is able to generate a return from its idle bullion inventories.



**Figure 3.1: THE NEGATIVE INTEREST-ADJUSTED BASIS AND THE LEASE RATE**

The figure shows the negative interest-adjusted basis in dark grey and the corresponding lease rate for tenors of 1, 3, 6, and 12 months in black. A linear trend has been removed from both series. Agreement between the plotted lease rate and the calculated adjusted basis increases with increasing lease tenor.

Unlike the derived lease rate, the GOFO rate is the mean of a series of rates offered by the market making members of the London Bullion Market Association (LBMA). As a result, the market making members can, to some extent, adjust the GOFO up or down depending on market conditions. Thus, we can think of the GOFO rate as an observable signal from the participating banks. When the GOFO rates are set such that there is a high differential with the LIBOR, the market makers are interested in exchanging bullion for U.S. dollars, a clear signal that banks are interested in obtaining cash using gold as collateral. This usually occurs under conditions of high demand for bullion. When the GOFO rate is set close to the LIBOR, neither strategy explained previously is highly profitable and consequently, the banks signal a willingness to contribute liquidity. This situation occurs under low demand for gold. This is because, despite the technical details behind the two agreements, they each earn the same return. Thus, when the GOFO rate approaches the LIBOR rate, it is a signal of low demand for physical gold; the carry trade is no longer expected to be profitable as a result of diminished lease rates and an increasing gold price. This situation can also occur when the gold price is high and/or rising. In light of this we can think of the lease rate as a proxy for aggregate demand for gold liquidity, more specifically, as the convenience yield of gold. Subsequently, the GOFO rate is the theoretical rate at which the price of a futures contract increases.

## Chapter 4

### Data and Summary Statistics

Our inventory data consists of daily observations of gold bullion inventories held by the COMEX market making members and is recorded in troy ounces. These aggregated inventory data are subdivided into two categories: registered stocks and eligible stocks. The “registered” designation implies that the bullion is eligible for delivery against a futures contract. Conversely, the “eligible” designation refers to bullion inventories kept in the warehouse but not yet certified for delivery. In general, these inventory levels are not necessarily indicative of underlying supply and demand conditions. This is because the major depository institutions<sup>1</sup> choose independently when to deposit their stocks. Additionally, other bullion warehouses exist for which COMEX does not possess inventory statistics. These observations span the period from the beginning of January 1996 until the end of October 2009 and were used to construct a weekly series of de-trended and studentized inventory levels similar to the procedure described in Dincerler et al. (2005). Initially, we created an inventory innovation series using an ARIMA(0,1,0) model and then studentized the resulting series of innovations. This procedure resulted in a series of discretionary inventories, as described by Routledge et al. (2000). The value of using discretionary inventory levels lies with the observation that this measure of inventory is indicative of the

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<sup>1</sup>These include Brink’s Inc., Scotia Mocatta, HSBC Bank, USA and Manfra, Tordella & Brookes, Inc.



Statistic	Series			
	Inventory	Spec. Press.	Hedge Press.	Small Press.
Mean	0.0000	0.1107	-0.2255	0.3254
Std. dev.	1.0000	0.3738	0.3222	0.2152
Skewness	0.2038	-0.6349	0.5657	-0.3358
Excess kurtosis	7.0800	-1.0270	-1.0830	-1.2130
Min	-6.8030	-0.6576	-0.6822	-0.0963
Median	-0.0951	0.2525	-0.3456	0.3818
Max	5.0450	0.6764	0.4919	0.6946
No. Obs.	712	712	712	712

**Table 4.1: SUMMARY STATISTICS FOR MARKET PRESSURE VARIABLES**

The table presents summary statistics for the discretionary inventory level along with speculative, hedging and small trader pressures for the years 1996-2009. Discretionary inventory is recorded weekly and on Wednesdays using the average of the previous week as the Wednesday observation. Using an ARIMA(0,1,0) model, we remove the stochastic trend to obtain a series of innovations. These are then studentized to construct the discretionary inventory series as described in Dincerler et al. (2005). The market pressures series are recorded with weekly frequency on the Tuesday of every week. Speculative pressure is the most volatile of all pressures series, while small trader pressure is the most consistent, suggesting substantial differences in the positions of the respective trader categories.

balance between the current and future consumption value of the commodity. The level of discretionary inventory is therefore closely associated with the concept of a convenience yield.

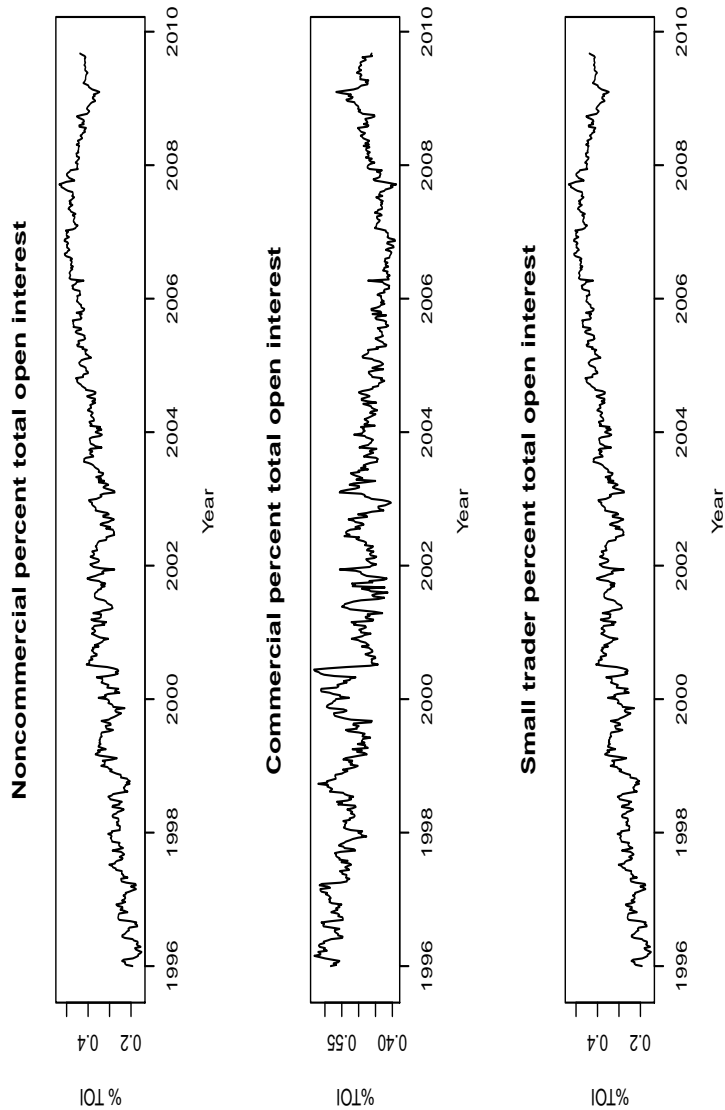
Our open interest data consists of weekly open interest values for commercial, non-commercial and small trader positions collected from the CFTC Commitment of Traders reports. The data span the period from January 1996 until October 2009 and consist of a total of 712 weekly observations. Table 4.1 shows summary statistics for the market pressures and discretionary inventory over the entire time period.

From Table 4.1 we can see that speculative pressure has maintained a mean positive value over the sample period with a sample mean of 0.1107. The standard deviation of

0.3738 is the highest of all pressures series suggesting that speculative pressure is considerably volatile in comparison to the other pressures. The skewness is highly negative at -0.6349 suggesting that, despite the high mean value, many of the observations are considerably less than the mean.

The hedging pressure statistics show that, contrary to the traditional view of the gold market as a hedging market, historical hedging pressure has maintained a negative value with the exception being the period from mid 1996 until 2001. This suggests that the market has been net short on average, although the result is more pronounced for more recent years.

Small traders are those agents who do not meet the minimum reporting levels enforced by the CFTC and are traditionally identified as small-scale speculators. From the increasing trend in the small trader pressure, it is clear that these agents are playing an increasing role in the gold futures market. Small trader pressure exhibits clear evidence of long-term positivity and has the smallest standard deviation of all the pressure series suggesting small traders are the most consistent in their positions over the sample period. The mean and median values are similar in magnitude, highlighting this regularity. For all pressures, and in particular the speculative pressure, the difference between the maximum and minimum values is quite large, being indicative of large swings in trader behaviour. Overall, small traders seem to be the most consistent in their use of the gold futures market as small trader pressure has remained preferentially positive over the sample period.



**Figure 4.1: PERCENT OF TOTAL OPEN INTEREST (TOI) BY MARKET POSITION FOR THE YEARS 1996 - 2009**

The figure shows the percent of total open interest for the various market positions. This includes non-commercial, commercial and small trader (i.e. non-reporting) open interest. Both non-commercial and small trader open interest is increasing over the sample period while commercial open interest is declining. This suggests an increase in activity by speculators and a scaling back of participation by hedgers.

Statistic	Unit Root Tests			
	Inventory	Spec. Press.	Hedge Press.	Small Press.
ADF Test	-5.52	-1.76	-1.61	-1.65
5% Crit. Val	-2.86	-2.86	-2.86	-2.86
KPSS Test	0.527	2.59	2.67	2.01
5% Crit. Val	0.463	0.463	0.463	0.463

**Table 4.2: RESULTS OF AUGMENTED DICKEY-FULLER (ADF) UNIT ROOT TESTS ON INVENTORY AND MARKET PRESSURES**

The table shows the augmented Dickey-Fuller and KPSS test statistic values for all market pressures and discretionary inventory over the time period from 1986 to 2009. The test regression was specified to contain a constant but no deterministic trend. As indicated by the test results, the null hypothesis of the presence of a unit root cannot be rejected for all pressures considered. We therefore conclude that the series are unit root non-stationary. For the discretionary inventory series, the ADF statistic rejects the null hypothesis of non-stationarity. However, the KPSS test results suggests rejection of the null hypothesis of stationarity, albeit weakly, for the inventory series.

Figure (4.1) shows the percent of total open interest for commercial, non-commercial and small trader positions. There are some clear trends present in the data. The reporting commercial and non-reporting positions show evidence of downward trends. Conversely, as a percentage of total open interest, it is clear that the non-commercial traders are increasing over time. If we take the traditional interpretation of non-commercial traders being identified as speculators, we see that speculators are playing a significant and increasing role in the gold futures market.

We next tested the selected series for unit root non-stationarity using the augmented Dickey-Fuller (ADF) and KPSS tests. Since some of the pressure series display evidence of a significant mean value, where appropriate we specified the tests to include a constant. Table (4.2) shows the results of our ADF unit root tests on selected time-series.

Looking at the ADF test statistics and their associated critical values, we cannot reject the null hypothesis of unit root non-stationarity for all of our pressures time series. The KPSS test confirms the findings of the ADF test. However, for discretionary inventory

series, the ADF test rejects the null hypothesis of a unit root at the 5% significance level. Conversely, the results of the KPSS test on the inventory provides a conflicting result, suggesting that this series may possess a unit root, although the critical value is not exceeded by a large margin.

From daily observations of the gold futures price, we compiled a weekly series of futures prices for the first, third, sixth and twelfth nearby gold futures contracts traded on COMEX that resulted in a series for which prices are observed every Tuesday. In order to construct a continuous returns series, we used the method outlined in de Roon et al. (2000). This series of Tuesday prices corresponds to the dates on which the Commodity Futures Trading Commission (CFTC) releases their weekly Commitment of Traders (CoT) report containing the levels of market open interest. Summary statistics for the returns series are provided in Table (4.3). Interestingly, with the exception of the 12 month contract returns, the mean value of all returns series is 0.0014. Standard deviation values are consistent across all contracts while skewness tends to decrease and excess kurtosis decreases across the 3 to 12 month series.

<b>Statistic</b>	<b>Returns Series</b>			
	<b>First</b>	<b>Third</b>	<b>Sixth</b>	<b>Twelfth</b>
Mean	0.0014	0.0014	0.0014	0.0010
Std. dev.	0.0239	0.0239	0.0239	0.0237
Skewness	0.5360	0.5442	0.5296	0.4831
Excess kurtosis	5.758	6.006	5.887	5.591
Min	-0.1131	-0.1132	-0.1134	-0.1139
Median	0.0010	0.0010	0.0010	0.0008
Max	0.1667	0.1689	0.1665	0.1577
No. Obs.	711	711	711	711

**Table 4.3: SUMMARY STATISTICS FOR THE FUTURES RETURNS SERIES OVER THE PERIOD FROM 1996 - 2009**

The table shows the summary statistics for the first, third, sixth and twelfth nearby futures contracts for the COMEX gold contract. Observations are weekly in frequency and have been made into a continuous returns series using the method of de Roon et al. (2000).

The data on the LIBOR, GOFO and lease rates span the period from January 2, 1996 until October 20, 2009. They are observed weekly, resulting in a total of 712 observations. Table 4.4 shows summary statistics for the LIBOR, GOFO and derived lease rates across all maturities.

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**Panel A: LIBOR Rate**

	<b>First</b>	<b>Third</b>	<b>Sixth</b>	<b>Twelfth</b>
Mean	3.8539	3.9574	4.0588	4.224
Std. dev.	1.9567	1.9170	1.8679	1.812
Skewness	-0.399	-0.3731	-0.3450	-0.2827
Excess kurtosis	-1.352	-1.385	-1.383	-1.327
Min	0.2425	0.2831	0.5856	1.019
Median	4.8637	4.9216	4.9194	4.862
Max	6.7688	6.8400	7.0625	7.450
No. Obs.	712	712	712	712

**Panel B: GOFO Rate**

	<b>First</b>	<b>Third</b>	<b>Sixth</b>	<b>Twelfth</b>
Mean	3.165	3.1568	3.131	3.1166
Std. dev.	1.703	1.6652	1.631	1.5658
Skewness	-0.0784	-0.071	-0.0724	-0.1028
Excess kurtosis	-1.298	-0.071	-1.298	-1.265
Min	0.034	0.1833	0.400	0.5829
Median	3.272	3.3508	3.395	3.4850
Max	6.160	6.1000	6.100	6.0900
No. Obs.	712	712	712	712

**Panel C: Lease Rate**

	<b>First</b>	<b>Third</b>	<b>Sixth</b>	<b>Twelfth</b>
Mean	0.6890	0.8005	0.9277	1.1079
Std. dev.	0.8703	0.8633	0.8565	0.8687
Skewness	1.776	1.544	1.309	0.7518
Excess kurtosis	3.175	2.792	2.24	0.5062
Min	-0.2113	-0.1544	0.0611	0.0284
Median	0.2366	0.3890	0.6661	0.9703
Max	4.8125	5.5600	5.3463	5.2013
No. Obs.	712	712	712	712

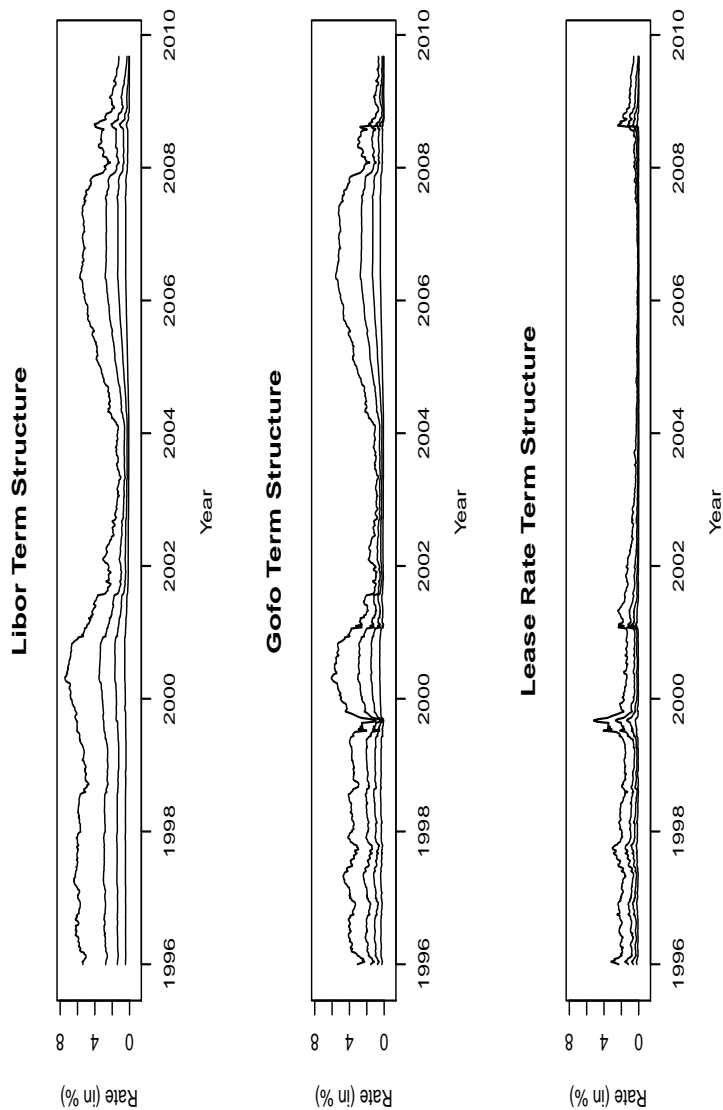
**Table 4.4: SUMMARY STATISTICS FOR THE MARKET RATES (LIBOR, GOFO, LEASE) FOR THE PERIOD 1996 - 2009**

The table shows summary statistics for the LIBOR, GOFO and derived lease rates for tenors of 1, 3, 6 and 12 years for the period spanning 1996 - 2009. The LIBOR and lease rates exhibit increasing mean value with increasing tenor. The exception is the GOFO rate, which demonstrates a decreasing mean value with increasing tenor. The LIBOR series have the highest standard deviations, followed by the GOFO rate series and the derived lease rate series exhibit the smallest values of standard deviation for all series. Significant differences between minimum and maximum values can be observed for all rate series.



