THE ECONOMICS OF GOLD PRICE MOVEMENTS*

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Recent gyrations in the price of gold may lead one to wonder whether economic theory has any power to explain gold price movements. Some observers believe that "the ongoing frenzy in the gold market may be only an illusion of crowds, a modern repetition of the tulip-bulb craze or the South Sea Bubble."[1] Has gold fever infected otherwise rational individuals, or is there an economic rationale behind this behavior?

Almost daily during the surge in the price of gold in late September and early October 1979, for instance, the financial press reported frenetic trading in gold and other precious metals. Typical reactions of gold dealers were: "The market was just crazy and wild" and "You can't explain it by talking of inflation and such things. It's absolutely insane."[2]

The view that markets occasionally fall prey to speculative manias and panics has long been accepted by many economists who regard such phenomena as a potential phase of market behavior. These economists maintain that at certain times mob psychology may dominate the market, thereby preempting the role of economic considerations in market behavior. In contrast to this view is the opposite contention that economic theory, relying on the assumption that market participants act rationally, is sufficient to explain price movements in speculative markets. This article seeks to explain changes in the price of gold from the latter point of view. Section I develops a simple model of gold price movements. Section II applies the theory in the preceding section to interpreting movements in the price of gold since the simultaneous legalization of private ownership of gold in the United States and beginning of gold futures trading in 1975. Section III presents empirical evidence to support the contention of market rationality, and finally Section IV offers some concluding comments.

I. ECONOMIC ANALYSIS OF GOLD PRICE MOVEMENTS

To begin, it is useful to distinguish between gold stocks and flows. The stock of gold is the quantity held at a given time, whereas the net flow of gold is the change in that stock during a particular interval of time. Production flows add to stocks as newly mined and refined gold becomes available to the market; consumption flows deplete stocks as gold is put to uses that render it irrecoverable. Gold's use in electronics, for example, depletes stocks of gold, since recycling gold is frequently uneconomical in these applications. The metal's use in art also depletes stocks because once incorporated in a work of art, gold is no longer available to the market. Presumably, if such a work of art is deemed "priceless," no price of gold would cause the work to be scrapped and the gold to be melted down, regardless of how high the price might be. In view of these distinctions, gold stocks should be understood to mean readily marketable stocks at a particular time.

Owners of gold stocks have the choice of selling gold today or storing it for future sale. This decision depends on current and anticipated future prices. The storage of gold yields no return other than the prospect of an appreciation in price. The assumption about rational behavior implies that participants in the gold market act to maximize anticipated net revenue from the storage of gold. They store a quantity of gold such that the anticipated appreciation in the price of gold equals the net marginal costs of storing gold.

Net marginal costs of storage are implicit storage costs that consist of the following components: (1) marginal outlay for storage, (2) marginal interest cost, and (3) marginal convenience yield. Marginal outlay costs comprise the charges for warehousing (in vaults) and insuring additional stocks of gold. The marginal interest cost reflects the opportunity cost of owning additional stocks of noninterest-bearing gold rather than alternative interest-bearing assets. Finally, the marginal convenience yield is the monetary

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1 **Wall Street Journal,** 26 September 1979, p. 22.

2 ————, 19 September 1979, p. 3.

value imputed to holding gold stocks for commercial uses which require gold for fabricating goods. The convenience yield accrues from avoiding costly changes in the production schedule and the associated frequent spot purchases of gold. Additionally, stocks of gold prevent loss of sales because of temporary shortages of gold on hand for fabrication.[3]

Marginal storage costs are defined above as net of the marginal convenience yield, which has the opposite sign from the other marginal components. The marginal convenience yield is a decreasing function of stocks held, diminishing to zero for some sufficiently large level of stocks. As long as the marginal convenience yield is positive, it offsets the other marginal costs of storage to some degree. Equation 1 expresses the definition of net marginal storage costs mathematically:

$$(1) \quad \text{NMSC} = \text{mo} + \text{mi} - \text{mc}.$$

The net marginal storage costs, NMSC, are the sum of the marginal outlay, mo, and the marginal interest cost, mi, minus the marginal convenience yield, mc.

The equilibrium relationship between anticipated gold price appreciation and net marginal storage costs is summarized in the following relationship:

$$(2) \quad E(P_{t+1}) - P_t = \text{NMSC}.$$

Equation 2 indicates that equilibrium in the gold market requires the difference or spread between the market's anticipated price of gold next period, $E(P_{t+1})$, and the current price, P_t, to equal net marginal storage costs, NMSC.

