SUPPLY AND DEMAND FOR GOLD

by

Howard N. Haugom

M.A., University of Victoria, 1984

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in the Department

of

ECONOMICS

SIMON FRASER UNIVERSITY

December, 1990

APPROVAL

Name: Howard Haugom

Degree: Ph.D. (Economics)

Title of Thesis: The Supply and Demand for Gold

Examining Committee:

Chairman: Dr. T. Heaps

Dr. Herbert G. Grubel
Professor
Senior Supervisor

Dr. Steven T. Easton
Associate Professor

Dr. Zane Spindler
Associate Professor

Dr. James W. Dean
Professor

Dr. Robert Mundell
Professor
Columbia University
External Examiner

Date Approved: Dec. 7, 1990

PARTIAL COPYRIGHT LICENSE

I hereby grant to Simon Fraser University the right to lend my thesis, project or extended essay (the title of which is shown below) to users of the Simon Fraser University Library, and to make partial or single copies only for such users or in response to a request from the library of any other university, or other educational institution, on its own behalf or for one of its users. I further agree that permission for multiple copying of this work for scholarly purposes may be granted by me or the Dean of Graduate Studies. It is understood that copying or publication of this work for financial gain shall not be allowed without my written permission.

Title of Thesis/Project/Extended Essay

The Supply and Demand for Gold

Author: _____
(signature)

Howard Haugom
(name)

Dec. 3 /90
(date)

ABSTRACT

The purpose of this dissertation is to analyze the major fundamental factors influencing the physical gold market. What distinguishes this study from other gold studies is its scope. One of the largest and most extensive historical databases of gold demand and supply variables has been compiled.

The dissertation is also unique in that it pays special attention to the supply side of the gold market, investigating how growing production has and will impact the market. A model of South African production is developed and unlike other gold studies, supply variables are incorporated in the reduced-form gold pricing models. In addition, the dissertation theoretically and empirically identifies the major factors influencing gold demand.

Supply and demand curves for each of the supply and demand components are estimated using a method similar to the Fair Method. The Fair method is a two stage least squares technique with an adjustment for autocorrelation.

Supply curve estimation results indicate there is a tendency towards low adjustment speeds. This is reflected in long run elasticities being greater than short run elasticities. In the case of South African production and Net Communist sales, both long and short run supply elasticities were inelastic. It was found that the long run supply curve for Other Country production is elastic.

On the demand side, adjustment speeds were found to be extremely high, meaning that there is very little difference between long and short run elasticities. In general, the demand elasticities were low in both the long and short runs.

In conclusion, the dissertation found that as Other Country gold production increases, as a percentage of total world production, this will cause the long run total supply curve to become more elastic. With demand being relatively inelastic, this implies that shifts in supply will impact the gold price rather than the physical quantity of gold. In contrast, with supply becoming more elastic, shifts in demand will impact the physical quantity of gold rather than the dollar gold price. In addition, it is shown that the introduction of supply variables in the reduced form gold pricing models significantly improves each models explanatory performance.

To Fiona

For her patience and loving support

Gold! Gold! Gold! Gold!
Bright and yellow, hard and cold,
Molten, graven, hammer'd, and roll'd;
Heavy to get, and light to hold:
Hoarded, barter'd, bought, and sold,
Stolen, borrow'd, squander'd, doled:
Spurn'd by the young, but hugg'd by the old
To the very verge of the churchyard mould;
Price of many a crime untold:
Gold! Gold! Gold! Gold!
Good or bad a thousand-fold.

Thomas Hood.

I would like to thank Dr. Herbert Grubel, Dr. Steve Easton, Dr. Zane Spindler and Alastair Murdoch for their support, assistance and helpful comments on the dissertation.

Table of Contents

List of Tables

Graphs

Figures

CHAPTER 1

INTRODUCTION

Man's interest in gold has been ongoing for thousands of years. Its historic reputation was founded on unique properties. Its yellow colour and the ease with which the metal could be worked made it a highly desired metal for use in art, decoration and industry. Its rarity, indestructibility, density and malleability, ensured it as an excellent store of value and medium of exchange.

As a result of these properties, the exploration of gold has been of central importance to man for centuries. Christopher Columbus' journey westward was largely motivated by his search for gold. To Spanish explorers the instruction of King Ferdinand was plain, " get gold, humanely if you can, but at all costs get gold!". The era of gold production that followed the discovery of the Americas was the greatest the world had witnessed to that time.

In the second great era of expanding production (1851-

1885) more gold was produced in the world than in all the years since 1492, chiefly because of the discoveries in California and eastern Australia. (See Tables 1 and 2).