The individual rates are subdivided into tenors of one, three, six and twelve months. These data are quoted daily but in order to analyze these in conjunction with the open interest data, we reduced the data set to weekly observation frequency, with the observation day being every Tuesday in accordance with the CoT report observations. The mean LIBOR rate increases with maturity along with displaying decreasing excess kurtosis. Conversely, the mean GOFO rate decreases with maturity and, similar to the LIBOR statistics, the GOFO rate exhibits declining leptokurticity with increasing tenor. The derived lease rates have mean values that increase with maturity, but remain relatively small being, on average, slightly less than or equal to 1%. The lease rate excess kurtosis decreases rapidly from 3.175 for the 1 month rate to 0.506 for the 12 month lease rate suggesting that as the lease rate increases, the rate changes frequently, but moderately.

Figure 4.2 shows a plot of the 1, 3, 6 and 12 month tenor term structure of the LIBOR, GOFO and resulting derived lease rate for the period spanning 1996 until 2009.



**Figure 4.2: TERM STRUCTURE OF THE LIBOR, GOF, AND DERIVED LEASE RATES FOR THE YEARS 1996 - 2009**

The figure shows the LIBOR, GOF and corresponding derived lease rate for tenors of 1, 3, 6 and 12 months. The lease rate is obtained by subtracting the GOF rate from the prevailing LIBOR rate. The lease rate is the rate at which a central bank will lend gold, while the GOF rate represents the rate a central bank is willing to pay on a loan secured using gold as collateral.

We can see from Figure 4.2 the clear relationship between the GOFO and the LIBOR rate that gives rise to the derived lease rates. When the difference between the LIBOR and GOFO is large, the derived lease rates are high. Conversely, when there is little difference between the LIBOR and GOFO, derived lease rates are exceedingly low.

The relation between LIBOR and GOFO suggests that the two series may be cointegrated and therefore exhibit a long-term relationship. Consequently we test series of paired LIBOR and GOFO tenors for cointegration using the Phillips and Ouliaris procedure since the Johansen method can produce errant results for a bivariate specification. Specifically, the finite sample specification of the Johansen maximum likelihood estimator results in the tails of the finite sample distribution being leptokurtic, thereby resulting in extreme values of the cointegration vector.

Table 4.5 shows the results of the Phillips-Ouliaris test for time series cointegration for the four different LIBOR and GOFO tenors.

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**1 Month Tenor**

<b>Test Description</b>	<b>Test Statistic</b>	<b>5% Critical Val.</b>
Phillips-Ouliaris	88.15	40.82

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**3 Month Tenor**

<b>Test Description</b>	<b>Test Statistic</b>	<b>5% Critical Val.</b>
Phillips-Ouliaris	59.94	40.82

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**6 Month Tenor**

<b>Test Description</b>	<b>Test Statistic</b>	<b>5% Critical Val.</b>
Phillips-Ouliaris	43.16	40.82

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**12 Month Tenor**

<b>Test Description</b>	<b>Test Statistic</b>	<b>5% Critical Val.</b>
Phillips-Ouliaris	29.74	40.82

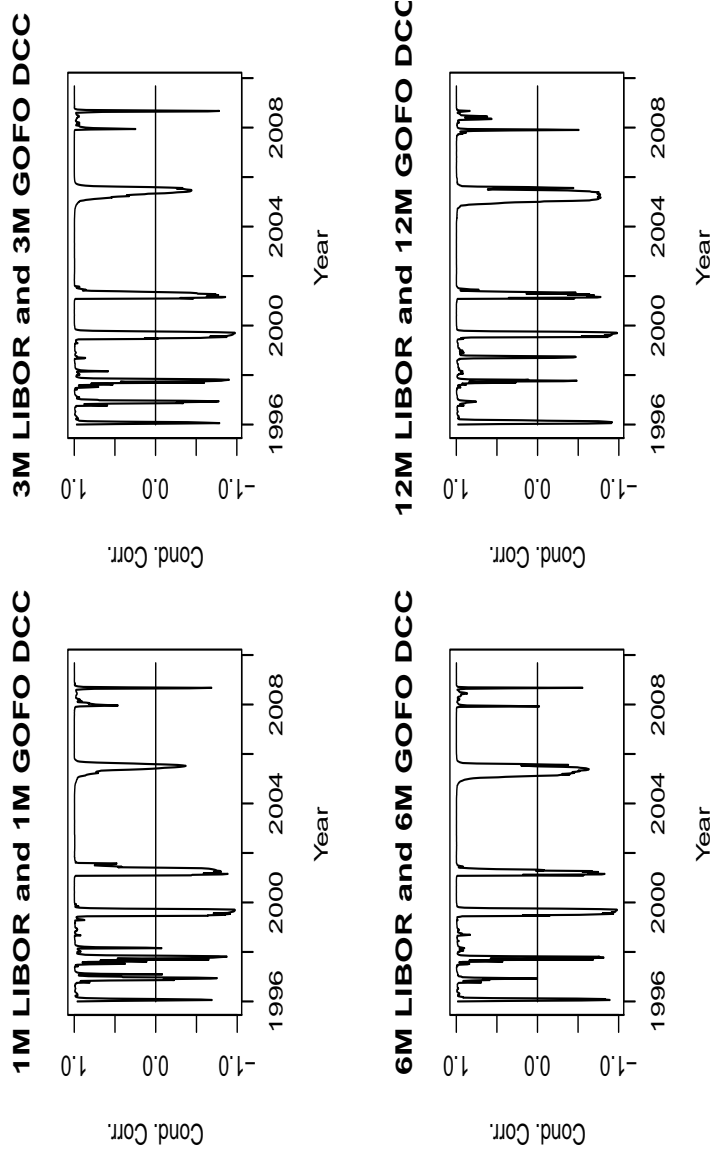
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**Table 4.5: COINTEGRATION TEST RESULTS FOR LIBOR AND GOFO RATES OF 1, 3, 6 AND 12 MONTH TENOR**

The table shows the results of the Phillips-Ouliaris test for cointegration between the bivariate LIBOR and GOFO time series. There is evidence for a cointegrating relationship if the value of the test statistic exceeds the critical value at the 5% level of significance. For 1, 3 and 6 month tenors we cannot reject the hypothesis that the LIBOR and GOFO rates are cointegrated. The results for the 12 month rates suggest that at this maturity duration, the LIBOR and GOFO rates are not cointegrated.

The results of the Phillips-Ouliaris cointegration test suggest that for the 1, 3 and 6 month tenors, we are able to reject the null hypothesis that the LIBOR and GOFO series are not cointegrated. However, we cannot reject the null hypothesis for the 12 month tenor. This suggests that there is a long-run relationship for the 1, 3 and 6 month GOFO and LIBOR series (i.e. they are cointegrated), but we must reject the notion of a long-term relation for the 12 month GOFO and LIBOR series. The lack of a cointegrating relationship between the 12 month series suggests that there may be a degree of mispricing for long term gold futures and forward contracts. It may also suggest that there are periodic occasions during which the co-movement of the LIBOR and GOFO series breaks down. To investigate this, we specify and estimate a multivariate GARCH model for the four individual tenor series.

Using the Engle and Kroner (1995) BEKK model, we use a BEKK(1,1) specification to estimate the dynamic conditional correlation between the GOFO and LIBOR series for all available tenors. The resulting conditional correlation series are plotted in Figure 4.3.



**Figure 4.3: DYNAMIC CONDITIONAL CORRELATIONS BETWEEN THE LIBOR AND GOFO RATES FOR 1, 3, 6 AND 12 MONTH TENORS**

The figure shows the results of the estimates of the dynamic conditional correlation (DCC) between the LIBOR and GOFO rates for tenors of 1, 3, 6 and 12 months. The correlations were estimated using the Engle and Kroner (1995) multivariate BEKK model with a GARCH(1,1) specification. Intermittent periods of strong decoupling of the conditional correlation between the GOFO and LIBOR rate can be observed.

The correlation between the two series is often strong and very close to unity. However, from the figure, sharp opposite movements between the LIBOR and GOFO rates are immediately evident. In total, there are approximately seven prominent breakdowns in the correlation structure. Some of these can be identified with strong movements in the derived lease rate, suggesting that high lease rates arise from strong opposite swings between the LIBOR and GOFO rates. This is fully consistent with the LIBOR/GOFO relationship as specified by Equation (2). Since a high lease rate represents a market condition consistent with high demand for physical gold, the correlation structure suggests that the swings in the dynamic conditional correlation may result from periods of high demand for bullion by gold producers or, in more recent years, exchange traded funds (ETFs). It may also be suggestive of a preference for bullion vs. dollars or vice versa. Because the GOFO rate is set by the market making members of the gold market, these swings are a direct result of the policies of the respective contributing members. Historically, these members have included such banks as J.P. Morgan, Scotia Bank and HSBC, among others.

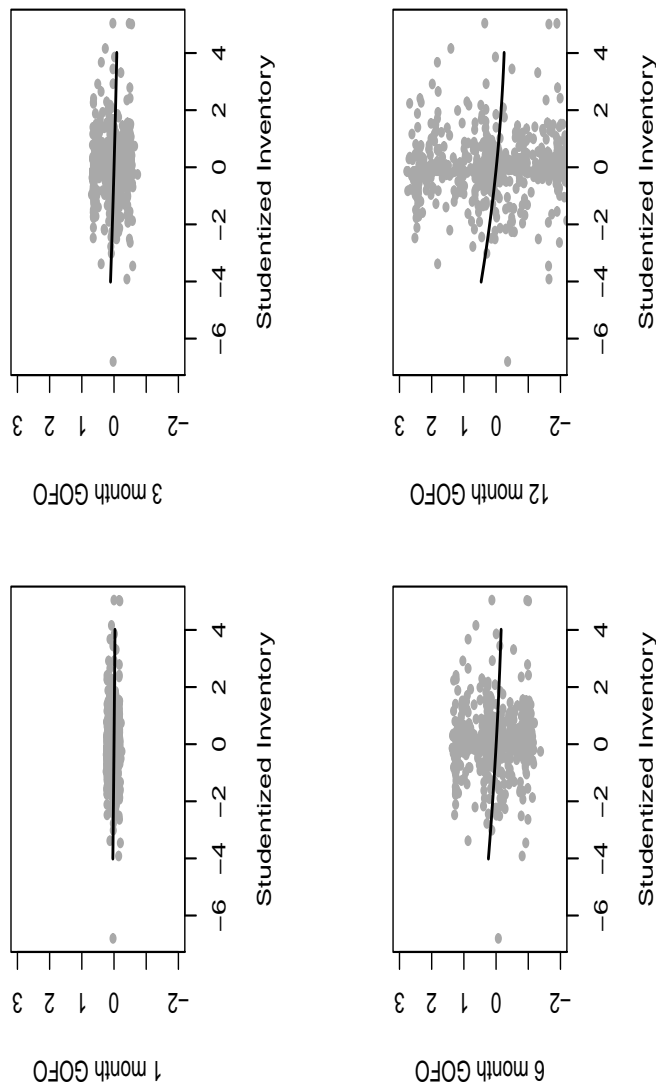
# Chapter 5

## Inventory Effects

### 5.1 Does the GOFO Rate Affect Inventory Levels?

In Figure (5.1) we have plotted the three, six and twelve month GOFO rates versus the level of discretionary gold stocks. To facilitate comparison over the various tenors, we used an ARIMA(0,1,0) model in order to remove linear trends from both the GOFO and interest-adjusted basis series. The scatter plots of Figure (5.1) show a relatively loose distribution of points, with some concentration about the zero discretionary inventory level, suggesting a weak connection between GOFO rate and the level of gold discretionary inventories. Notably, the dispersion of the points increases considerably with increasing maturity, suggesting a larger range between maximum and minimum rates, increasing volatility, and a decreasing statistical relationship with inventory level particularly for the longer tenors.





**Figure 5.1: RELATIONSHIP BETWEEN THE GOLD FORWARD OFFERED (GFO) RATE AND THE DISCRETIONARY INVENTORY LEVEL FOR THE YEARS 1996-2009.**

The first row of the figure shows the relationship between the GFO rate and the level of discretionary inventory for tenors of 1 and 3 months. The second row shows the corresponding relationship between the GFO rate and discretionary inventory level for tenors of 6 and 12 months. The black line is a second-order polynomial fit to the data. We can see that the fitted lines for the various tenors are all concave up, although this is difficult to discern for the 1 month tenor. They are also asymmetric about the zero level of discretionary inventory. While the asymmetry of the fitted curves is visible, with increasing GFO tenor, the asymmetry is much more pronounced. More specifically, the degree of asymmetry increases with increasing tenor. That is, the GFO rate appears to be higher during periods of high and low discretionary inventory levels. A linear trend has been removed from both the inventory and GFO series.

To visualize the relationship between the GOFO rate and the level of discretionary inventory, we fitted a second order polynomial to the data using the regression in Equation (5.1):

$$GOFO(i)_t = \alpha + \beta_1 Inv_t + \beta_2 Inv_t^2 + \varepsilon_t \quad (5.1)$$

where  $GOFO(i)_t$  represents the GOFO rate for the  $i^{th}$  month tenor,  $Inv_t$  is the level of discretionary inventory at time  $t$  and  $Inv_t^2$  is the squared level of discretionary inventory also at time  $t$ . The latter term is present in order to capture any non-linear effects in inventory. The first row of Figure (5.1) shows second order polynomial to the 1 and 3 month GOFO tenors, while the second row shows the corresponding second order fits for the 6 and 12 month tenors. The black line is a second-order polynomial fit to the data as calculated using Equation (5.1). We can see that the fitted lines are all concave up and slightly asymmetric about the zero level of discretionary inventory. Furthermore, they exhibit a more pronounced concavity and asymmetry for increased GOFO tenor. That is, GOFO rates appear typically higher when discretionary inventories are net negative and slightly lower when discretionary inventories are net positive, suggesting the possibility that higher GOFO rates may be associated with lower inventory levels.

We have argued that the GOFO rate is related to the percentage increase in the gold future price, specifically the theoretical gold forward price should rise at the GOFO rate. To assess the effect of the level of inventory on the GOFO rate, and therefore the change in the gold futures price, we follow Dincerler et al. (2005) and use a regression of the form:

$$GOFO(i)_t = \beta_1 Inv_t + \beta_2 Inv_t^2 + \varepsilon_t \quad (5.2)$$

where  $GOFO(i)_t$  represents the  $i^{th}$  month GOFO tenor series, and  $Inv_t$  and  $Inv_t^2$  are the inventory and inventory level squared, respectively. From an econometric perspective, the GOFO rate possesses a high degree of autocorrelation. Indeed, an ADF test on the 3 month GOFO series gives a test statistic of -1.825 compared to the 1% critical value of -3.43, indicating we cannot reject the hypothesis of unit root non-stationarity. This is weakly

<b>GOFO Moving Block Bootstrap Results</b>				
	<b>First</b>	<b>Third</b>	<b>Sixth</b>	<b>Twelfth</b>
<b>Panel A: Coefficient of <math>Inv_t</math></b>				
Original	-0.0082	-0.0243	-0.0493	-0.0891
Bias	-0.0008	-0.0015	-0.0047	-0.0096
Std. Error	0.0073	0.0203	0.0412	0.0767
95% C.I.	(-0.0251, 0.0040)	(-0.0709, 0.0102)	(-0.1378, 0.0171)	(-0.2613, 0.0359)
<b>Panel B: Coefficient of <math>Inv_t^2</math></b>				
Original	0.0002	0.0006	0.0024	0.0064
Bias	0.0002	0.0010	0.0021	0.0051
Std. Error	0.0029	0.0083	0.0169	0.0352
95% C.I.	(-0.0047, 0.0073)	(-0.0122, 0.0216)	(-0.0241, 0.0434)	(-0.0441, 0.0968)

**Table 5.1: RESULTS OF THE MOVING BLOCK BOOTSTRAP OF THE GOFO RATE ON LEVEL OF DISCRETIONARY INVENTORY AND LEVEL OF DISCRETIONARY INVENTORY SQUARED**

Displayed are the nonparametric moving block bootstrap results for the regression model specified as  $GOFO(i)_t = \beta_1 Inv_t + \beta_2 Inv_t^2 + \varepsilon_t$ . Despite the suggestions of the second-order polynomial fits, the results of the bootstrapping suggest that there is no significant relationship between the GOFO rate and either the level of discretionary inventory or the squared discretionary inventory level. The results indicate there are neither level nor non-linear inventory effects on the GOFO rate. Furthermore, these results are consistent across all tenors.

supported by a KPSS test for stationarity that yields a test statistic of 0.441 compared to a critical value of 0.463 at the 5% level<sup>1</sup>. One consequence of unit root non-stationarity is that the standard errors of a least squares regression will be underestimated while the t-statistics will be overestimated. This can lead to erroneous results regarding the statistical significance of the regression coefficients, and thus we employ the moving block bootstrap (MBB) with a block length of  $l = 16$  so that consecutively sampled data blocks will not be correlated.