The aggregate effect of individual market participants seeking profits assures that the equilibrium condition in the gold market holds. A geometric model of price movements will help illustrate the relationship between the price spread and net marginal storage costs. For this exposition, marginal outlay and convenience yield are assumed to be negligible compared to the marginal interest cost. Under these conditions, if the interest rate is r percent, then the full equilibrium rate of gold price appreciation over the period will be r percent. Such an equilibrium is shown in Figure 1 for a gold price of P_0 at the beginning of the period, and a price of P_1 at the end of the period, where the percentage price appreciation $\log P_1 - \log P_0$ is r percent.[4]

Now suppose some economic or political disturbance occurs that causes market participants to revise their anticipations of price appreciation so that an incipient excess demand (positive or negative) develops at the initial price. Market participants will try to profit from the change in anticipations and in so doing will bring the anticipated price spread over the period back into equality with the interest rate. Specifically, suppose the anticipated end of period gold price rises from P_1 to P_1^* so that the anticipated capital gain on gold over the period momentarily exceeds r percent. Market participants will attempt to realize profits by storing gold; but since the stock of gold is essentially fixed, they will only succeed in bidding up the spot price. Equilibrium will be restored at a new spot price of P_0^*, where the anticipated capital gain has been brought back to r percent.

It should be emphasized that the anticipated future price does not completely determine the spot price. A change in current supply conditions could affect the spot price which in turn would cause anticipated future prices to be revised via the storage adjustment process. As discussed in more detail in the next section, individuals may choose to hold more wealth in gold than in other assets in times of political and economic uncertainty because of the greater security and anonymity of gold. Such a shift in the composition of wealth might be made without regard for the

[3] This discussion of storage applies to any storable commodity. See [2] for a detailed treatment of the theory of storage.

[4] The reader may wonder how this theory of gold price movements would account for secularly stable gold prices. In this situation, the anticipated price of gold would equal the current price. Individuals would be willing to hold gold, a noninterest-bearing asset, only if net marginal storage costs for gold were zero. This implies that the marginal convenience yield would offset the positive marginal interest cost, which would occur for sufficiently small stocks of gold.

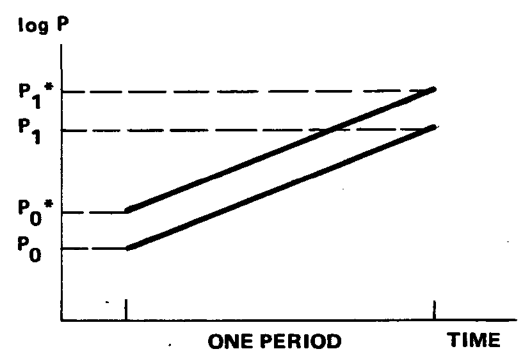


Figure 1

metal's future rate of price appreciation. The spot price of gold would be bid upward, drawing gold out of storage for sale on the spot market. The anticipated future price of gold would also rise, since the interest rate would otherwise exceed the price spread.

The preceding theory of gold price movements is readily applied to gold futures markets.[5] An individual's decision to store gold for future sale requires a prediction of the gold price. Futures trading facilitates this process by making market price anticipations explicit in futures prices. According to the theory of gold price movements, net marginal storage costs should influence the spread between futures prices.

Chart 1 shows the percentage spread between the prices of the October 1980 and the December 1979 futures contracts during 1979.[6] From January through September 1979, the spread fluctuated around 8 percent. After September, the spread widened rapidly and varied around 11 percent. The greatest increase of 1.53 percentage points occurred between the observations on October 5, 1979 and October 12, 1979. This was the week the Federal Reserve announced a more restrictive monetary policy. The associated rise in short-term interest rates sharply increased the opportunity cost of storing gold.

In the particular case of the futures contracts in Chart 1, the relevant opportunity cost is not a directly observable interest rate. Rather, it is a forward interest rate over a 10-month period beginning in December 1979 given implicitly in the term structure of interest rates. The forward rate implicit in the futures price spread for these contracts was in the neighborhood of 10 percent at an annual rate in the months before the October 6th policy change. The implicit forward rate increased to roughly 13 percent following the policy change. This observation is consistent with the view that the market anticipated persistently higher interest rates associated with tighter monetary policy. Consequently, the spread between gold futures prices increased because of the higher anticipated net marginal storage costs for holding gold.