TABLE 1: HISTORICAL GOLD PRODUCTION
(tonnes)

Period	Period Output	% of Total
1493 - 1600	759.0	0.8
1601 - 1700	916.0	0.9
1701 - 1800	1,911.0	1.9
1801 - 1850	1,191.0	1.2
1851 - 1885	6,316.0	6.4
1886 - 1929	21,350.0	21.6
1930 - 1959	27,424.0	27.7
1960 - 1987	39,047.0	39.5
Total since 1493	98,914.0	100.0

Sources: Busschau (1948), and various issues of Consolidated Gold Fields

The third significant increase in gold production occurred in the late 1800's. Major gold discoveries were made on the Witwatersrand (White Waters Ridge) in South Africa in 1886 and in the Western Klondike area of Canada in 1896. The discoveries in South Africa were of such importance that they significantly altered the supply picture of gold. Even though South Africa was not a producer of gold prior to 1886, to date it has produced roughly 50% of

the worlds current stock of gold.

The impact of the discovery of gold in South Africa can be seen in Column C in Table 2.[1] In the 1850's, world production of gold totalled 531 tonnes and during the 1860's production increased significantly to over 2000 tonnes, the majority of this increase coming from South Africa. South Africa production in the 1960's and 1970's averaged 850 tonnes per year and during the 1970's South African production comprised roughly 80% of total non communist production. Graph 1 illustrates the degree of concentration in gold production and the importance of South Africa.[2]

---

1. Table 2 gives a numerical picture of how gold stocks and flows have changed by decade for the last 187 years. Column (B) is a stock figure indicating the amount of gold that has been mined to date. Column (C) is the amount of gold that was produced in the respective decade. Column (D) is an estimate of official reserve stocks. Column (E) is the amount of reserves that have been added to the stock in the decade. Column (F) is the stock of gold that has been absorbed in fabricated products. Column G is the flow of fabricated gold. Column (H) is an estimate of the stock of gold held for private investment purposes (Column B - D - F). Column (I) is an estimate of the amount of gold demanded in each decade by private investors. This is determined by subtracting Column G and E from C.

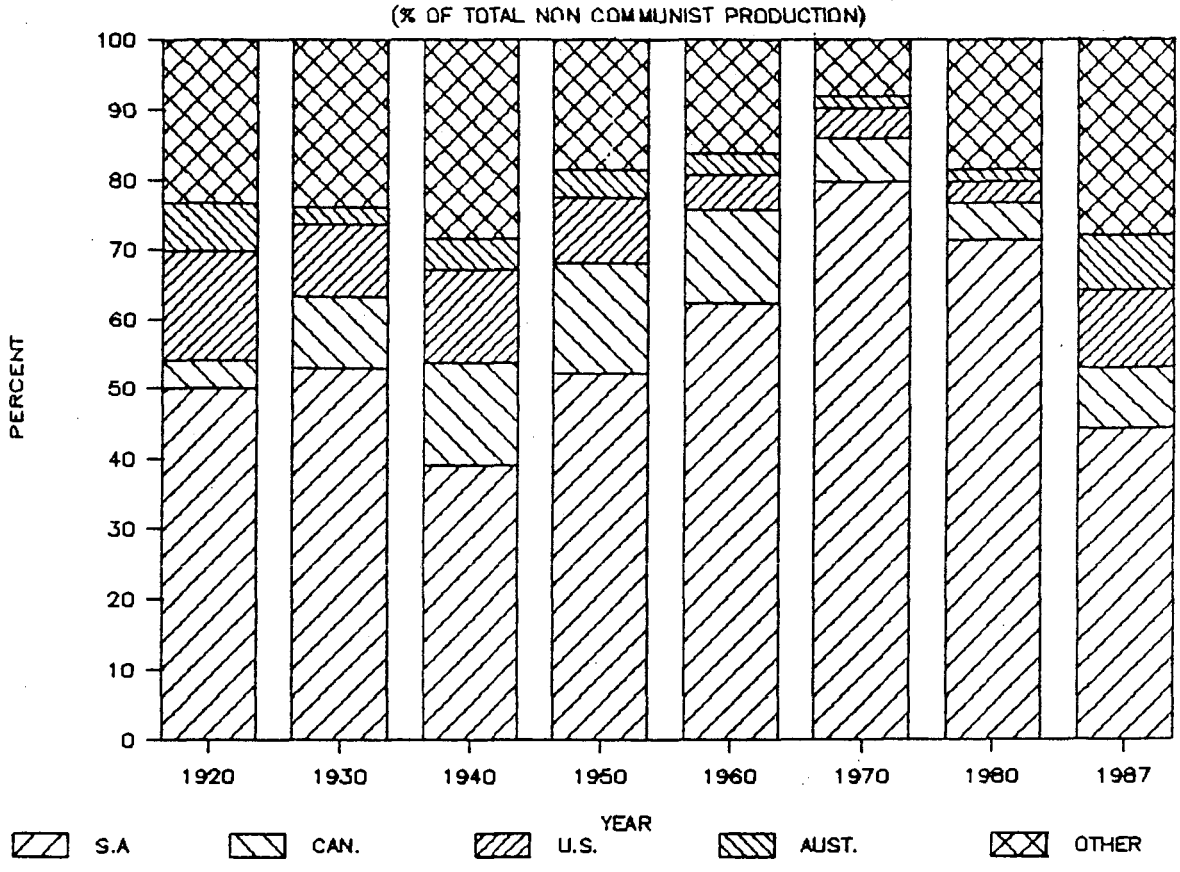
2. Graph 1 only includes non communist gold production.