The bootstrapping results for Equation (5.2) are given in Table (5.1) where we provide the results the observed GOFO tenors.

<sup>1</sup>Similar conclusions are obtained for all maturities.

In analyzing the GOFO rate bootstrapping, we find no statistically significant relationship between the level of inventory or inventory squared and the gold forward offered rate, despite the suggestions of the second order polynomial fits. The coefficients on inventory are small and negative and the confidence intervals suggest that the coefficients may be equivalent to zero. For the level of inventory squared, the coefficients are positive across all maturities, but remain statistically insignificant, showing no indication of non-linear inventory dependence. We conclude that inventory levels do not influence the GOFO rate setting and thus the gold forward rate, is not inventory-level dependent. This is also consistent with an interpretation that links the GOFO rate to a preference for dollars in relation to bullion. We conclude that the level of discretionary inventory does not affect the futures price of gold, which is in keeping with the large levels of above ground gold inventories that greatly exceed annual levels of gold mine production.

## 5.2 Changes in GOFO and Changes in Inventory

Figure (5.1) suggests that discretionary inventory changes with the GOFO rate. However, we cannot establish a direct relationship between the GOFO rate and the level of inventory since the various GOFO tenor time series display evidence of unit root nonstationarity. Table (5.2) shows the numerical results of three different tests for unit roots in the various GOFO rate tenors.

The ADF test column shows the calculated test statistic and the associated 5% critical value for the null hypothesis of a unit root in parentheses. Across all tenors the critical value is less than the value of the test statistic and we are unable to reject the presence of a unit root. To confirm these findings we perform two additional tests, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and the Phillips-Perron (PP) test. The PP test shares the same null hypothesis of the ADF test and shown in brackets are the  $p$ -values of the test. These values suggest that we cannot reject the null hypothesis of nonstationarity. Finally, the KPSS

<b>GOFO tenor</b>	<b>ADF Test</b>	<b>KPSS Test</b>	<b>PP Test</b>
1M GOFO	-1.867 (-2.86)	0.5054 (0.463)	-8.615 (0.6216)
3M GOFO	-1.825 (-2.86)	0.4406 (0.463)	-7.024 (0.7915)
6M GOFO	-1.841 (-2.86)	0.3909 (0.463)	-6.293 (0.899)
12M GOFO	-1.644 (-2.86)	0.3538 (0.463)	-5.627 (0.9162)

**Table 5.2: RESULTS OF UNIT ROOT TESTS ON 1, 3, 6 AND 12 MONTH GOFO TENORS**

The table shows the results of testing the 1, 3, 6 and 12 month tenor GOFO rate time series. We used three separate unit root tests: the Augmented Dickey-Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and the Phillips-Perron (PP) test. The ADF and PP tests examine the null hypothesis that the series being tested has a unit root (against the alternative of stationarity). The KPSS test evaluates the null hypothesis that the series is level or trend stationary. The table provides the value of the test statistic and the associated 5% critical values in the case of the ADF and KPSS tests. The PP test shows the ADF regression coefficient along with the  $p$ -value of the test.

test examines the null hypothesis that the series being tested is level or trend stationary. For the 1 month tenor the test statistic exceeds the 5% critical value given in parentheses while the higher tenors exhibit an increasingly weak rejection of the null hypothesis. Taken together, the results of all three tests indicate that the four GOFO time series are all unit root nonstationary.

To transform the nonstationary GOFO series to stationary series, we take a first differences approach. In differencing the four GOFO tenor series, the resulting series are stationary. Subsequently, we can regress the change in the GOFO rate on the contemporaneous change in the level of discretionary inventory. Because the price of gold rises at the GOFO rate, a regression of this specification effectively allows us to establish a relationship between the driving factor of the gold price and inventory withdrawals. The expectation is that a positive change in the GOFO rate will be accompanied by a negative inventory withdrawal, indicative of a decrease in inventory levels resulting in an increase in the gold

price. However, given the large magnitude of bullion inventories, the relationship may not be statistically significant.

$$\Delta GOF O_t(i) = \alpha + \beta_1 \Delta Inv_t + \beta_2 \Delta Inv_t^2 + \varepsilon_t \quad (5.3)$$

We have included a second-order term of the change in level of discretionary inventory in Equation (5.3) in order to capture any nonlinear effects of inventory on the change in the GOFO rate. Due to residual autocorrelation in the differenced GOFO series, we estimate Equation (5.3) using a maximum likelihood GLS procedure. The process  $\varepsilon_t$  is assumed to be a second-order ARMA( $p, q$ ) process with  $p = 2$ . Under this specification, the resulting regression residuals contain no residual serial correlation.

Table (5.3) contains the maximum likelihood coefficient estimates for the regression model given in Equation (5.3). For all four tenors, we check the residuals for autocorrelation using a portmanteau Box-Ljung test with a null hypothesis of serial independence. The Box-Ljung statistics for the 1, 3, 6 and 12 month residual series are 17.15, 16.18, 16.43, and 7.359 with  $p$ -values of 0.144, 0.183, 0.172, and 0.833, respectively. Consequently, we cannot reject the hypothesis that the residuals are not serially correlated. Therefore, the coefficient estimates suggest that for all tenors, the GOFO series remains unaffected by inventory level and withdrawals.

### **5.3 Inventory, Convenience Yield and the Lease Rate**

When a central bank engages in a gold leasing transaction there is a transfer of title that occurs, the ownership of the bullion being transferred to the leasing institution for the duration of the lease. In this transaction, the central bank earns the difference between the prevailing LIBOR and current GOFO rate; in other words, they earn the derived lease rate on the transaction. As a result, the lease rate is an observable form of the convenience yield, traditionally proxied by the interest-adjusted basis. According to Fama and French (1988)

<b>Coefficient</b>	<b>Estimate</b>	<b>Std. Err.</b>	<b>t-ratio</b>	<b>p-value</b>
<b>1M GOFO Tenor</b>				
$\alpha$	-0.0039	0.0097	-0.41	0.68
$\beta_1$	-0.0066	0.0088	-0.74	0.46
$\beta_2$	0.0017	0.0030	0.56	0.57
<b>3M GOFO Tenor</b>				
$\alpha$	-0.0039	0.0082	-0.47	0.64
$\beta_1$	-0.0065	0.0068	-0.95	0.34
$\beta_2$	0.0013	0.0024	0.53	0.59
<b>6M GOFO Tenor</b>				
$\alpha$	-0.0038	0.0074	-0.51	0.61
$\beta_1$	-0.0085	0.0058	-1.47	0.14
$\beta_2$	0.0020	0.0020	1.00	0.32
<b>12M GOFO Tenor</b>				
$\alpha$	-0.0035	0.0071	-0.49	0.63
$\beta_1$	-0.0073	0.0053	-1.38	0.17
$\beta_2$	0.0016	0.0019	0.87	0.38

**Table 5.3: COEFFICIENT ESTIMATES FOR THE REGRESSION OF CHANGE IN GOFO ON INVENTORY WITHDRAWALS**

The table presents the coefficient estimates of a GLS regression estimated using maximum likelihood for the model  $\Delta GOFO_t(i) = \alpha + \beta_1 \Delta Inv_t + \beta_2 \Delta Inv_t^2 + \varepsilon_t$ . The results in the table show that there is no coefficient on inventory withdrawals that is statistically significant at the <5% level. The coefficient for inventory withdrawals squared is not significant at the 5% across all tenors.

the interest-adjusted basis can be written as:

$$IAB(t) = \frac{F(t, T) - S(t)}{S(t)} - R(t, T) = w(t, T) - c(t, T) \quad (5.4)$$

where  $F(t, T)$  is the futures price,  $S(t)$  is the spot price at time  $t$ ,  $R(t, T)$  is the interest rate over the period from  $t$  to  $T$ , and  $w(t, T)$  and  $c(t, T)$  are the relative warehousing cost and relative convenience yield, respectively.

Since a central bank can earn the lease rate simply by holding physical gold, the lease rate can be thought of as the convenience yield. Therefore, the price of gold must rise at a rate that equals the difference between the LIBOR and lease rates; in other words it must rise at the GOFO rate. Equation (5.4) can therefore be rewritten as:

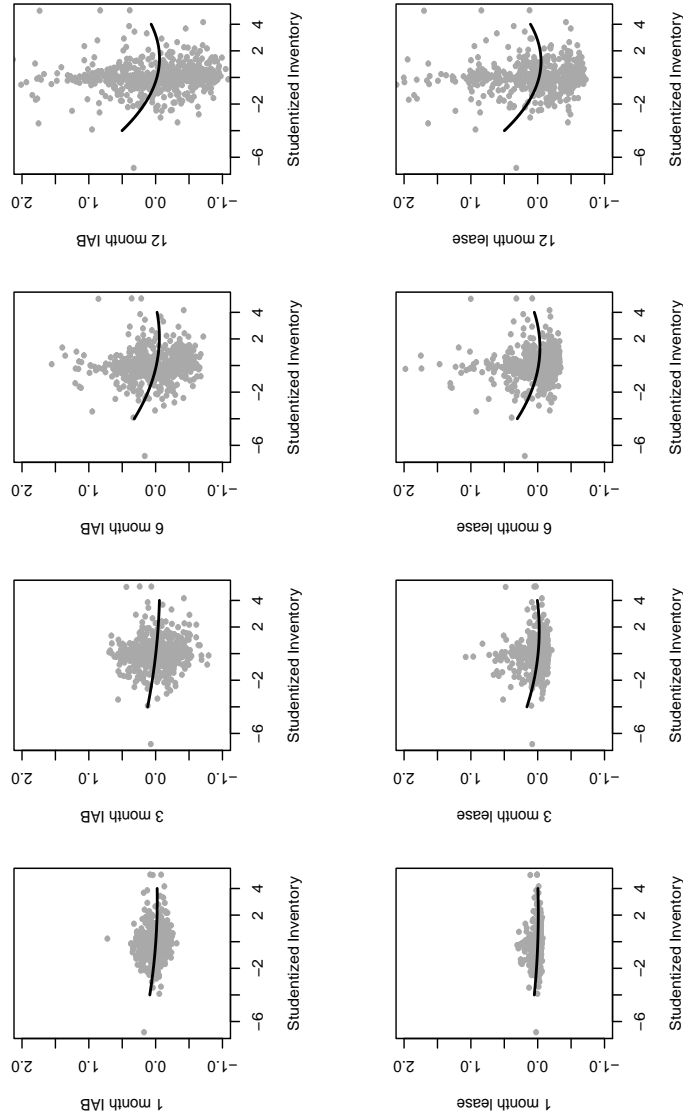
$$IAB(t) = GOFO(t, T) - LIBOR(t, T) = w(t, T) - c(t, T) \quad (5.5)$$

where we have replaced  $R(t, T)$  with  $LIBOR(t, T)$ . In accordance with equation (3.1), equation (5.5) is equivalent to the negative derived lease rate. Rearrangement of equation (5.5) subsequently gives:

$$lease = -IAB(t) = c(t, T) - w(t, T) \quad (5.6)$$

It can be seen from equation (5.6), then, that the lease rate serves as a proxy for the relative convenience yield, particularly in the limit when  $w(t, T)$  approaches zero. We therefore expect to find a relationship between the lease rate and the level of inventory. In order for the lease rate to remain small,  $w(t, T)$  must be of the same magnitude as  $c(t, T)$ . A high lease rate or, equivalently, a high convenience yield under low storage costs, implies high demand for physical gold and thus should have a negative coefficient in a regression of inventory level on the lease rate. Additionally, we should expect that the influence of the lease rate on inventory levels decreases with the increasing maturity of the lease. This is because short-term leasing will have a more immediate effect on inventory levels than long-term leases. Figure (5.2) shows the relationship between the lease rate and the level of discretionary inventory.





**Figure 5.2: RELATIONSHIP BETWEEN THE DERIVED LEASE RATE, THE NEGATIVE INTEREST-ADJUSTED BASIS AND DISCRETIONARY INVENTORY LEVEL FOR THE YEARS 1996 - 2009**

The scatter plots illustrate the relationship between the lease rate and the level of discretionary inventory. For all lease durations we notice that the lease rate tends toward zero with increasing level of inventory. This is consistent with the idea that the lease rate can be considered as an observable form of the convenience yield of gold. Furthermore, data point dispersion increases with increasing lease rate tenor suggesting that short-term leasing will have a more pronounced effect on inventory levels. The black line is a second-order polynomial fit to the data and is consistent with the shape of the convenience yield curve as discussed in Fama and French (1988). We note the similarity between the observable and inferred forms of the convenience yield as represented by the lease rate and interest-adjusted basis, respectively. However, increased dispersion and proliferation of data points less than zero present in the interest-adjusted basis series suggests that inference of the convenience yield directly from weekly price data may result in important inaccuracies.

In a similar manner to the GOFO rate, we observe an asymmetric response of convenience yield to positive and negative levels of discretionary inventory, but with one important difference. When the level of discretionary inventory is positive, the derived lease rate tends towards zero as would be expected of the convenience yield. Conversely, for the GOFO rate we observed a concave upwards fitted curve, suggesting that for positive inventory levels, the GOFO rate does not decline towards zero, but rather increases with increasing levels of inventory after exhibiting a local minimum when the level of discretionary inventory is close to zero.

To examine this relationship between the lease rate and the discretionary inventory, we use the linear regression model specified in Equation (5.7):

$$Inv_t = \beta_1 Lease(i)_{t-1} + \beta_2 Inv_{t-1} + \varepsilon_t \quad (5.7)$$

where  $Lease(i)_{t-1}$  is the prevailing  $i^{th}$  month lease rate in the previous time period, and  $Inv_{t-1}$  is the level of discretionary inventory at time  $t - 1$ . The lagged inventory term is present in order to capture any residual autocorrelation. The results of the regression are given in Table (5.4).

We can see that across all lease maturities, the coefficient,  $\beta_1$ , is negative. However, it is only highly significant for lease rates of one, three and six month maturities. For the twelve month rate, the coefficient is only weakly significant at the 10% level and is less than half the value of the 6 month coefficient. The magnitude and statistical significance of the coefficient diminishes with increasing maturity being -0.11 for the 1 month rate and -0.05 for the 12 month lease duration. This reflects the diminishing impact of leasing activity on inventory levels as lease late tenor increases. The influence of discretionary inventory from the previous period is consistent across all maturities and the value of the coefficient remains close to 0.1, but is statistically insignificant. The negative lease rate coefficient and decreasing influence with maturity suggests that short term leasing activities act to reduce gold inventory levels. This occurs most likely because at time  $t$ , the bullion leased

Variable	Coefficient	Std. Error	t-value	p-value
<b>1 Month Lease Rate</b>				
$\beta_1$	-0.1068	0.0379	-2.82	0.005 **
$\beta_2$	0.0916	0.0736	1.24	0.214
<b>3 Month Lease Rate</b>				
$\beta_1$	-0.0887	0.0353	-2.51	0.012 *
$\beta_2$	0.0942	0.0745	1.26	0.207
<b>6 Month Lease Rate</b>				
$\beta_1$	-0.0682	0.0322	-2.12	0.034 *
$\beta_2$	0.0977	0.0750	1.30	0.193
<b>12 Month Tenor</b>				
$\beta_1$	-0.0511	0.0284	-1.80	0.072 .
$\beta_2$	0.1001	0.0747	1.34	0.181

**Table 5.4: RESULTS OF THE REGRESSION OF INVENTORY LEVEL ON PAST 3 MONTH LEASE RATE AND LAGGED INVENTORY LEVEL OVER THE PERIOD 1996-2009**

Shown are the results of the regression  $Inv_t = \beta_1 Lease_{t-1} + \beta_2 Inv_{t-1} + \varepsilon_t$ , which is specified in order to investigate the effect of lagged lease rates on the level of discretionary gold inventory. The lag-1 level of inventory was included to capture any remaining autocorrelation. Across all maturities, the coefficient of lagged inventory remains positive, consistent but statistically insignificant suggesting there is no carry-over inventory effect. Notably, the effect of the lagged lease rate diminishes with increasing lease rate duration. This suggests that short-term leasing has a more pronounced effect on current inventory levels. The negative coefficient implies that short-term lease repayments, in the form of physical bullion, act to reduce the current inventory level.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1

in previous time periods must be returned either to the central bank or the institution that leased the gold, the additional interest being charged in the form of bullion as opposed to dollars. Consequently, high lease rates in period  $t - 1$  lead to repayments at time  $t$ , which, in turn, leads to a reduction in market inventories at time  $t$ . One plausible explanation for the declining influence with lease maturity is that, for the borrower, short-term lease rates tend to be lower than long-term rates and are therefore less expensive, resulting in increased short-term leasing activity. Other factors that may be of concern when considering lease rate durations are fluctuations in exchange rates and increases in the spot price of gold, which can result in the lease transaction being more expensive to the borrower.