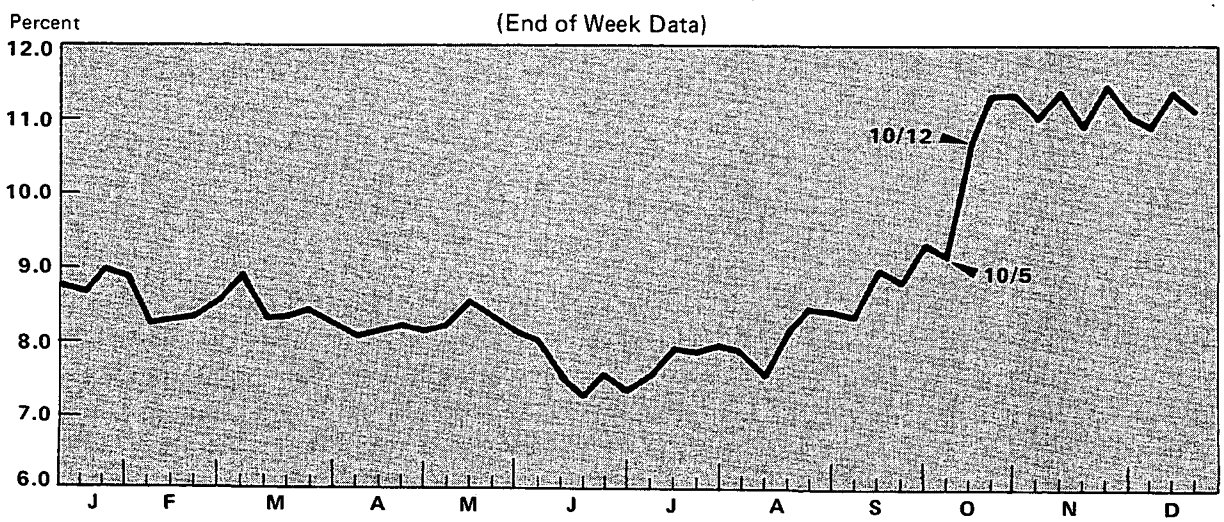
[5] A futures market is a market for the deferred (future) delivery of a commodity. The gold futures market broadens the time frame for buying and selling gold. Gold may be bought and sold for immediate delivery in the spot market, or it may be bought and sold today for deferred delivery via the purchase and sale of gold futures contracts. A futures contract is a legally binding agreement to buy or sell a standardized amount of a commodity in a specified future period at a specified price. The price of this financial instrument is determined in an open, competitive auction on the trading floor of a futures exchange. See [3, 5] for detailed discussions of futures markets.

[6] These contracts were traded on the Commodity Exchange in New York.

Chart 1

PERCENTAGE SPREAD BETWEEN THE OCTOBER 1980 FUTURES PRICE AND THE DECEMBER 1979 FUTURES PRICE DURING 1979

(End of Week Data)



II.
INTERPRETING GOLD PRICE MOVEMENTS

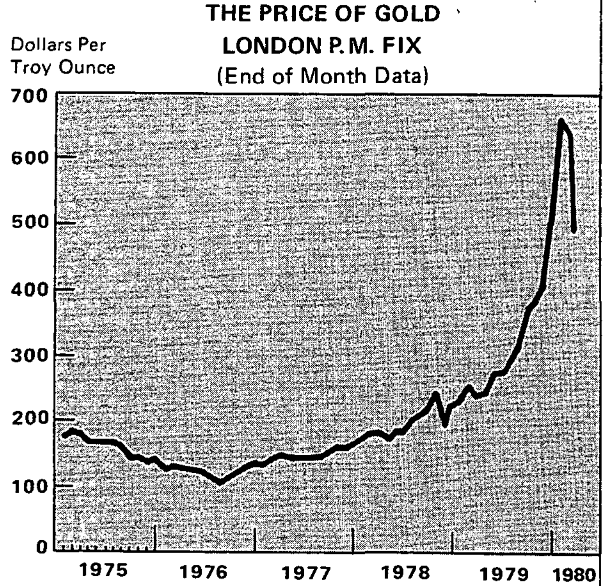
Gold prices change over the course of time because of the influence of disparate economic and political forces on the market. Generally, these influences affect the gold market simultaneously, though at times certain factors exert a greater impact on the market price than other factors. Chart 2 shows the path of the gold price since 1975, reflecting the net result of these various factors on the price of gold.

This section examines the probable causes of gold price movements. The economic and political forces that affect the gold market fall into the following basic categories: (1) extreme political and economic uncertainty, (2) flow supply and demand for gold, (3) inflation, and (4) government auction policy. No systematic attempt is made to single out events that may have affected the price of gold in particular instances since 1975. Rather, each factor is discussed separately with regard to its probable relative importance in causing price movements.

(1) Extreme Political and Economic Uncertainty. Gold is a unique commodity because throughout history it has been considered the ultimate store of value, a haven for the preservation of wealth, particularly in times of turmoil. Gold has served preeminently as a store of value for many reasons, the most important of which are outlined below.

Chart 2

THE PRICE OF GOLD
LONDON P.M. FIX
(End of Month Data)



Stocks of gold grow only very slowly because increasing stocks requires the use of much labor, capital, and time. Many other real assets share the quality of scarcity. For example, the stock of Rembrandt's masterpieces is also in fixed supply, and each painting is universally deemed to be an exceptional store of value relative to other assets. The critical difference between gold and Rembrandt paintings as stores of value stems from the relative liquidity of these assets. Gold is a homogeneous, divisible, and virtually indestructable asset; Rembrandt paintings are not. The difference in liquidity means that gold is readily marketable in any quantity. The transactions costs involved in auctioning Rembrandt paintings are considerable by comparison. These distinctions can be made for other real assets compared to gold as well. In short, few other real assets possess to the same degree the properties that create gold's demand as a store of value.