Besides bullion leasing, there is another possible factor that can affect gold inventory levels. An increase in the number of open futures contracts may cause exchange inventory levels to increase since a gold futures contract is an expectation of future delivery of physical gold. Therefore, as a robustness check, we test the hypothesis that speculative pressure results in increased inventory levels and, to that effect, specify a linear regression of the form shown in Equation (5.8):

$$Inv_t = \alpha + \beta_1 Lease(i)_{t-1} + \beta_2 Inv_{t-1} + \beta_3 \text{ }_{t-1} + \varepsilon_t \quad (5.8)$$

Here  $Inv_t$  is the inventory level in millions of troy ounces at time  $t$ ,  $Lease(i)_{t-1}$  is the  $i^{th}$  month tenor derived lease rate at time  $t - 1$ , and  $\text{ }_{t-1}$  is the speculative pressure at time  $t - 1$  which we include in order to capture any dependence of the inventory on increasing long trader positions. Once again, lagged inventory is included in the regression in order to capture the significant lag-1 component of the inventory partial autocorrelation function. The results of regression (5.8) are shown in Table (5.5).

The results in Table (5.5) show that, by including speculative pressure as an additional variable, the effect of the lease rate on discretionary inventory level decreases substantially. The results for the 1 month contract show that the influence of the lease rate has diminished

Variable	Coefficient	Std. Error	t-value	p-value
<b>1 Month Lease Rate</b>				
$\beta_1$	-0.0650	0.0379	-1.71	0.08683 .
$\beta_2$	0.0680	0.0742	0.92	0.35997
$\beta_3$	0.4139	0.1088	3.81	0.00015 ***
<b>3 Month Lease Rate</b>				
$\beta_1$	-0.0559	0.0354	-1.58	0.11
$\beta_2$	0.0683	0.0748	0.91	0.36
$\beta_3$	0.4283	0.1095	3.91	<0.0001 ***
<b>6 Month Lease Rate</b>				
$\beta_1$	-0.0426	0.0326	-1.31	0.19
$\beta_2$	0.0696	0.0750	0.93	0.35
$\beta_3$	0.4416	0.1089	4.05	<0.0001 ***
<b>12 Month Tenor</b>				
$\beta_1$	-0.0316	0.0285	-1.11	0.27
$\beta_2$	0.0705	0.0746	0.95	0.34
$\beta_3$	0.4498	0.1071	4.20	<0.0001 ***

**Table 5.5: RESULTS OF THE LEASE REGRESSION INCLUDING SPECULATIVE PRESSURE OVER THE PERIOD 1996-2009**

The table shows the coefficient estimates and associated regression statistics for the regression model:  $Inv_t = \alpha + \beta_1 Lease(i)_{t-1} + \beta_2 Inv_{t-1} + \beta_3 Inv_{t-2} + \varepsilon_t$ . By controlling for speculative pressure, we note that the effect of the lease rate on discretionary inventory level is now very weak and significant at just under the 10% level of significance for the 1 month rate tenor. This suggests that speculative pressure increases inventory levels counteracting the negative effect of lease repayments.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1

in significance, the regression coefficient is now significant at the 10% level and has decreased in magnitude from a value of -0.11 to -0.07. In the case of the 1 month contract, the relation between the lease rate and the inventory level is now considerably weaker, significance being just outside the 5% level of confidence. For the 3, 6 and 12 month contracts, we conclude that there is no statistically significant relationship between the lease rate and the level of inventory.

Interestingly, although the lease rate relationship has weakened, there is now a positive and statistically significant relationship between the lagged speculative pressure and the discretionary inventory level. Furthermore, this relationship gradually increases with lease duration. The speculative pressure coefficient for the 1 month contract is 0.414 while that for the 12 month contract is 0.449. The lease rate and the speculative pressure appear to work in opposition to one another; the former acts to decrease short-term bullion inventories via lease repayments, while the latter result suggests speculators dominate leasing activity in the long-term. Finally, we note the continued presence of the carry-over effect such that the value of inventory at time  $t - 1$  is positively related to inventory at time  $t$ . The results for the speculative pressure coefficient suggest that, due to increased speculative activity in long futures contracts, COMEX inventories have increased in order to cover the open contract positions. We conclude that inventory levels are affected only by short-term leasing activity and therefore gold convenience yields do not affect inventory equally across maturities.

## **5.4 The Effect of Lease Rates on Inventory Withdrawals**

It is worthwhile to investigate whether changes in the lease rate, or convenience yield, influence the level of bullion inventory and whether or not this changes with lease duration. While the gold lease rate is available primarily to agents and institutions participating in the over-the-counter (OTC) market, it should remain a viable proxy for overall gold market

liquidity demand. Consequently, when the lease rate is high it signals a period of high demand for bullion by the market. Under this assumption, we might expect to see increased inventory withdrawals along with increases in the derived lease rate.

Following Dincerler et al. (2005), we define withdrawals as the first-differenced series of discretionary inventory. Although the lease rate may not strongly influence the level of discretionary inventory, it is possible that a change in the lease rate could affect inventory withdrawals. Accordingly, we regress inventory withdrawals on the change in the lease rate using the regression specified in Equation (5.9).

$$\Delta Inv_t = \beta_1 \Delta Lease(i)_t + \beta_2 \Delta Inv_{t-1} + \varepsilon_t \quad (5.9)$$

Table (5.6) shows the positive influence of changes in the lease rate on inventory withdrawals.

The coefficient,  $\beta_1$ , is positive for all contract maturities. However, it remains statistically insignificant for all maturity contracts. This positive dependence may result from increased lease rates increasing supply to the market with a subsequent reduction in demand for physical bullion. Dependence on previous inventory levels is consistently negative and highly significant and has the rather intuitive interpretation that withdrawals in period  $t - 1$  serve to reduce inventory levels at time  $t$ . The statistical significance of the results shows that there is a regular turnover of gold inventories in the futures market, but suggests that the quantity of leased gold remains independent of the level of the lease rate.

Variable	Coefficient	Std. Error	<i>t</i> -value	<i>p</i> -value
<b>1 Month Lease Rate</b>				
$\beta_1$	0.1068	0.1063	1.0	0.32
$\beta_2$	-0.4988	0.0504	-9.9	<0.0001 ***
<b>3 Month Lease Rate</b>				
$\beta_1$	0.1198	0.1424	0.84	0.4
$\beta_2$	-0.4982	0.0506	-9.85	<0.0001 ***
<b>6 Month Lease Rate</b>				
$\beta_1$	0.2265	0.1914	1.18	0.24
$\beta_2$	-0.4978	0.0507	-9.82	<0.0001 ***
<b>12 Month Tenor</b>				
$\beta_1$	0.1901	0.2421	0.79	0.43
$\beta_2$	-0.4977	0.0509	-9.79	<0.0001 ***

**Table 5.6: RESULTS OF THE REGRESSION OF WITHDRAWALS ON CHANGES IN THE LEASE RATE OVER THE PERIOD 1996-2009**

The table shows the regression output for the model:  $\Delta Inv_t = \beta_1 \Delta Lease(i)_t + \beta_2 \Delta Inv_{t-1} + \varepsilon_t$ . This examines the effect of the lease rate on inventory withdrawals, while controlling for past inventory withdrawals. The estimation results for the coefficient of lagged inventory withdrawals suggest that there is a consistent level of withdrawals that acts to diminish withdrawals at time  $t$ . The coefficient  $\beta_2$  remains nearly constant in value, negative and statistically significant across all lease rates. In addition, we observe that the lease rate is a statistically insignificant factor in explaining gold stock withdrawals.

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## Chapter 6

# The Effect of Speculative Pressure on Returns

In recent years, commodities have become popular as an investment in and of themselves and are now present in the portfolios of investors as an asset class that provides not only diversification but profitable returns. To that effect, it is apropos to study the factors affecting commodity futures returns. We do so using a similar regression model similar to that of de Roon et al. (2000):

$$r_{i,t} = \alpha + \beta_1 r_{i,t-1} + \beta_2 r_t^{SNP500} + \beta_3 \text{ }_t + \varepsilon_t \quad (6.1)$$

Equation (6.1) regresses the return of the  $i^{th}$  returns series for the 1, 3, 6 and 12 month futures contracts on past returns,  $r_{i,t-1}$ , the return on the S&P 500 market portfolio,  $r_t^{SNP500}$ , and the speculative pressure,  $\text{ }_t$ . Least-squares coefficient estimates and their associated standard errors are reported in Table (6.1).

For all returns series, the constant coefficient is small, positive and not statistically significant. A similar result holds for the coefficient of lagged returns, confirming the well-known result that past returns are not reliable predictors of current futures returns. The

Variable	Coefficient	Std. Error	t-value	p-value
<b>1 Month Returns</b>				
$\alpha$	0.000426	0.000829	0.51	0.60767
$\beta_1$	0.004186	0.050199	0.08	0.93356
$\beta_2$	0.032827	0.038148	0.86	0.38980
$\beta_3$	0.008385	0.002148	3.90	0.00010 ***
<b>3 Month Returns</b>				
$\alpha$	0.000405	0.000827	0.49	0.62
$\beta_1$	0.010812	0.049374	0.22	0.83
$\beta_2$	0.036614	0.037727	0.97	0.33
$\beta_3$	0.008421	0.002144	3.93	$9.4 \times 10^{-5}$ ***
<b>6 Month Returns</b>				
$\alpha$	0.000393	0.000825	0.48	0.63
$\beta_1$	0.010615	0.049777	0.21	0.83
$\beta_2$	0.038689	0.037616	1.03	0.30
$\beta_3$	0.008467	0.002148	3.94	$9 \times 10^{-5}$ ***
<b>12 Month Returns</b>				
$\alpha$	0.000365	0.000815	0.45	0.65
$\beta_1$	0.008258	0.050412	0.16	0.87
$\beta_2$	0.045925	0.037524	1.22	0.22
$\beta_3$	0.008573	0.002136	4.01	$6.6 \times 10^{-5}$ ***

**Table 6.1: RESULTS FOR THE REGRESSION OF RETURNS ON SPECULATIVE PRESSURE FOR THE YEARS 1996 - 2009**

The table contains the estimation statistics of the regression model:  $r_{i,t} = \alpha + \beta_1 r_{i,t-1} + \beta_2 r_t^{SNP500} + \beta_3 p_t + \varepsilon_t$ . The results demonstrate that current returns are not related to past returns. Additionally, we note that gold futures returns are positively, but insignificantly related to returns on the S&P 500 index. Additionally, we note that the level of speculative pressure is positively and significantly related to futures returns, suggesting that increased speculation leads to slightly higher returns, although the coefficient,  $\beta_3$  is rather small in magnitude, being on the order of 0.008.

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returns to the gold futures contract are positively related to the returns on the market portfolio, but the result is not statistically significant. We note in particular that speculative pressure exerts a positive influence on returns. For all months, the speculative pressure coefficient is positive and highly significant having a consistent value of approximately 0.008. As a robustness check, we include the “price pressure” term as discussed in de Roon et al. (2000). This takes the form of a change in speculative pressure,  $\Delta_t$ , and captures any bias in the futures contract price resulting from increased demand for contracts. Specifically, an increase in demand for futures contracts will result in a temporary upward futures price bias. This is the price pressure hypothesis. In order to compare the regression coefficients on speculative pressure and price pressure, we divide each term by its respective standard deviation. This leads to the regression model of Equation (6.2):

$$r_{i,t} = \alpha + \beta_1 r_{i,t-1} + \beta_2 r_t^{SNP500} + \beta_3 \frac{t}{\sigma(t)} + \beta_4 \frac{\Delta_t}{\sigma(\Delta_t)} + \varepsilon_t \quad (6.2)$$

The associated coefficient estimates are shown in Table (6.2).

We confirm that neither the constant term nor past returns influence current returns, which is consistent with our previous findings. However, the inclusion of the price pressure term leads to a decrease in the speculative pressure coefficient estimates, nonetheless, the speculative pressure coefficient,  $\beta_3$  remains statistically significant for all maturity returns series and increases with maturity. There seems to be, therefore, a more pronounced speculative effect for the longer maturity futures returns series, which is consistent with the idea that speculators make bets on the long-term price of gold. Despite this, price pressure effects dominate speculative pressure effects, the former being highly significant while the latter exhibits exceedingly small  $p$ -values. Thus, for long-term returns series, there is a conclusive speculative effect such that speculative pressure, in part, determines futures returns even after controlling for both price pressure and past returns. Additionally, we note that the price pressure coefficient,  $\beta_4$ , is positive and highly significant across all returns series suggesting that demand for futures contracts, in part, determines futures risk-premia.

Variable	Coefficient	Std. Error	t-value	p-value
<b>1 Month Returns</b>				
$\alpha$	0.000771	0.000774	1.00	0.320
$\beta_1$	-0.048322	0.051790	-0.93	0.351
$\beta_2$	0.032327	0.034208	0.95	0.345
$\beta_3$	0.002219	0.000804	2.76	0.006 **
$\beta_4$	0.009725	0.000870	11.17	$<2 \times 10^{-16}$ ***
<b>3 Month Returns</b>				
$\alpha$	0.000750	0.000774	0.97	0.3331
$\beta_1$	-0.043383	0.051143	-0.85	0.3966
$\beta_2$	0.036005	0.033796	1.07	0.2871
$\beta_3$	0.002239	0.000804	2.78	0.0055 **
$\beta_4$	0.009756	0.000874	11.16	$<2 \times 10^{-16}$ ***
<b>6 Month Returns</b>				
$\alpha$	0.000736	0.000773	0.95	0.3412
$\beta_1$	-0.043567	0.051610	-0.84	0.3989
$\beta_2$	0.038082	0.033649	1.13	0.2581
$\beta_3$	0.002261	0.000805	2.81	0.0051 **
$\beta_4$	0.009715	0.000870	11.17	$<2 \times 10^{-16}$ ***
<b>12 Month Returns</b>				
$\alpha$	0.000702	0.000764	0.92	0.358
$\beta_1$	-0.045052	0.052161	-0.86	0.388
$\beta_2$	0.045321	0.033345	1.36	0.175
$\beta_3$	0.002317	0.000802	2.89	0.004 **
$\beta_4$	0.009556	0.000857	11.15	$<2 \times 10^{-16}$ ***

Table 6.2: **ROBUSTNESS CHECK FOR THE REGRESSION OF RETURNS ON SPECULATIVE PRESSURE AND PRICE PRESSURE FOR THE YEARS 1996 - 2009**

The table shows the results of a robust specification of the returns regression model given by the following equation:  $r_{i,t} = \alpha + \beta_1 r_{i,t-1} + \beta_2 r_t^{SNP500} + \beta_3 \frac{\Delta}{\sigma(\Delta)} \frac{t}{t} + \beta_4 \frac{\Delta}{\sigma(\Delta)} \frac{t}{t} + \varepsilon_t$ . In this regression, we include both a speculative pressure term and a price pressure term, specified as the change in speculative pressure from time  $t - 1$  to time  $t$ . We divide both series by their respective standard deviation in order to compare them effectively. Results show that, after controlling for price pressure, the effect of speculative pressure on returns is mitigated. While still significant at the 1% level, the value of the speculative pressure coefficient,  $\beta_3$ , is considerably reduced. However, we note that the speculative pressure effect does remain statistically significant at the  $<5\%$  level across all returns series and increases with the maturity horizon. This is consistent with our previous findings that speculators may be induced to speculate long term as their increased risk-aversion for long-term bets resulting in higher futures contract risk-premiums.

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1

## Chapter 7

# Price Differences Between Forward and Futures Contracts

### 7.1 Mispricing and Speculative Pressure

Prior work on the difference between forward and futures contract prices was carried out by Park and Chen (1985) and French (1983). In their empirical analysis they found that futures contract prices were significantly different from forward contract prices and that, on average, futures prices exceeded forward prices. If we consider the pricing of futures contracts on gold, which is considered an investment asset, then for a forward contract of time to delivery,  $T$ , we have:

$$F_0 = S_0 e^{(r+u-y)T} \quad (7.1)$$

where  $r$  is the risk-free rate,  $u$  is the storage cost that is proportional to the spot price and  $y$  is the convenience yield. To express Equation (7.1) in terms relevant to the gold market, we recall that a central bank has two main options to enhance the yield on their gold bullion inventories. They can either lease the gold directly, in which case they earn the lease rate, or they can engage in a gold swap with a suitable counter party. In the former case, the central

bank earns the lease rate as a pure result of holding physical gold. Since this quantity is earned by holding physical inventory rather than a paper contract, the lease rate can be interpreted as the convenience yield of gold. The counter party to the leasing agreement may be charged the lease rate on the bullion loan, but they can immediately sell the gold on the spot market and invest the proceeds in a secure investment at, for example the LIBOR rate. Thus, the borrower is able to earn the difference between the LIBOR and lease rates, which is equivalent to GOFO.

The second strategy, a swap, allows the central bank to exchange gold for dollars. The swap is therefore a loan of dollars, secured using gold as collateral. Under the swap agreement, the central bank can invest the dollars at LIBOR while agreeing to pay the GOFO rate to the holder of the bullion. At the end of the leasing transaction, the gold is repurchased by the central bank. The central bank has earned the lease rate on the gold exchange and the bullion holder has earned the GOFO rate on his loaned dollars. As we should expect, the respective yields from the swap are equivalent to the yields earned in the normal leasing transaction.

Given the preceding analysis and under the assumption that storage costs are equal to zero, the price of a gold futures contract in terms of market variables can be expressed as:

$$f_0 e^{(lease)T} = S_0 e^{(LIBOR)T} \quad (7.2)$$

$$f_0 = S_0 e^{(GOFO)T} \quad (7.3)$$

From (7.3) we can see that the theoretical price of a gold futures contract rises at the gold forward rate. Consequently, the observed GOFO rates serve as a measure of the degree of contango in the gold price.

To compare the relationship between the futures price calculated using equation (7.3) and the observed market futures prices, we define the log mispricing level between the observed futures price and the theoretical forward price as:

$$M = \log(futures) - \log(forward) \quad (7.4)$$

We express the mispricing in terms of natural logarithms in order to reduce heteroskedasticity in the series for  $M$ . This metric provides us with a measure of the difference between gold forward and gold futures prices under both stochastic interest rates and stochastic convenience yields. Table (7.1) shows summary statistics for the 1, 3, 6 and 12 month forward/futures mispricing series.

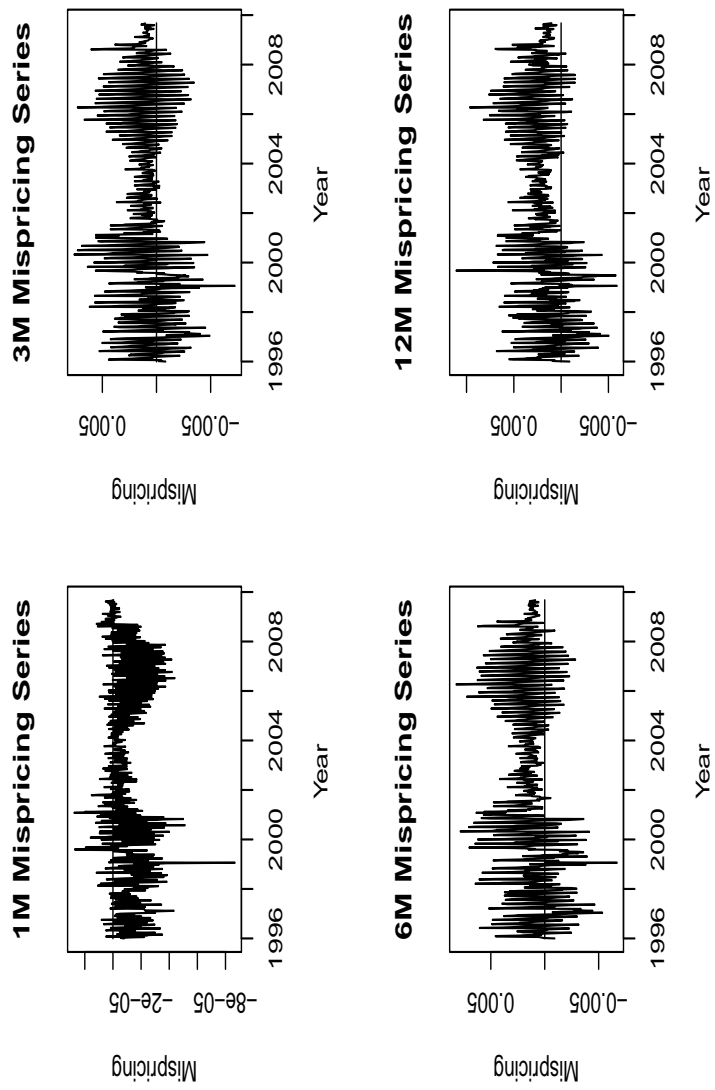
The mean values of the mispricing series increase with increasing maturity from a low mean value of -0.0009 for the one month period to a high mean value of 0.19 for the 12 month calculation. In addition, the standard deviation increases with maturity in the same manner.

<b>Variable</b>	<b>Statistic</b>
<b>1 Month Tenor</b>	
Mean	-0.0009
Std. Dev.	0.0012
Min	-0.0087
Median	-0.0007
Max	0.0028
<b>3 Month Tenor</b>	
Mean	0.0941
Std. Dev.	0.2129
Min	-0.7248
Median	0.0819
Max	0.7614
<b>6 Month Tenor</b>	
Mean	0.1294
Std. Dev.	0.2148
Min	-0.6706
Median	0.1228
Max	0.8221
<b>12 Month Tenor</b>	
Mean	0.1932
Std. Dev.	0.2268
Min	-0.5912
Median	0.1917
Max	1.1103

**Table 7.1: SUMMARY STATISTICS FOR THE 1, 3, 6 AND 12 MONTH MISPRICING SERIES FOR THE YEARS 1996 - 2009**

The table shows summary statistics for the mispricing series of the log-difference of observed futures prices and theoretical forward contract prices. Separate statistics are given for 1, 3, 6 and 12 month contract maturities. Although the 1 month contract exhibits a small degree of under-pricing of futures relative to forwards, we observe an increasingly positive mean in the 3, 6 and 12 month series, suggesting that, for these contracts, futures are over-priced, on average, relative to forwards.



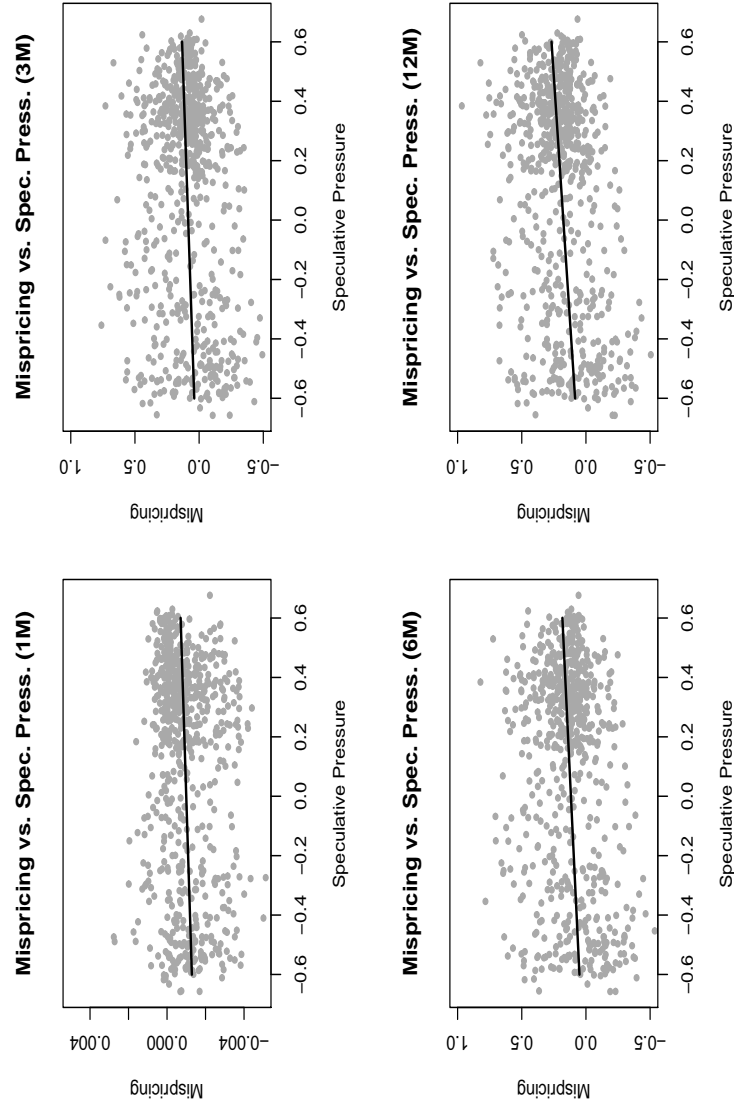


**Figure 7.1: PLOTS OF RELATIVE FUTURES CONTRACT MISPRICING BY YEAR FOR VARIOUS FUTURES CONTRACT MATURITIES**

The figure shows the degree of relative mispricing between gold forward and gold futures contracts for maturities of 1, 3, 6 and 12 months. As contract maturity increases, we note an increasing amount of under-pricing of forward contracts relative to future contracts. Furthermore, the degree of under-pricing seems to be increasing in more recent years. This may be indicative of risk-averse speculators demanding higher risk premiums for contracts of longer maturity.

Figure (7.1) depicts a plot of the four mispricing time series. We see that for the 1 month contract, the mispricing is preferentially negative, indicating that calculated forward prices exceed observed futures prices. However, with increasing maturity, the degree of mispricing is such that observed futures prices exceed forward prices as calculated using equation (7.3). For the 12 month contract, we see from the figure that the degree of mispricing is preferentially positive. This indicates a situation in which the futures price is higher than the forward price and is in agreement with the previous findings of Park and Chen (1985) and French (1983).

It is known that increased speculation can affect pricing imperfections. We therefore expect a relationship between the gold market speculative pressure and the degree of relative mispricing. Figure (7.2) shows the percentage relative mispricing between the forward and futures contract versus the level of speculative pressure for the entire sample period.



**Figure 7.2: PLOTS OF RELATIVE FUTURES CONTRACT MISPRICING VS. THE LEVEL OF SPECULATIVE PRESSURE FOR VARIOUS FUTURES CONTRACT MATURITIES**

The figure shows the mispricing between gold forward and futures contracts against the level of market speculative pressure. The black line is a least squares regression fit to the sample data. The slope becomes increasingly positive with increasing time to maturity of the contracts. If risk-averse speculators require higher risk-premiums to act as counter-parties to long-term futures contracts. This behaviour would manifest itself in future prices that increasingly exceed forward prices leading to positive price differences and, subsequently, an upward sloping regression line.

In the plots, we have fitted a regression line to the data. As rate tenor increases, the slope of the fitted regression lines becomes more negative suggesting that, as tenor increases, the degree of relative mispricing becomes increasingly negative. Equivalently, this implies that futures prices increasingly exceed forward prices as speculative pressure increases. If speculators operate in the long-term market, this suggests that there may be an increased risk premium attached to longer maturity futures contracts over the respective forward contract. This may be indicative of a preference by speculators for a higher risk-premium when speculating on the long-term price of gold. This could be attributed to increasing risk-aversion among speculators when they bet on prices in the distant future.

To examine possible links between futures-forward mispricing and speculative activity, we employ a vector autoregression (VAR) model<sup>1</sup> to model the dynamic relationship between the speculative pressure and the various mispricing series. This approach also allows us to obtain impulse response functions for the model. The generalized reduced form specification of a VAR( $p$ ) model is given by equation (7.5).

$$\mathbf{r}_t = \phi_0 + \Phi \mathbf{r}_{t-1} + \dots + \Phi_p \mathbf{r}_{t-p} + \varepsilon_t \quad (7.5)$$

where  $\phi_0$  is a  $k \times 1$  vector,  $\Phi$  is a  $k \times k$  matrix, and  $\varepsilon_t$  is a serially uncorrelated random process with zero mean and positive definite variance-covariance matrix  $\Sigma$  and  $p > 0$ . It is common in the literature to assume that  $\varepsilon_t$  is distributed as a multivariate normal. To build our model, we determine the optimal lag length,  $p$  using minimization of the Bayesian information criteria (BIC). The model is evaluated for multiple lag lengths and the length that corresponds to the smallest value of the information criteria is used as the lag length  $p$  for the VAR( $p$ ) model.

Using weekly data, for the 1, 3, 6 and 12 month contracts along with the speculative pressure, we test consecutively downwards from a maximum of  $p = 6$  lags, calculating

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<sup>1</sup>Cointegration tests were carried out between speculative pressure and the four mispricing series to determine if a VECM type model for cointegrated series was necessary. Using the Engle and Granger test, for all series the hypothesis of cointegration was rejected for the 1, 3, 6 and 12 month mispricing series and the speculative pressure. We do not provide the results of the tests here.

the associated information criteria, to find the optimal lag length. For comparison, and to eliminate dependence on a single criteria, we employ three separate measures, the Akaike (AIC), the Schwarz (BIC) and the Hannin-Quinn (HQ) information criteria. If the individual criteria select different lag lengths, we first choose any lag length that is selected by two information criteria. If all three criteria differ, we defer to the BIC selection. Using this procedure, the information criteria select a lag of 3 for the 1 month series, and a lag of 2 for the 3, 6 and 12 month series. With a lag length of  $p = 2$ , equation (7.5) the VAR(2) model can be written in the more explicit bivariate form of equation (7.6):

$$\begin{aligned} \begin{bmatrix} r_{1t} \\ r_{2t} \end{bmatrix} &= \begin{bmatrix} \phi_{10} \\ \phi_{20} \end{bmatrix} + \begin{bmatrix} \Phi_{11}^1 & \Phi_{12}^1 \\ \Phi_{21}^1 & \Phi_{22}^1 \end{bmatrix} \begin{bmatrix} r_{1,t-1} \\ r_{2,t-1} \end{bmatrix} \\ &+ \begin{bmatrix} \Phi_{11}^2 & \Phi_{12}^2 \\ \Phi_{21}^2 & \Phi_{22}^2 \end{bmatrix} \begin{bmatrix} r_{1,t-2} \\ r_{2,t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \end{aligned} \quad (7.6)$$

In terms of the speculative pressure,  $t$  and the mispricing,  $M_t$ , equation (7.6) can be written as equation (7.7):

$$\begin{aligned} \begin{bmatrix} t \\ M_t \end{bmatrix} &= \begin{bmatrix} \phi_{10} \\ \phi_{20} \end{bmatrix} + \begin{bmatrix} \Phi_{11}^1 & \Phi_{12}^1 \\ \Phi_{21}^1 & \Phi_{22}^1 \end{bmatrix} \begin{bmatrix} t_{-1} \\ M_{t-1} \end{bmatrix} \\ &+ \begin{bmatrix} \Phi_{11}^2 & \Phi_{12}^2 \\ \Phi_{21}^2 & \Phi_{22}^2 \end{bmatrix} \begin{bmatrix} t_{-2} \\ M_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \end{aligned} \quad (7.7)$$

The OLS estimated VAR coefficients are shown in table (7.2).