Times of economic turmoil and political upheaval tend to produce a demand for gold to safeguard wealth. Gold is a concentrated, anonymous asset. Wealth held in the form of gold is less susceptible to confiscation by governments than wealth held in other forms. Small quantities of gold generally exchange for large physical quantities of other real assets. Gold is therefore highly mobile compared to most other forms of wealth, ideal for taking flight across national boundaries. Also, wealth may be converted from gold into other assets without divulging the precious metal's history of ownership.

Particularly during 1979, the political and economic unrest that has beset much of the Middle East and neighboring Asia has engendered a considerable demand for gold as a store of value. Newspaper accounts of activity in the gold market routinely reported the market's speculation that the Middle Eastern demand for gold was the driving force behind the upsurge in the price of gold in late 1979 and early 1980. But before the international turmoil of 1979, other factors were probably more important causes of gold price movements.

(2) Flow Supply and Demand for Gold. Evaluating the impact of flow supply and demand on gold price movements requires a consideration of stock-flow relationships. On the one hand, the demand for gold consists of the derived demands for gold originating from goods fabricated using gold and of the demand for gold itself as an asset. On the other hand, the supply of gold consists of newly mined gold coming into the market and of gold being drawn from stocks. The salient characteristic of gold markets is that changes in flows, i.e., changes in the rate of commercial demand for gold or in gold's rate of production, affect the stock of gold insignificantly compared to changes in rates of production and consumption on the stocks of other storable commodities. For this reason flow supply and demand for gold have a relatively small impact on the price of gold.

Table I gives a rough estimate of the size and composition of the world gold stock in December 1975. Table II provides world gold production and consumption data since 1968. Official and private holdings of gold dwarf the magnitudes of gold production and consumption flows. Official stocks are equivalent to approximately 30 years' recent annual worldwide production, while readily marketable private stocks amount to slightly more than 10 years' annual production.

To put these stock-flow data in perspective, consider an alternative metal, copper, which differs

Table I

ESTIMATED WORLD GOLD STOCKS

(millions of troy ounces with metric ton equivalents)

Estimated Private Gold Stocks, December 1975

	million oz.	metric tons
Coins	400	12442
Private bullion holdings	75	2333
Industrial inventories	25	778
Total	500	15552

Source: Wolfe [13].

Official Gold Stocks, IMF and Central Banks of Non-Communist Countries, December 1975

	million oz.	metric tons
	1168	36322

Source: Samuel Montagu & Co. [1].

Estimated Quantity of Gold in Artwork and Jewelry

	million oz.	metric tons
	1000	31104

Source: Wolfe [13].

Table II

GOLD FLOWS 1968-1978[1]

Components of Supply
Metric Tons

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Non-Communist world mine production	1245	1252	1274	1236	1183	1121	1006	953	967	968	969
Net trade with Communist bloc[2]	−29	−15	−3	54	213	275	220	149	412	401	410
Official sales[3]	620	−90	−236	96	−151	6	20	9	58	269	362
Net private purchases	1836	1147	1035	1386	1245	1402	1246	1111	1437	1638	1741

Components of Demand
Metric Tons

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Fabrication categories:											
Carat jewelry	912	904	1062	1060	996	512	220	519	931	996	1001
Electronics	82	100	89	86	105	127	92	67	76	77	85
Dentistry	60	60	59	63	66	68	57	62	76	82	87
Other industrial/decorative uses	58	63	62	69	71	72	67	60	66	67	75
Medals, medallions, and fake coins	40	44	54	52	41	21	7	21	47	47	46
Official coins	68	26	46	54	63	54	287	244	184	137	259
Total fabrication categories	1221	1197	1372	1383	1341	854	729	973	1380	1405	1552
Net private bullion purchases[4]	615	−50	−337	3	−96	548	517	138	57	233	189
Net private purchases	1836	1147	1035	1386	1245	1402	1246	1111	1437	1638	1741

[1] For the non-Communist world.

[2] Most of the Communist bloc total represents sales of newly mined gold by the Soviet Union.

[3] Definition of official sales has been extended from 1974 to include *activities of government controlled investment and monetary agencies* in addition to central bank operations. This category also includes IMF disposals.

[4] This category excludes coins, but includes small bar hoarding and all other forms of bullion investment.

Source: Consolidated Gold Fields Limited, *Gold 1979*.

greatly from gold in terms of the foregoing economic relationships. As a base or nonprecious metal, copper is mined in huge amounts compared to gold or other precious metals and has wide-ranging industrial uses. Based on Bureau of Mines data, world mine production of gold and copper in 1977 was respectively 1,212 and 7,687,000 metric tons. Commercial stocks of copper in the United States amounted to 522,000 metric tons as of December 31, 1977, increasing 4.9 percent over the previous year. In 1977, industry used 2,050,000 metric tons; U. S. refinery production and refined imports of newly mined copper came to 1,712,000 metric tons. (This figure does not include 410,000 metric tons of copper recovered from scrap.) The high ratio of consumption and production to stocks on hand for copper gives these flows the potential to affect the price dynamics in the copper market significantly.