Looking at the  $\Phi$  matrices shown in the table, we see that for all maturities, the speculative pressure dynamics are driven by both lagged values of speculative pressure and the level of mispricing. Conversely, the effect of lagged speculative pressure on the level of mispricing is statistically significant only for the 3, 6 and 12 month series, suggesting there exists a linear dependence between the degree of mispricing and the speculative pressure solely for maturities exceeding 1 month duration. Even though this dependence is exhibited only for the long-term maturities, it is consistent with our finding that the relationship

<b>Panel A: VAR Model Estimation</b>						
Tenor	Parameter	$\phi_0$	$\Phi_1$		$\Phi_2$	
1 Month	Coefficient	0.0056	1.1557	6.4058	-0.1896	-4.3062
		-0.0008	0.0005	0.2930	-0.0002	-0.0737
	Std. Err.	0.0047	0.0364	2.6700	0.0364	2.6784
0.0001		0.0005	0.0376	0.0005	0.0377	
3 Month	Coefficient	0.0050	1.1552	0.0298	-0.1868	-0.0474
		0.0556	0.1829	0.5022	-0.1355	-0.1474
	Std. Err.	0.0037	0.0363	0.0169	0.0363	0.0169
0.0081		0.0799	0.0372	0.0800	0.0372	
6 Month	Coefficient	0.0051	1.1559	0.0348	-0.1875	-0.0488
		0.0711	0.1982	0.5149	-0.1331	-0.1181
	Std. Err.	0.0039	0.0362	0.0171	0.0363	0.0171
0.0085		0.0792	0.0373	0.0793	0.0373	
12 Month	Coefficient	0.0043	1.1584	0.0369	-0.1909	-0.0411
		0.1028	0.2404	0.5008	-0.1489	-0.0840
	Std. Err.	0.0045	0.0363	0.0165	0.0364	0.0164
0.0102		0.0825	0.0375	0.0828	0.0373	

**Table 7.2: VAR(2) MODEL ESTIMATION RESULTS**

The table shows the OLS estimated coefficients along with their standard errors for the VAR(2) model defined in equation (7.5).

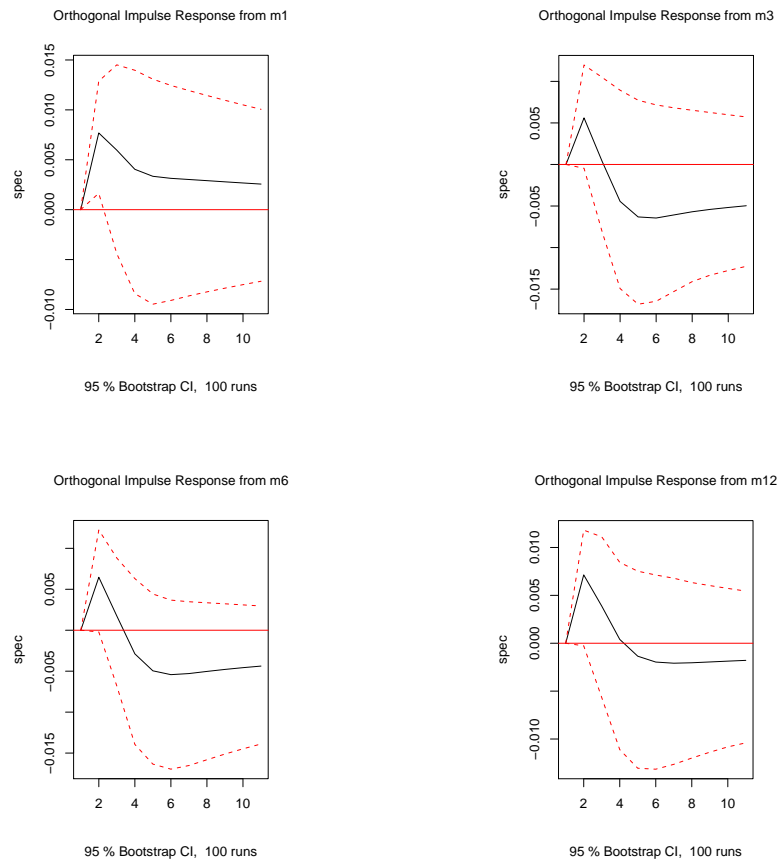
between futures contract returns and the speculative pressure is significant across all maturities: 1, 3, 6 and 12 months. For all maturities, both the lagged mispricing and lagged speculative pressure are significant determinants of the speculative pressure at time  $t$ .

To check the models, we test the residuals for serial correlation using the multivariate Ljung-Box statistic,  $Q_k(m)$ , where  $k$  is the dimension of  $\mathbf{r}_t$  and  $m$  is the number of lags used for the test. This statistic is distributed asymptotically as  $\chi^2$  with  $mk^2 - g$  degrees of freedom,  $g$  being the number of parameters estimated in the VAR model coefficient matrices. For the 1 month series, the multivariate Ljung-Box statistic is 171.9 using 4 lags, with a  $p$ -value of less than 0.0001, suggesting that there is residual serial dependence in the bivariate return series. For the 3 month series, we have a value of 19.85 for the Ljung-Box test with an associated  $p$ -value of 0.3. Somewhat different results are obtained for the 6 month contract with a test statistic of 13.56 and  $p$ -value of 0.13. Finally, for the 12 month model,  $Q_2(4) = 12.96$  with a  $p$ -value of 0.23, indicating that the model is sufficient at the 5% level.

The VAR estimation allows for computation of the impulse response functions between variables. These functions graphically depict the effect on one variable resulting from an orthogonal innovation in the associated variable. Figures (7.3) and (7.4) show the impulse response functions and their 95% confidence intervals for the fitted VAR model of equation (7.7).

Figure (7.3) shows the response of the speculative pressure to a shock in the degree of mispricing for the 1, 3, 6 and 12 month difference between the futures price and the theoretical forward price. In all instances, the speculative pressure initially increases sharply, then declines in magnitude over time. This behaviour suggests that speculators respond to mispricing by increasing their net long positions.

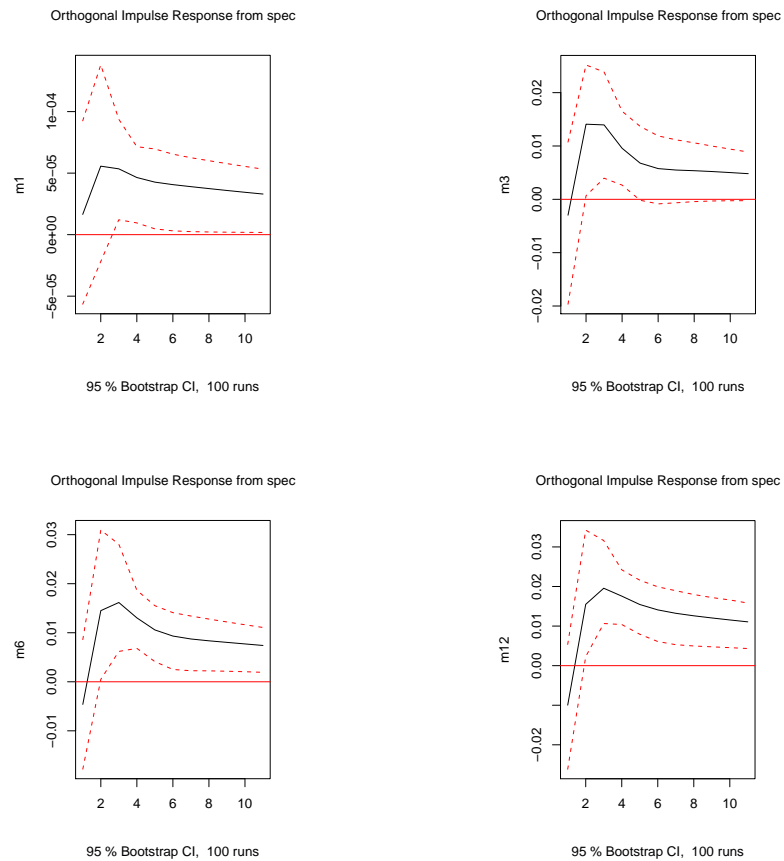
Figure (7.4) contains the impulse response functions for the mispricing series resulting from an orthogonal shock in the speculative pressure. Due to the linear dependence between the mispricing and speculative pressure series, we see similar behaviour in the



**Figure 7.3: THE IMPULSE RESPONSE OF THE SPECULATIVE PRESSURE FROM AN ORTHOGONAL SHOCK IN THE AMOUNT OF MISPRICING.**

Plots of the impulse response functions for the VAR(2) model estimated using weekly observations of the speculative pressure and futures/forward mispricing. Shown are the responses of speculative pressure to an innovation in the mispricing. The sample period is from January 1996 to October 2009. Dashed lines indicate the 95% confidence interval.





**Figure 7.4: THE IMPULSE RESPONSE OF THE DEGREE OF MISPRICING FROM AN ORTHOGONAL SHOCK IN SPECULATIVE PRESSURE.**

Plots of the impulse response functions for the VAR(2) model estimated using weekly observations of the speculative pressure and futures/forward mispricing. Shown are the responses of the 1, 3, 6 and 12 month mispricing series to an innovation in the speculative pressure. The sample period is from January 1996 to October 2009. Dashed lines indicate the 95% confidence interval.

response of the price difference. A shock in the speculative pressure induces an increase in the degree of mispricing that decreases slowly after the initial shock, suggesting that speculative activity can increase the futures price relative to the theoretical forward price.

## Chapter 8

# The Growth Rate of Gold Forward vs. Gold Futures Contracts

To compare the rate of increase of the futures price of gold with the market quoted GOFO rate, the Kalman filter is employed to estimate a model of the joint dynamics between the gold futures price and the dynamics behind its rate of increase. The Kalman filter is used for two main reasons. First, under stochastic interest rates, forward and futures prices differ. This means that we cannot expect the rate of increase of forward contract prices to be identical to that for futures contracts. Secondly, due to heterogeneity in the expectations of different classes of traders, futures prices may contain noise which may result in a systemic price bias (Sanders et al. (1998)). We cannot, therefore, assume that the rate of increase of the futures contract price is directly observable in the presence of noise. This is equivalent to assuming that the rate of increase of the futures price of gold is not identically equal to the GOFO rate and is therefore unobservable.

Consequently, we construct a two-variable state space model using the spot price and the rate of growth of the gold futures price. For a forward contract, the rate of growth in the asset price is equal to the GOFO rate. However, under stochastic interest rates, the futures and forward prices will not be equivalent suggesting that it is appropriate to treat the growth

rate of the futures contract as a state variable. We denote the gold spot price by  $S_t$  where  $t \in [0, \infty)$ . The dynamics of the model are specified as follows.

ASSUMPTION 1. *The spot price,  $X_t$  is treated as a logarithm:*

$$X_t = \ln S_t \quad (8.1)$$

Let  $\mu_t$  be equal to the the rate of growth in the asset price plus a risk premium term:

$$\mu = \quad + \pi \quad (8.2)$$

where  $\quad$  is the stochastic rate of growth and  $\pi$  is the risk premium. The market price of risk can be written:

$$\lambda = \frac{\pi}{\sigma} \quad (8.3)$$

Equations (8.2) and (8.3) give:

$$\lambda = \frac{\mu - \quad}{\sigma} \quad (8.4)$$

where  $\sigma$  is the asset volatility. Under these conditions the dynamics of the spot price under the risk-neutral measure can be written as in Assumption 2.

ASSUMPTION 2. *The dynamics of the spot price,  $X_t$ , under the risk-neutral probability measure are governed by the following stochastic differential equation:*

$$\frac{dS_t}{S_t} = \quad dt + \sigma d\widetilde{W}_t \quad (8.5)$$

where  $\quad$  is the growth rate at time  $t$ , and  $\widetilde{W}_t$  is Brownian motion under the  $\mathbb{Q}$ -measure.

Assumption 2 is founded on the basis that the price of gold increases at a rate roughly approximated by the GOFO rate. Thus, there is a single factor,  $\quad$  that we propose as a variable suited to modeling the dynamics of the gold price. We corroborate this by noting that in the Schwartz (1997) paper both the interest rate and the convenience yield are used as state variables. Conversely, in the case of gold we have argued that the dynamics between the interest rate (LIBOR) and the convenience yield (derived lease rate) are captured by a single variable, the GOFO rate, or  $\quad$ .

ASSUMPTION 3. *The dynamics of the growth rate,  $r_t$ , under the real probability measure are assumed to follow an Ornstein-Uhlenbeck mean-reverting process:*

$$d r_t = \kappa (\alpha - r_t) dt + \eta dB_t \quad (8.6)$$

where  $\kappa$ ,  $\alpha$  and  $\eta$  are constants. We see that  $\kappa$  governs the rate of mean reversion and  $\alpha$  is the (constant) long-run mean of the process.

If the GOFO rate represents the rate at which a loan in dollars can be secured using gold as collateral, then this rate should be mean reverting in the sense that it represents a relationship between the value of gold and the U.S. dollar. We remark that some of the results of the unit root tests on the GOFO rate presented in table 5.2 suggest that the GOFO rate may be mean reverting.

Under the equivalent martingale measure, (8.6) can be written:

$$d r_t = \kappa \left( \left( \alpha - \frac{\eta \lambda}{\kappa} \right) - r_t \right) dt + \eta d\tilde{B}_t \quad (8.7)$$

where  $\lambda$  is the market price of interest rate risk. The correlation coefficient,  $\rho$  is given as:

$$\rho dt = d\tilde{W}_t d\tilde{B}_t \quad (8.8)$$

We are working in a complete markets framework<sup>1</sup>. Consequently, this ensures the existence and uniqueness of a risk-neutral measure,  $\mathbb{Q}$ . Assumptions 2 and 3 lead to the following joint stochastic dynamics under the equivalent martingale measure:

$$\frac{dS_t}{S_t} = r_t dt + \sigma d\tilde{W}_t \quad (8.9)$$

$$d r_t = \kappa \left( \left( \alpha - \frac{\eta \lambda}{\kappa} \right) - r_t \right) dt + \eta d\tilde{B}_t \quad (8.10)$$

where  $d\tilde{W}_t$  and  $d\tilde{B}_t$  are elements of Brownian motion under the risk-neutral measure,  $\mathbb{Q}$ . Using equation (8.1) and assumption 2, we can derive the joint dynamics for the log-price

<sup>1</sup>COMEX trades at least 5 liquid gold futures contracts. In our two-factor model we have but a single source of uncertainty. Thus the number of traded instruments exceeds the number of sources of risk so markets are complete.

and asset growth rate:

$$dx_t = \left( r_t - \frac{\sigma^2}{2} \right) dt + \sigma dW_t \quad (8.11)$$

$$d r_t = \kappa(\alpha - r_t) dt + \eta dB_t \quad (8.12)$$

Within the pricing framework of Cox, Ingersoll and Ross Cox et al. (1985), the price,  $F(X_t, r_t, t)$ , of the gold futures contract must satisfy the following partial differential equation:

$$\begin{aligned} \frac{\partial F}{\partial t} + (r_t + \kappa(\alpha - X_t)) \frac{\partial F}{\partial X_t} + b(m - r_t) \frac{\partial F}{\partial r_t} + \frac{1}{2} \sigma_X^2 \frac{\partial^2 F}{\partial X_t^2} \\ + \rho \sigma_X \sigma \frac{\partial^2 F}{\partial X_t \partial r_t} + \frac{1}{2} \sigma^2 \frac{\partial^2 F}{\partial r_t^2} = 0 \end{aligned} \quad (8.13)$$

This is subject to the terminal condition that the expected future spot price converges to the futures price at maturity,  $T$ :

$$F(X_T, r_T, T) = S(T) = e^{X_T} \quad (8.14)$$

Equation (8.14) will be the basis for the initial conditions that solve the pricing differential equation, (8.13).

Following Duffie and Kan (1996), the solution to equation (8.13) gives the price of the futures contract at time to maturity  $\tau = (T - t)$  under the risk-neutral measure and can be solved using the following exponential-affine function:

$$F_t^T = E_Q(S_T | \mathcal{F}_t) = e^{A(\tau) + B(\tau) r_t} \quad (8.15)$$

Substitution of equation (8.15) into (8.13) yields the following system of differential equations:

$$B'(\tau) + \kappa B(\tau) - 1 = 0 \quad (8.16)$$

$$A'(\tau) + \kappa \left( \alpha - \frac{\eta \lambda}{\kappa} \right) B(\tau) + \frac{1}{2} \eta^2 B^2(\tau) + \sigma \eta \rho B(\tau) = 0 \quad (8.17)$$

with initial conditions given by:

$$A(\tau = 0) = 0 \quad (8.18)$$

$$B(\tau = 0) = 0 \quad (8.19)$$

$$(8.20)$$

The solutions for the system of equations (8.16) are:

$$A(\tau) = \left( -\frac{\alpha}{\kappa} + \frac{2\eta\lambda}{\kappa} + \frac{\eta^2}{\kappa^3} + \frac{\sigma\eta\rho}{\kappa^2} \right) e^{-\kappa\tau} + \left( -\alpha + \frac{\eta\lambda}{\kappa} + \frac{\eta^2}{2\kappa^2} + \frac{\sigma\eta\rho}{\kappa} \right) \tau + \frac{1}{\kappa^3} \left( \alpha\kappa^2 - \kappa\eta\lambda - \frac{3}{4}\eta^2 - \sigma\eta\rho\kappa \right) \quad (8.21)$$

$$B(\tau) = \frac{1 - e^{-\kappa\tau}}{\kappa} \quad (8.22)$$

For our model, these equations, in combination with equation (8.15), govern the price of a gold futures contract and depend upon six parameters:  $\alpha, \kappa, \lambda, \sigma, \eta$  and  $\rho$ . These parameters must be estimated from the observation data. One common method used for state space model estimation is the Kalman filter. Due to its ease of implementation and ubiquitous presence in the literature, it provides a convenient method by which to estimate and compare our model to existing models in the literature, for example that of Schwartz (1997).