In sharp contrast to the copper market, the commercial use of gold is a relatively unimportant component of the total demand for this precious metal. Unfortunately, statistics on gold and copper stocks are difficult to compare because only data relating to commercial stocks are reliable. Statistics relating to private noncommercial stocks are largely conjectural. According to the estimates in Table I, commercial inventories represent only 5 percent of the estimated private world gold stocks in December 1975. Bureau of Mines data show that in the United States commercial gold stocks constituted 59 percent of year-end 1977 gold stocks. The remainder consisted predominantly of gold bullion. This statistic for the U. S. does not include the considerable quantity of gold coins held privately.

The copper price might behave differently from the gold price owing to the particular stock-flow relationships in the two markets. Because of the relatively great quantities of copper held in storage, marginal outlay costs are probably substantial for firms using copper as an input to production. To minimize costs, therefore, industries probably draw more copper from current copper production than from copper stocks. Firms store copper primarily to have stocks on hand to maintain a smooth flow of production of goods fabricated with copper. These commercial stocks provide a convenience yield to the firm for the reasons discussed in the preceding section. It should be noted, of course, that a small fraction of gold stocks is held for its convenience yield analogously to copper stocks. However, most gold stocks may be termed speculative stocks, i.e., stocks for which the primary motivation for ownership rests on an anticipation of capital gain. Because of the great industrial demand for copper, however, commercial stocks are likely to be of far greater magnitude than purely speculative copper stocks.

The greater relative magnitude of flows to stocks and the greater price sensitivity of flow supply and demand to the current price for copper compared to gold could potentially make for differences in the price dynamics of these two metals. For example, events temporarily affecting production (such as a strike) or consumption (such as a recession) are more likely to affect the price of copper than gold. As another example, a speculatively induced fall in the spot price would be more likely to reduce current production and increase current consumption for copper than gold. The greater production and consumption effect could tend to offset the initial spot price fall and prolong the price adjustment to anticipated future disturbances.

(3) **Inflation.** The following provides an analysis of the effects of a fully anticipated inflation on the path of the gold price. Suppose there occurs an increase in the government budget deficit. Furthermore, suppose it to be financed largely with money creation so that the public comes to expect an increase in the long-run rate of money growth and an associated increase in the long-run rate of inflation. What happens to the price of gold?

Because this is a fully anticipated increase in the rate of inflation, an inflationary premium is incorporated into the nominal rate of interest. For example, if anticipated inflation rises by 5 percentage points, the nominal rate of interest will rise by the same amount. This means, first of all, that the new long-run equilibrium rate of gold price *appreciation* will be higher by 5 percentage points. In other words, in the new long-run equilibrium the gold price will rise at the new, higher general rate of inflation.

Figure 2 illustrates these changes in the path of the gold price. The change in the rate of money growth and inflation occurs at time t. For reasons outlined above, the tilt of the gold price path is greater after time t. But the whole "level" of the price path is shown to shift up at time t as well. Why should this be the case?

The dollar price of gold is the relative price of gold in terms of dollars. The relative price depends on the demand for gold relative to dollars, which in turn depends on the relative anticipated rate of return on gold versus dollars. Inflation and the increased anticipated capital gain on gold increases the return on gold relative to money. It is the one time perma-

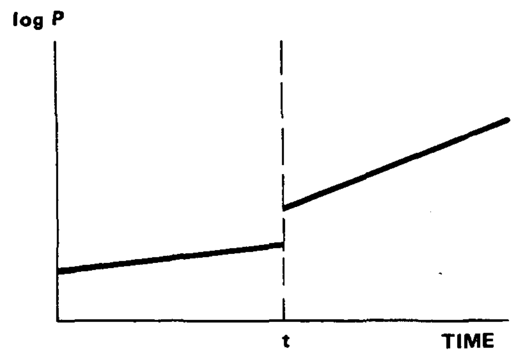


Figure 2

nent increase in the demand for gold relative to money associated with anticipated inflation that leads the entire price path to shift up at time t. This relative rate of return effect is partly responsible for the sensitivity of the spot price of gold to a change in anticipated inflation.[7] In the foregoing example, anticipated inflation rises by 5 percentage points. However, if the sensitivity of demand for gold relative to money with respect to a change in the anticipated rate of price appreciation is high, the jump in the gold price at time t could greatly exceed 5 percentage points.

(4) **Government Auction Policy.** Official gold stocks of the non-Communist world's central banks and the International Monetary Fund (IMF) amounted to 35,382 metric tons as of September 30, 1978. These stocks constitute roughly half of the world's gold stock and therefore have the potential to influence the gold price significantly if supplied to gold markets in sizable quantities. Particularly in the late 1970's, as seen in Table II, these official stocks of gold have contributed substantially to supplies of gold on world markets.