## 8.1 The Linear Filtering Problem

The Kalman filter is a recursive algorithm that produces estimates of the latent variables of a dynamical system. It proceeds by updating our knowledge of the system upon the arrival of a new observation. The state of the system at time  $t$  is described by a vector of state variables. With the arrival of a new observation we apply a linear operator to the state at time  $t$  in order to generate a new state for the system. A second operator is applied (in the presence of noise) and this generates estimates of the latent state variables. To apply

the filter to our model, we must first derive the filtering equations. To obtain the requisite matrices to input into the filter we first have to write our model in a compact state-space form.

To derive the Kalman filter equations, we have to discretize our continuous time model in the time domain. To do so we relate the vector of observables  $Y_t^F$  to the state variable vector  $Z_t$  using a linear Gaussian model. Letting  $\tau = 1, \dots, T$  be the discrete time observation date index at continuous time date  $t$  we have:

$$\ln(F_{t_\tau}^{T_i}) = Y_\tau^F = \Pi_\tau + \Lambda_\tau Z_\tau + \nu_\tau \quad (8.23)$$

where  $\Pi_\tau$  is an  $J \times 1$  vector and ( $j = 1, \dots, J$ ) is the number of contract maturities observed at date  $\tau$ . At a given date,  $\tau$ , we have

$$\Pi_\tau = \left[ A(t_\tau, T_i) \right]_{J \times 1} \quad (8.24)$$

$$\Lambda_\tau = \left[ B(t_\tau, T_i) \quad C(t_\tau, T_i) \right]_{J \times 2} \quad (8.25)$$

and  $i = 1, \dots, J$ . The vector  $\nu_\tau$  is a  $J \times 1$  vector of serially uncorrelated disturbances with distribution  $N(0, \Omega)$ .  $\Omega$  is a diagonal matrix with diagonal elements given by  $\Omega_{ii} = \omega_i$  for  $i = 1, \dots, J$ .

$$Z_\tau = \begin{bmatrix} X_{\tau-\Delta t} \\ \tau-\Delta t \end{bmatrix} \quad (8.26)$$

is the state variable vector and  $\tau = 1, \dots, T$  is the observation time index. Equation (8.23) is the *measurement equation*.

To derive the *transition equation*, we can put equations (8.5) and (8.7) into a compact matrix form. By letting

$$\Phi_t = \begin{bmatrix} -\frac{\sigma^2}{2}\Delta t \\ \kappa\alpha\Delta t \end{bmatrix} \quad (8.27)$$

and

$$\Theta = \begin{bmatrix} 1 & \Delta t \\ 0 & 1 - \kappa\Delta t \end{bmatrix} \quad (8.28)$$



the state space form for the model can be written as a linear stochastic differential equation given by:

$$dZ_\tau = (\Phi_\tau + \Theta Z_\tau) dt + \Sigma_\tau dW_\tau \quad (8.29)$$

Writing (8.29) in discrete-time gives:

$$Z_t = \Phi_t + \Theta_t Z_{t-\Delta t} + R\xi_t \quad (8.30)$$

The variance-covariance matrix of  $\xi_t$  is denoted  $\Sigma_t$  and is given by

$$\Sigma_t = \begin{bmatrix} \sigma^2 \Delta t & \rho \sigma \eta \Delta t \\ \rho \sigma \eta \Delta t & \eta^2 \Delta t \end{bmatrix} \quad (8.31)$$

Equation (8.30) is the discrete time *transition equation*.

To perform the filtering we use weekly observations of COMEX gold futures contracts for the first, third, sixth and twelfth nearby gold futures contract prices over the period of October 1986 to October 2009 yielding a total of 712 observations. At each observation date,  $t$ , we possess data for four contract maturities,  $\tau_i$ ,  $i = 1, \dots, 4$ . Our time series has been constructed such that the contract maturities at date  $t$  are constant and equal to  $\frac{1}{12}$ ,  $\frac{3}{12}$ ,  $\frac{6}{12}$  and  $\frac{12}{12}$ . Initialization of the Kalman filter requires that we choose an initial parameter vector  $\phi = \{\alpha, \kappa, \lambda, \sigma, \eta, \rho, |h_1|, |h_3|, |h_6|, |h_{12}|\}$ . Furthermore, we must initialize the variance-covariance matrix,  $H$  which is a diagonal matrix with elements  $h_1^2, h_3^2, h_6^2, h_{12}^2$  on the diagonal. With these chosen parameters, we can estimate the parameters using maximum likelihood.

## 8.2 Kalman Filter and Estimation Results

After initialising the parameter vector and the Kalman filter matrices we ran the filter and obtained the optimised parameter set given in table (8.1).

Table (8.1) displays the results of the log-likelihood estimation of the model parameters. Parameters  $\lambda$ ,  $|h_2|$  and  $|h_3|$  are not statistically significant. However, all remaining

Parameter	Estimation	Std. Err.	<i>t</i> -value	<i>p</i> -value
$\sigma$	1.3618	0.0313	43.5138	0.0000
$\kappa$	0.2396	0.0245	9.7779	0.0000
$\alpha$	0.0248	0.0167	1.4805	0.1392
$\lambda$	0.0000	0.2853	0.0000	1.0000
$\eta$	0.0163	0.0006	25.3381	0.0000
$\rho$	0.4255	0.0324	13.1239	0.0000
$h_1$	-0.0024	0.0001	36.1522	0.0000
$h_3$	0.0000	0.0001	-0.0001	0.9999
$h_6$	-0.0005	0.0000	-32.3597	0.0000
$h_{12}$	0.0003	0.0001	3.9473	0.0001
Log-Likelihood		-11778.7		

Table 8.1: **KALMAN FILTER ESTIMATION RESULTS**

Parameter vector optimisation results from the log-likelihood maximization. Parameters  $\lambda$ ,  $\alpha$ ,  $|h_3|$  and  $|h_{12}|$  are not statistically significant. The remaining parameters are significant at the  $< 1\%$  level.

parameters are significant at the  $< 1\%$  level. We observe that the market price of risk,  $\lambda$  is not statistically significant which is in agreement with the results of the Schwartz (1997) two-factor model which finds a statistically insignificant market price of risk for the periods of 1/2/85 to 6/13/95, 11/21/90 to 6/13/95 and 11/21/90 to 6/13/95. However, our model differs from Schwartz's two factor model in that he uses the futures price and convenience yield as state variables. Owing to the persistent state of contango in the gold market, the convenience yield<sup>2</sup> for gold is low. For this reason, the use of convenience yield as a state variable for a gold price model may not be appropriate and could lead to excessive negative values of the convenience yield for gold. While possible, frequent negative values are not often observed in practice and we should keep this in mind if we accept the derived lease rate as a suitable proxy for the convenience yield of gold.

Figures (8.1) and (8.2) graphically depict the results of the Kalman filter estimation of the joint system dynamics. In figure (8.1), we can observe a positive and consistent

<sup>2</sup>i.e. the derived lease rate.

difference between the 3 month GOFO rate and the Kalman filtered asset growth rate. The figure suggests that since approximately 2003 until the end of 2007, the futures contract price has been priced consistently higher than the forward contract price. In terms of our model, this has the interpretation of an additional risk-premium in the value of the futures contract compared to the forward contract. It is interesting to note that the disappearance of the risk-premium coincides approximately with the beginning of the recent financial crisis.

This effect is depicted more clearly by the absolute difference between the filtered and quoted GOFO rate as illustrated by figure (8.2). The figure shows the absolute difference between the two series and the consistent positive difference can easily be seen beginning in the early part of 2003 and lasting until the end of 2007. It is this difference between the two growth rates that seems to be responsible for the degree of mispricing between the gold forward and futures contracts. This positive discrepancy between the two rates will be the subject of future research.

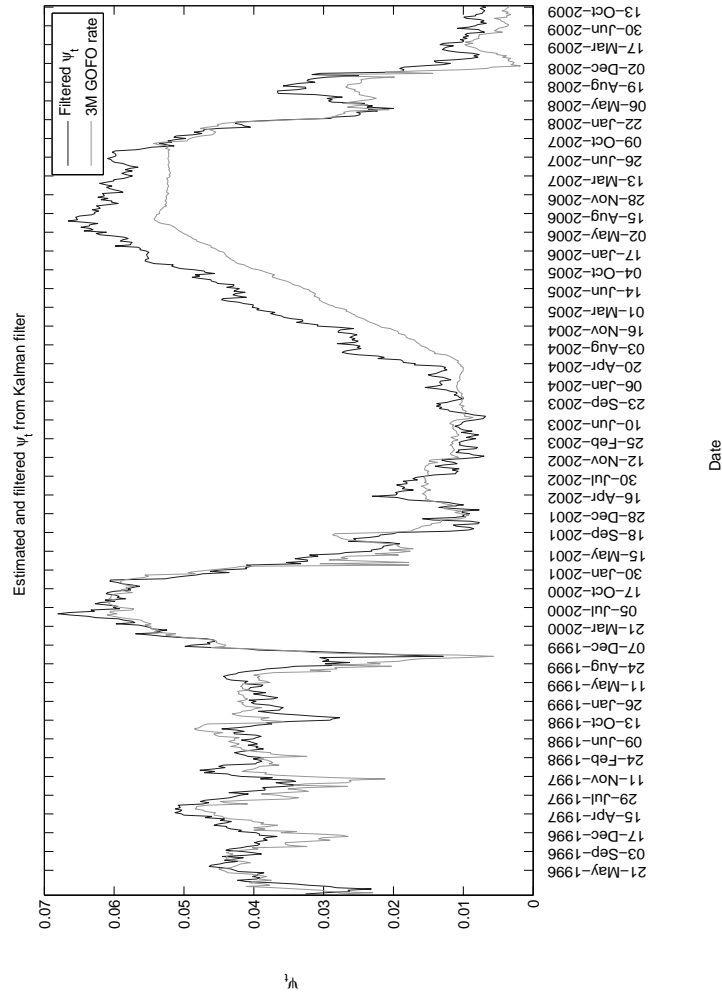
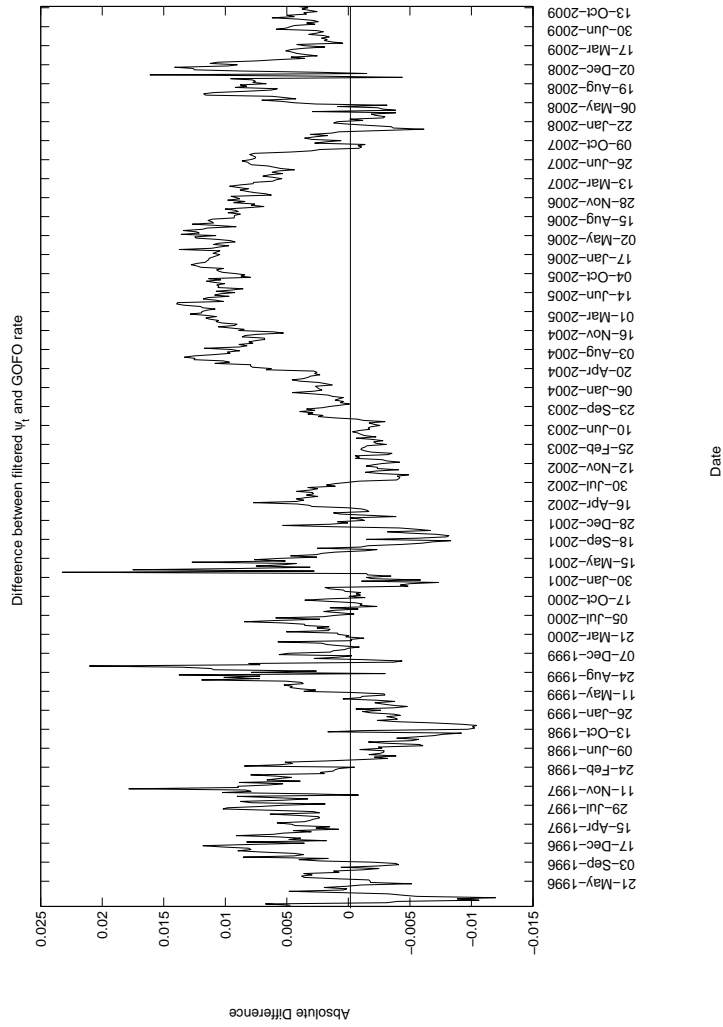


Figure 8.1: **COMPARISON BETWEEN MARKET-QUOTED 3M GOFO RATE AND KALMAN ESTIMATED GROWTH RATE**

The figure shows a comparison between the market quoted 3 month GOFO rate and the asset growth rate estimated using the Kalman filter. Starting in approximately February 2003 and ending in the latter half of 2007, there is an observable separation between the GOFO rate and the filtered value.



**Figure 8.2: ABSOLUTE DIFFERENCE BETWEEN THE 3 MONTH GOFO RATE AND THE KALMAN ESTIMATED ASSET GROWTH RATE.**

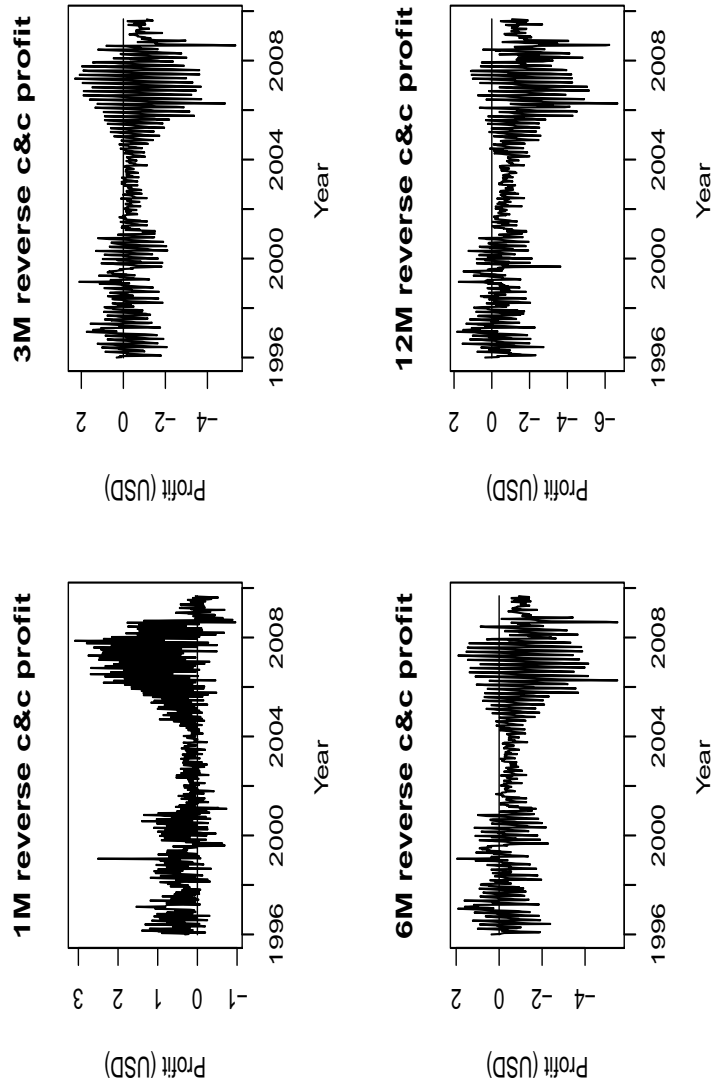
Shown in the figure are the absolute differences between the Kalman filtered asset growth rate and the prevailing 3 month GOFO rate. The positive absolute difference between the two series can be observed beginning around February 2003. In addition, this difference appears to be consistently positive over the remainder of the sample period.

## Chapter 9

# Transaction Costs and Profitability of Trading Strategies

In this section, we examine the potential profitability of two common commodity-trading strategies. In particular, we consider whether the cash and carry and reverse cash and carry strategies can be profitable to an investor in the gold market. The reverse cash and carry trade is profitable if, at time  $t$  an investor observes that  $F_0 < S_0 e^{(GOFO)T}$ . Under this condition, an investor can lease bullion from a central bank, sell the leased gold on the spot market and invest the proceeds of this sale at LIBOR. Because the gold must be repurchased at the end of the trade, an investor can secure the otherwise risky repurchase price at  $F_0$  by taking a long position in the futures contract.

Using gold futures contract data for contracts of 1, 3, 6 and 12 month maturity, we calculate the potential profitability of the reverse cash and carry trade in the gold market. Figure 9.1 shows time series of potential profitability of the reverse cash and carry trade of 1, 3, 6 and 12 month maturity for the years spanning 1996 - 2009.