The International Monetary Fund and the United States Treasury have been principal sellers of gold through their auctions during this period. In January 1976, the IMF announced that it would sell one-sixth of its gold stocks via monthly auctions. The U. S. Treasury announced in December 1974 that it would conduct gold auctions. Two Treasury auctions occurred in 1975. Partly to support the exchange value of the dollar in 1978, the Treasury decided to hold regular monthly auctions commencing in May 1978. Both the Treasury and IMF auction series continue to the present day.[8] What are the probable effects of auctions on the price of gold?

An analysis of the probable effects of official auctions on the gold price based on the model of gold price movements is given in general terms in the following example. After an announcement by the U. S. Treasury of a gold auction, including the quantity to be auctioned and the time of the auction, the actual auction would have little effect on the gold price when it occurs if the market anticipates the auction. The market price would fall in reaction to the initial announcement, entirely discounting the effects of the auction before it takes place.

Obviously, the gold market does not predict the effects of such an auction perfectly; the market price changes as forecasts are revised. For example, if the demand at a given price has been underestimated at the time of the auction, the price will rise to clear the market.

III. EMPIRICAL EVIDENCE

This section presents empirical evidence in support of the model of gold price movements set forth in Section I. That simple model is based on the assumption that participants in the gold market are rational and act in their self-interest. The aggregate effect of their actions produces a particular path of the gold price. It is assumed that these market participants continually assess new information about the gold market and all the political and economic events that impinge on the supply and demand for gold. This view of the market implies that the apparently erratic short-run changes in the price of gold register the market's perception of changing economic events. Some important questions arise in this context. How quickly does the market respond to new information? Does the price of gold reflect available information at a given time, or does it take time for new information to affect the market price?

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[7] The price of gold is also likely to be more sensitive to changes in anticipated inflation than prices of other storable commodities. Gold is more liquid than other storable commodities since the transactions costs of bringing buyer and seller together tend to be less. Therefore, in response to a change in anticipated inflation, anticipated net revenue from storage can be maximized more readily for gold than for other commodities.

[8] On October 16, 1979, the Treasury changed its gold auction policy in a move officially designed to "deter speculation." Further auctions would be announced only several days in advance, at which time at least the minimum amount of gold to be auctioned would be disclosed. See **Wall Street Journal**, 17 October 1979, p. 4. One auction on November 1, 1979 has been undertaken by the Treasury under this new policy. See Henderson and Salant [12] for an account of the effects of this kind of policy on the price of gold. The last scheduled IMF auction will be in May 1980.

The economic theory of gold price movements implies that available information about the future price of gold is rapidly discounted into the current spot price. According to this theory, to the extent that stocks are sufficiently large relative to flows, successive price changes tend to be uncorrelated. Additionally, futures prices should be unbiased forecasts of future spot prices. In other words, errors in forecasting future spot prices should arise from unpredictable influences on future spot prices, not from systematic biases in predicting these prices. Forecast errors therefore should be uncorrelated and have zero mean.

Regression analysis is used to empirically evaluate the gold market's response to new information. The following regression estimates the amount of current price movement that can be explained (1) by past price movements and (2) by the level of a current interest rate. Price movements are expressed as monthly percentage changes, e.g.,

$$\Delta \ln P_t \equiv \ln P_t - \ln P_{t-1}.$$

The percentage change in the gold price in the current period, $\Delta \ln P_t$, is regressed on the percentage change in the gold price in preceding monthly periods, $\Delta \ln P_{t-1}$ and $\Delta \ln P_{t-2}$, and the yield on a security of one-month maturity, r_t. The regression equation is specified as follows:

$$(3) \quad \Delta \ln P_t = \alpha + \beta_1 r_t + \beta_2 \Delta \ln P_{t-1} + \beta_3 \Delta \ln P_{t-2} + u_t.$$

The disturbance term u_t captures any movements in the current price not explained by the included lagged percentage price change variables or by the interest rate.

The data consist of first-of-month gold prices as quoted at the P.M. Fixing of the London Gold Market and first-of-month Treasury bill yields (on a discount basis) of one-month maturity. These data span a period from January 1973 to December 1979, although after differencing and lagging the variables, the sample period runs from April 1973 to December 1979, containing 81 observations.

Equation 3 was estimated as follows:

$$\Delta \ln P_t = \underset{(.035)}{-.028} + \underset{(.519)}{.678} r_t + \underset{(.111)}{.056} \Delta \ln P_{t-1} + \underset{(.113)}{.043} \Delta \ln P_{t-2}$$

$R^2 = .039$ SEE $= .077$ SSR $= .461$ DW $= 1.99$[9]

As indicated by the R^2, this regression explains only 3.9 percent of the variation in the percentage change in the current gold price. The coefficients on the lagged percentage price changes are both insignificantly different from zero. (The standard errors appear in parentheses.) Current percentage price changes therefore appear to be statistically independent of percentage price changes in preceding months. In addition, the coefficient on the interest rate is significant at a 90 percent level of confidence, and the constant is insignificantly different from zero.

This test of statistical independence of price changes has a straightforward interpretation in terms of the model of gold price movements. The test results support the contention that market participants respond quickly, i.e., within a month, to new information. According to the empirical results, no further market price adjustment to that information occurs in the following month.

The interest rate coefficient also has an interesting interpretation. The model of gold price movements includes several assumptions about the components of net marginal storage costs. In particular, it was argued above that marginal outlay and convenience yield are negligible compared to marginal interest costs for gold. If this is in fact the case, other things held constant, a rise in the interest rate should cause an equiproportionate increase in the current percentage change in the gold price, i.e., the coefficient on the interest rate should differ insignificantly from unity.

The interest rate coefficient in the regression has an estimated value of .678, which is insignificantly different from unity and significantly different from zero at a 90 percent level of confidence under the appropriate one-tailed test. Even though the regression explains only a small amount of the variation in the current percentage price change, the interest rate is significantly correlated with the contemporaneous gold price change.

Viewed in isolation, the relatively weak significance of the estimated coefficient on the interest rate does not seem to shed much light on price movements. Is it reasonable to assume that the other marginal storage costs are negligible? A comparison of gold price movements with copper price movements can highlight several points about net marginal storage costs.

In particular, components of net marginal storage

[9] Because this regression includes lagged dependent variables, the Durbin-Watson statistic is biased toward 2 if there is no first order serial correlation in the residuals.

costs that are negligible for gold are likely to be important for copper. In the copper market, marginal outlay costs, especially for warehousing, may be an increasing function of copper stocks, and marginal convenience yield may be a positive, decreasing function of these stocks. Furthermore, net marginal storage costs are likely to be sensitive to changes in the physical volume of copper stocks held.

For example, an increase in the interest rate raises net marginal storage costs. If anticipations of future copper prices are unchanged, the current copper price would fall as holders of copper attempt to reduce their stocks in response to higher net marginal storage costs. The lower copper price would tend to reduce current production and increase current consumption, thereby reducing physical stocks. Consequently, net marginal storage costs would diminish because the marginal convenience yield would rise and marginal outlay costs would fall.

To evaluate the importance of an interest rate in explaining copper price movements, a copper price regression similar to the gold price regression is estimated. Since changes in marginal outlay and convenience yield are more likely to offset changes in the interest rate for copper than gold, the interest rate coefficient should come in less significantly different from zero in the copper price regression than in the gold price regression.

The sample period is the same as the period for the gold price series, and the data consist of first-of-month noon spot wirebar prices as quoted on the London Metal Exchange. The specification of the regression is the same as Equation 3.

The copper price equation was estimated as follows:

$$\Delta \ln P_t = .002 + .046 r_t + .187 \Delta \ln P_{t-1} - .054 \Delta \ln P_{t-2}$$
$$(.042) \quad (.606) \quad (.114) \qquad (.115)$$

$R^2 = .035$ SEE $= .095$ SSR $= .699$ DW $= 1.96$

The coefficient on the interest rate is insignificantly different from zero and significantly different from unity. The t-statistic for the interest rate is .0756, which indicates far less statistical significance than the t-statistic (1.307) for the interest rate in the gold price regression. The considerably greater significance of the interest rate coefficient in the gold price regression as compared to the copper price regression supports the theoretical differences advanced above about the composition of net marginal storage costs for these metals.[10]

The copper price regression also reveals that copper price changes are serially uncorrelated at a 95 percent level of confidence. However, evidence that price changes are serially uncorrelated is less clear in the copper price regression than in the gold price regression. The suggested potential importance of flow supply and demand responses to copper price movements discussed in Section III appears to be weakly discernible, since copper price changes are serially correlated at a 90 percent level of confidence.

As an additional test, the gold market's response to new information is examined in the relationship between futures prices and future spot prices. If the market absorbs new information rapidly, futures prices should be unbiased forecasts of future spot prices. In the particular test constructed, the logarithm of the spot price on the first trading day of the delivery month is regressed on the logarithm of the futures price on the first trading day three months earlier. The estimated equation is:

$$(4) \quad \ln S_t = \alpha + \beta \ln F_{t-3} + u_t,$$

where S_t is the spot price, F_{t-3} is the futures price for the same contract lagged three months, and u_t is a random disturbance term.[11]

These data include the relevant spot and futures prices on contracts that have traded on the Chicago Mercantile Exchange's International Monetary Market. New delivery months occur in March, June, September, and December of each year. Running from the September 1975 through the December 1979 futures contracts, the sample consists of 18 observations. The sample is small. Nonetheless, these data permit a useful test of the gold market's ability to assimilate new information.

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[10] There is a statistical problem with the copper price series that could bias the interest rate coefficient downward and reduce its t-statistic. The copper price is quoted in pounds sterling and was converted to dollars using a first-of-month exchange rate series derived from the Federal Reserve's dollar/pound daily certified noon buying rates for cable transfers in New York City. The pound sterling copper price series and the exchange rate series are not contemporaneous, but differ by six hours. It is doubtful that this statistical problem alone could account for the great disparity in statistical significance of the interest rate coefficient in the gold and copper price regressions. One way to avoid the problem would be to use a British Treasury bill yield series, but such a series was not available to the author.