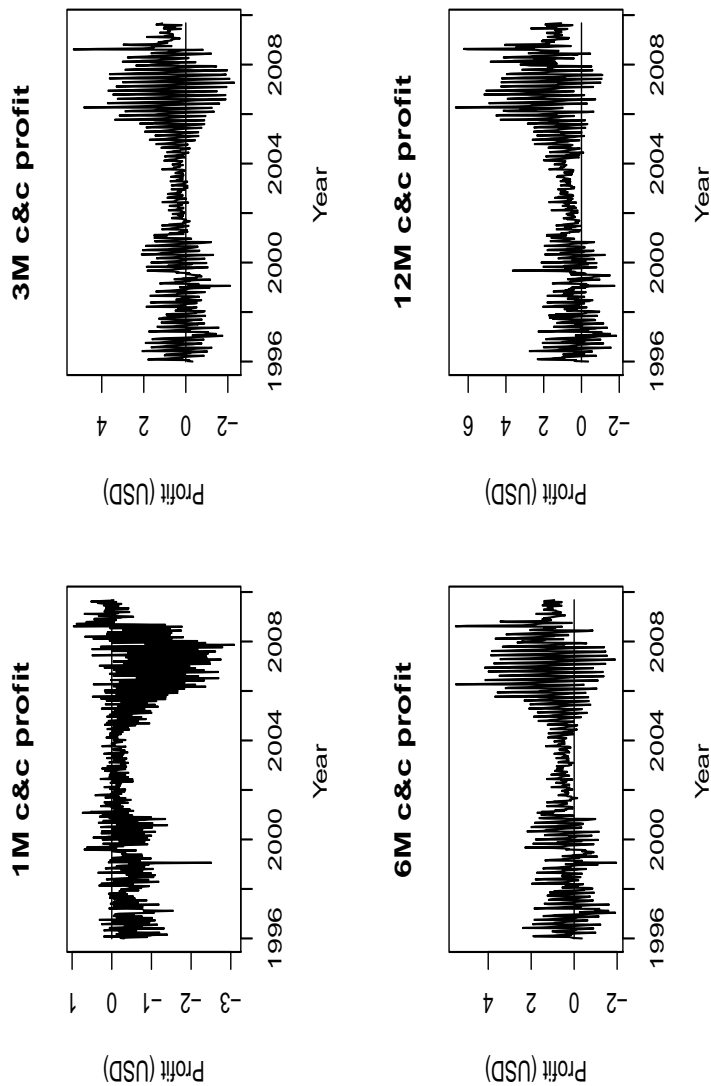


**Figure 9.1: POTENTIAL PROFIT OF THE GOLD REVERSE CASH AND CARRY TRADE (IN U.S. DOLLARS) OVER THE YEARS 1996 - 2009.**

The plots show the potential profit of the reverse cash and carry trade for the gold market. This strategy consists of leasing gold from a central bank, selling the gold on the spot market and entering into a long futures contract. Proceeds from the sale are invested at the LIBOR rate and at maturity; the profit is calculated as the difference between the value (at maturity) of the money invested and the repurchase cost of the bullion at the futures price. Potential profitability of the reverse cash and carry is positive for the 1 month duration and becomes increasingly negative for the 3, 6 and 12 month trade durations. The 12 month trade is not profitable at all from 2001 until 2009.

The results for the one month maturity trade duration indicate that the reverse cash and carry trade is potentially profitable in the short-term. However, as contract maturity increases, we see from the 3, 6 and 12 month plots that possible profit becomes increasingly negative; for the 12 month contract there is a negative profit of 6 U.S. dollars, suggesting an investor engaging in the 12 month reverse cash and carry would realize a significant loss. For the 1 month contract, average profitability is approximately 0.43 U.S. dollars, suggesting that transaction costs and/or taxes may render the reverse cash and carry trade in gold an overall unprofitable trading strategy. However, diminishing profit with increasing duration renders the cash and carry trade unattractive for long term trading strategies. Conversely, the cash and carry trade is profitable if we observe  $F_0 > S_0 e^{(GOF0)T}$ . Under this inequality, it is potentially profitable for the investor to obtain a loan for  $S_0$  at the LIBOR rate, purchase a unit of gold, short a futures contract and hold the gold until maturity. For the duration of the carry, the investor can earn the lease rate on the bullion. At maturity, the investor delivers the gold and earns a profit of  $F_0 - S_0 e^{(GOF0)T}$ . Unlike the reverse cash and carry strategy, the cash and carry trade is not profitable in the short-term but is profitable in the long-term.





**Figure 9.2: POTENTIAL PROFIT OF THE GOLD CASH AND CARRY TRADE (IN U.S. DOLLARS) OVER THE YEARS 1996 - 2009.**

Figure 9.2 shows the potential profitability for the 1, 3, 6 and 12 month gold cash and carry trade. The strategy consists of obtaining a loan at the LIBOR rate in order to purchase a unit of gold, shorting a futures contract and holding the gold until maturity. For the duration of the strategy, the trader has the possibility to earn the lease rate on the gold bullion. At maturity, the gold is delivered, the position is dissolved and the investor earns a potential profit that is the difference between the loan repayment amount and the money received for bullion delivery. The 1 month duration trade is seen to be highly unprofitable. Conversely, the 3, 6 and 12 month trade durations are potentially profitable and profitability is seen to increase with increasing trade duration.

Figure (9.2) shows a plot of potential profitability of the gold cash and carry trade. In further contrasts to the reverse cash and carry, the profitability is inversely related to the GOFO rate and is positively related to the derived gold lease rate. The 1 month cash and carry strategy proves unprofitable, on average, over the entire sample period from 1996 to 2009 and becomes increasingly unprofitable from 2004 onwards. In contrast, the 3, 6 and 12 month profitability series suggest that the carry trade has been a profitable strategy and, particularly for the 12 month contract, is increasing in profitability in recent times. Since 2002, the 12 month series is almost strictly positive and increasing. Potential profits are as high as 6 U.S. dollars on a troy ounce of gold. Furthermore, the magnitude of the profit suggests that after accounting for taxes and transaction costs, the long-term cash and carry may remain a profitable trade.

To estimate gold futures transaction costs we employed the method of Lesmond et al. (1999). To estimate proportional costs, Lesmond et al. employ the limited dependent variable (LDV) model of Tobin (1958). The method consists of observing the frequency of zero returns in a yearly series and therefore comparing measured and “true” returns to one another. The difference between the measured and true return is given by the threshold cost of trading on negative and positive returns. These costs can be thought of as the costs at which a marginal investor will be willing to engage in a transaction. By estimating the log-likelihood function for the LDV model linking measured and true returns, we are able to extract the proportional costs of gold futures buying and selling in addition to the round-trip transaction costs.

The LDV model assumes the relationship between measured and true returns to be a linear function of the proportional transaction costs of selling,  $\alpha_1$ , and buying,  $\alpha_2$ . These coefficients can also be thought of as the threshold costs of trading on negative information in the case of  $\alpha_1$ , and the threshold for trading on positive information in the case of  $\alpha_2$ . The basic formulation of the LDV model is therefore given by equation (9.1):

$$R_t^* = \beta R_{mt} + \epsilon_t \quad (9.1)$$

where  $R_t^*$  are the true returns to gold futures,  $R_t$  are the measured returns, and  $R_{mt}$  represents the market returns on the S&P500 index. Subsequently, we have:

$$\begin{aligned}
R_t &= R_t^* - \alpha_1 & \text{for } R_t^* < \alpha_1 \\
R_t &= 0 & \text{for } \alpha_1 < R_t^* < \alpha_2 \\
R_t &= R_t^* - \alpha_2 & \text{for } R_t^* > \alpha_2
\end{aligned} \tag{9.2}$$

To estimate the transaction costs, we maximize the log-likelihood function of equation (9.1). This function is given in Lesmond et al. (1999) and is defined by:

$$\begin{aligned}
\ln L &= \sum_{r_t \in R_1} \ln \frac{1}{(2\pi\sigma^2)^{1/2}} - \sum_{r_t \in R_1} \frac{1}{2\sigma^2} (R_t + \alpha_1 - \beta R_{mt})^2 \\
&+ \sum_{r_t \in R_2} \ln \frac{1}{(2\pi\sigma^2)^{1/2}} - \sum_{r_t \in R_2} \frac{1}{2\sigma^2} (R_t + \alpha_2 - \beta R_{mt})^2 \\
&+ \sum_{r_t \in R_0} \ln \left( \Phi_2 \left( \frac{\alpha_2 - \beta R_{mt}}{\sigma} \right) - \Phi_1 \left( \frac{\alpha_1 - \beta R_{mt}}{\sigma} \right) \right)
\end{aligned} \tag{9.3}$$

The sets  $R_0, R_1, R_2$ , in the summation indices correspond to regions in which returns are zero, returns are non-zero when  $R_m$  is negative and when returns are non-zero when  $R_m$  is positive, respectively. The functions  $\Phi_1$  and  $\Phi_2$  are standard normal distribution functions. The likelihood maximization procedure thus provides estimates of the parameter set  $(\alpha_1, \alpha_2, \beta, \sigma)$ .

Table (9.1) shows the results of the log-likelihood maximization for Tobin's LDV model. In the table,  $\beta$  represents the regression coefficient of true returns on measured returns,  $\alpha_1$  and  $\alpha_2$  are the proportional costs of buying and selling, respectively. Round trip costs are calculated as the difference between the proportional costs of buying and selling. We see from the table that round-trip costs for the latter half of the 1990s were small in comparison to the post-2000 years. The one exception is 1999, where the highest round trip costs of the sample period peaked at approximately 6 percent. The post 2000 years have seen transaction costs consistently in excess of 3.5%, which, as a yearly average, is not prohibitively high. In particular, costs of this magnitude would have only a marginal impact

<b>Year</b>	$\beta$	$\alpha_1$	$\alpha_2$	$\sigma$	<b>Round-trip</b>
1996	1.1443	-0.0131	0.0129	0.0401	0.0260
1997	1.0063	-0.0179	0.0179	0.0844	0.0358
1998	0.6623	-0.0124	0.0112	0.0869	0.0236
1999	2.0049	-0.0284	0.0312	0.1209	0.0595
2000	1.3857	-0.0251	0.0283	0.1037	0.0534
2001	1.5075	-0.0282	0.0282	0.1078	0.0564
2002	0.7056	-0.0178	0.0183	0.0901	0.0361
2003	-0.2264	-0.0013	0.0010	0.1119	0.0023
2004	2.2309	-0.0211	0.0179	0.1093	0.0390
2005	3.1244	-0.0302	0.0232	0.0938	0.0535
2006	4.1802	-0.0375	0.0319	0.1592	0.0694
2007	0.2529	-0.0015	0.0010	0.1171	0.0026
2008	0.0297	-0.0029	0.0025	0.2139	0.0054
2009	0.7644	-0.0223	0.0187	0.1605	0.0410
<i>Averages:</i>	1.955232	-0.021310	0.018430	0.102861	0.039740

**Table 9.1: GOLD FUTURES TRANSACTION COST ESTIMATES BY YEAR**

The table shows transaction costs estimated using the method in Lesmond et al. (1999). Costs were estimated on a year-by-year basis using a full year of daily returns data based on the linear dependent variable (LDV) model. In the table,  $\alpha_1$  and  $\alpha_2$  represent the proportional transaction costs for selling and buying, respectively. Round trip transaction costs are estimated by subtracting  $\alpha_1$  from  $\alpha_2$ . The coefficients were estimated by maximizing the log-likelihood function given in Lesmond et al. (1999).

on the profitability of the cash and carry and reverse cash and carry strategies mentioned previously.

# Chapter 10

## Conclusion

By examining the gold bullion leasing market, we have shown that the derived lease rate can serve as an observable form of the convenience yield of gold. Under such a framework, we demonstrate a short-term relationship between the lease rate and the level of discretionary market inventory. In particular, we have shown that bullion leases of 1 month duration have a strong impact on inventory levels. Due to the nature of the gold leasing transaction, whereby interest on a bullion lease is repaid in bullion, our results suggest that the 1 month lease rate has a negative effect on inventories such that lease repayments cause inventory levels to fall. However, this effect seems to be mitigated by the actions of speculators whose demand for long futures contracts results in increased inventory levels. Additionally, this speculative effect is seen to be consistent independent of the lease rate duration. Despite this, the lease rate does not appear to influence the size of inventory withdrawals. Rather, past withdrawals appear to decrease inventory withdrawals at time  $t$ , suggesting that gold inventories are replenished rather quickly. This could also explain the absence of influence of inventories on the price of gold.

Returns to futures contracts are negatively related to the market portfolio as proxied by the return on the S&P 500 index, suggesting that adding gold to an investment portfolio has diversification benefits and can possibly offset falls in the equity market. We have also

shown that speculative pressure is positively and significantly related to futures returns. Controlling for price pressure, we show that while the price pressure hypothesis dominates speculative effects for futures returns calculated from short-term contracts, we cannot reject the idea that long-term speculation has a positive effect on gold futures returns. That is, increased speculative activity in gold futures contracts is associated with higher futures returns. Estimates of gold futures transaction costs are rather small, suggesting that these costs are not a significant barrier to speculator entry in the gold market.

Finally, our state space model has revealed a curious relationship between the GOFO rate and the dynamics of the gold price. In particular, there appears to be an interesting decoupling of the GOFO rate and the growth rate of gold futures contract prices. In the period beginning late 2003 until the approximate onset of the recent crisis, there is evidence of a distinct and positive difference between the market quoted GOFO rate and the Kalman filter estimated growth rate. As both the investment banks implicated in the crisis and the central banks that provided liquidity support were both active participants in the gold and money markets, this decoupling will be the subject of further inquiry.

Historically, monetary authorities and the hedging activities of gold producers dominated the gold market. However, rising prices, diminishing lease rates and shareholder pressure on gold miners in the presence of rising gold prices seems to have changed the market dynamics. The decreases in producer hedging activity and increased demand for gold as a financial asset have led to increased speculative activity in the bullion market. The subsequent recent participation and activities of gold ETFs may lead to an even more fundamental change in the operation of the gold futures market and this may provide a productive avenue for future research.

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Vu: le Président Vu les suffragants

M.:

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Vu et permis d'imprimer: le Vice-Président du Conseil Scientifique Chargé de la Recherche  
du l'Université Paris Dauphine.

By examining the gold leasing market and employing data on the gold forward offered rate (GOFO) and derived lease rates, we propose that rather than using the interest-adjusted basis as a proxy for the convenience yield of gold, the convenience yield is better approximated by the derived gold lease rate. Additionally, using the interest-adjusted basis as opposed to the lease rate can lead to incorrect inferences pertaining to the convenience yield. Using the lease rate, we study the relationship between gold leasing and the level of COMEX discretionary inventory. The results suggest that the lease rate has an asymmetric relationship with the level of discretionary inventory, which we calculate using weekly inventory data obtained from the COMEX futures trading exchange. Linear regressions of the level of discretionary inventory on lagged lease rates reveal that lease rate tenors of 1, 3 and 6 months have a negative effect on the level of discretionary inventory. After controlling for speculative effects we find that for bullion leases exceeding one month in duration inventory levels are dominated by speculative effects rather than lease rates. Furthermore, this speculative activity acts to increase the amount of bullion available to the gold futures market by decreasing the repayment effect. Finally, we show that the presence of speculation in gold futures contracts can be associated with increased futures contract returns and that this effect increases with increased futures contract maturity. These results suggest that speculation plays a significant role in the COMEX gold futures market.

**Key words:** commitments of traders, gold futures market, convenience yield, gold leasing, speculative effects

À travers l'examen du marché de l'emprunt d'or et l'utilisation à la fois des données relatives aux taux à terme offerts sur ce marché (GOFO) et aux taux du leasing de l'or, nous suggérons l'adoption de ce dernier taux comme étant une << proxy >> pour quantifier le rendement de l'or. Une telle approche permet de remédier aux insuffisances d'une approximation par un ajustement du différentiel de taux (interest-adjusted basis). En effet, l'utilisation de ce dernier est sujette à des biais d'inférence aboutissant à une estimation

erronée du rendement de l'actif en question. Dans ce contexte, il est naturel d'utiliser le taux le plus approprié, en l'occurrence le taux d'emprunt (lease rate) pour étudier la relation entre l'emprunt de l'or et le niveau d'inventaire du COMEX. Enfin, notre analyse révèle qu la présence de spéculateurs sur les marchés des contrats à terme est un facteur d'accroissement à la fois des rendements, mais aussi des maturités des contrats futures.

**Mots clés:** commitments of traders, marché à terme de l'or, convenience yield, gold leasing, effets spéculatifs