[11] The logarithmic transformation is used because it is the proportionate difference between these variables that matters, not the absolute difference.

If futures prices are unbiased predictors of future spot prices, the constant in this regression should differ insignificantly from zero and the coefficient on the futures price should differ insignificantly from unity.[12] Such estimates would be consistent with the view that a one percent increase or decrease in today's futures price would result in a one percent change in the spot price in the same direction three months later.[13] Equation 4 was estimated as follows:

$$\ln S_t = -0.815 + 1.166 \ln F_{t-3}$$
$$(.520) \quad (.101)$$

$R^2 = .893$ SEE $= .124$[14] SSR $= .247$ DW $= 2.23$

At a 95 percent confidence level, the constant is insignificantly different from zero and the coefficient on the futures price variable is insignificantly different from unity.[15] The Durbin-Watson statistic indicates no first-order serial correlation in the residuals, i.e., forecast errors are uncorrelated.[16]

As an additional test, the futures price one month earlier, F_{t-4}, was added as a second explanatory variable:

$$(5) \quad \ln S_t = \alpha + \beta_1 \ln F_{t-3} + \beta_2 \ln F_{t-4} + u_t.$$

If futures price F_{t-3} reflects all available information at $_{t-3}$, including prices one month earlier, the estimated coefficient β_2 on the new explanatory variable should be insignificantly different from zero. In addition, the amount of variation in the dependent variable S_t explained by this regression, measured by the regression's R^2, should remain relatively unchanged. Equation 5 was estimated as follows:

$$\ln S_t = -0.929 + 1.000 \ln F_{t-3} + .190 \ln F_{t-4}$$
$$(.603) \quad (.424) \qquad (.466)$$

$R^2 = .894$ SEE $= .128$ SSR $= .244$ DW $= 2.07$

The inclusion of the second futures price does not increase the explanatory power of this regression and the new variable's coefficient differs insignificantly from zero at a 95 percent level. Though admittedly not very powerful because of the small sample size, this further test of the gold market's response to new information provides additional statistical evidence to support the basic model of gold price movements.

IV. CONCLUSION

Financial writers cite a variety of factors that influence gold price movements. These writers typically view the price of gold as a barometer of economic and political instability. Left unexplained, however, is the mechanism determining gold price movements that leads these prices to foreshadow changes in the rate of inflation, the stability of governments, official gold auction policy, etc. This article has explained the economics that underlies movements in the price of gold.

As argued above, gold differs only *in degree* from other storable commodities in the way various economic factors influence its price. The spot prices of all storable commodities, including gold, are particularly influenced by anticipations of future spot prices. In the case of gold, however, the relative insignificance of flow supply and demand compared to stocks, the relative insensitivity of flow supply and demand with respect to spot price movements, and the relative liquidity of gold all tend to make current changes in the gold price especially sensitive to changes in its anticipated future spot price.

The episodic run ups and run downs in the price of gold associated with periods of economic and social turmoil have fascinated and frequently bewildered observers of the gold market. At such times, analysts often conclude that mob psychology overwhelms the

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[12] A further test of the independence of forecast errors involves a direct measure of serial correlation in these errors. The parameters α and β in regression 4 are constrained to equal 0 and 1 respectively, and the logarithm of the futures price is subtracted from the logarithm of the spot price to give a series of percentage forecast errors, FE. This procedure of constraining the coefficients in effect makes the assumption that forecast errors are indeed independent. An autoregression of these forecast errors directly tests the hypothesis that these errors are uncorrelated. The autoregression follows:

$$FE_t = .051 - .024 FE_{t-1} + .304 FE_{t-2}$$
$$(.034) \quad (.283) \qquad (.280)$$

$R^2 = .085$ SEE $= .129$ SSR $= .217$ DW $= 2.06$

The hypothesis that forecast errors are uncorrelated and have zero mean cannot be rejected at a 95 percent level of confidence.

[13] Note that by the delivery month the spot price may diverge from its futures price forecast as the market responds to new information received in the intervening period.

[14] Note that in this regression the standard error of estimate (SEE) multiplied by 100 is the average percentage forecast error over the sample period.

[15] The joint restriction that $\alpha = 0$ and $\beta = 1$ could not be rejected at a 90 percent level of confidence using the appropriate chi-square test with 2 degrees of freedom.

[16] Estimated residual autocorrelations at lags 1 and 2 were insignificantly different from zero at a 95 percent level of confidence.

market as market participants lose sight of so-called market fundamentals. However, the theory and empirical evaluation of gold price movements presented here demonstrate that *ad hoc* appeals to mob psychology are unnecessary to explain the behavior of the gold price. In other words, economic theory appears sufficient to account for gold price movements in recent years.

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