TABLE:2 WORLD PRODUCTION, DISTRIBUTION, AND GOLD STOCKS, 1800-1987
(TONNES)

(A) FOR DECADE ENDING	(B) CUMULATIVE WORLD MINE PRODUCTION	(C) INCREMENT IN WORLD MINE PRODUCTION	(D) ESTIMATES OF OFFICIAL RESERVE STOCKS	(E) INCREMENT IN OFFICIAL RESERVES	(F) CUMULATIVE ABSORPTION IN FABRICATED PRODUCTS	(G) INCREMENT IN ABSORPTION IN FABRICATED PRODUCTS	(H) PRIVATE INVESTMENT RESIDUAL	(I) INCREMENT IN PRIVATE INVESTMENT RESIDUAL
1800	3515							
1810	3697	182			2494			
1820	3816	119			2519	25		
1830	3962	146			2563	44		
1840	4166	204			2717	154		
1850	4697	531			3007	290		
1860	6707	2010			3522	515		
1870	8607	1900			4518	996		
1880	10367	1760			5638	1120		
1890	11996	1629			6700	1062		
1900	15156	3160	3732	3732	7882	1182	3542	
1910	20899	5743	6320	2588	10263	2381	4316	774
1920	27318	6419	10918	4598	12843	2580	3557	-759
1930	33109	5791	16470	5552	14809	1966	1830	-1727
1940	42928	9819	26059	9589	15450	641	1419	-411
1950	51814	8886	33571	7512	16486	1036	1757	338
1960	61594	9780	37950	4379	21442	4956	2202	445
1970	75600	14006	38661	711	32061	10619	4878	2676
1980	88848	13248	37693	-968	41485	9424	9670	4792
1987	99469	10621	38402	709	48910	7425	12157	2487

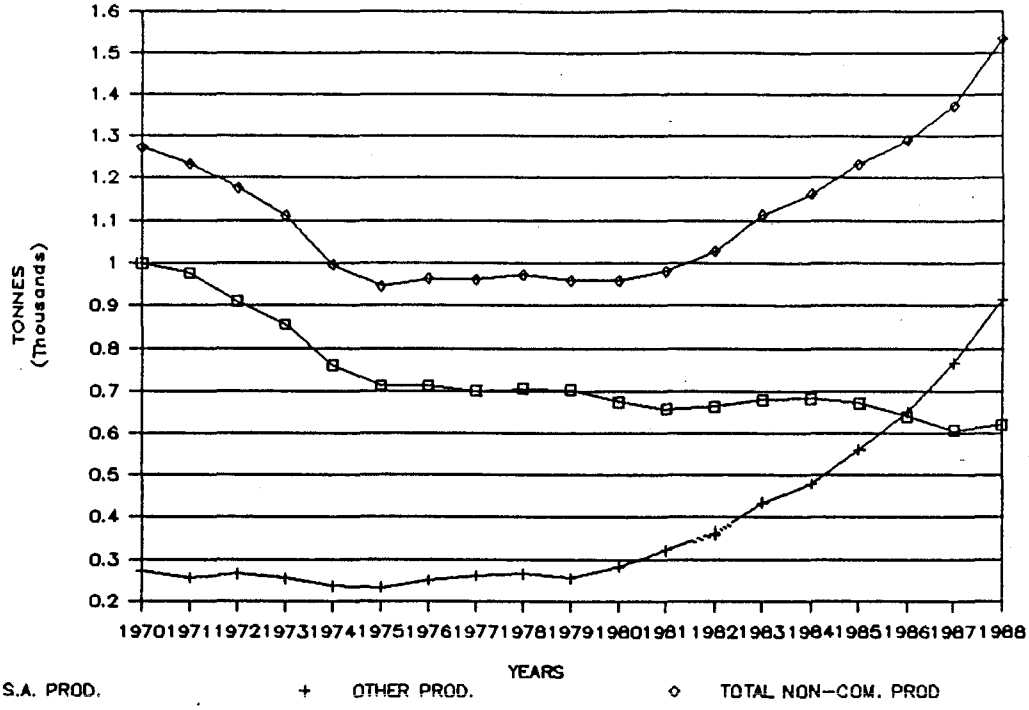
Sources: Sherman(1986), Consolidated Gold Fields "Gold 1988". Note: 1987 only includes 7 years of production.

GRAPH 1: GOLD PRODUCTION, 1920–1987



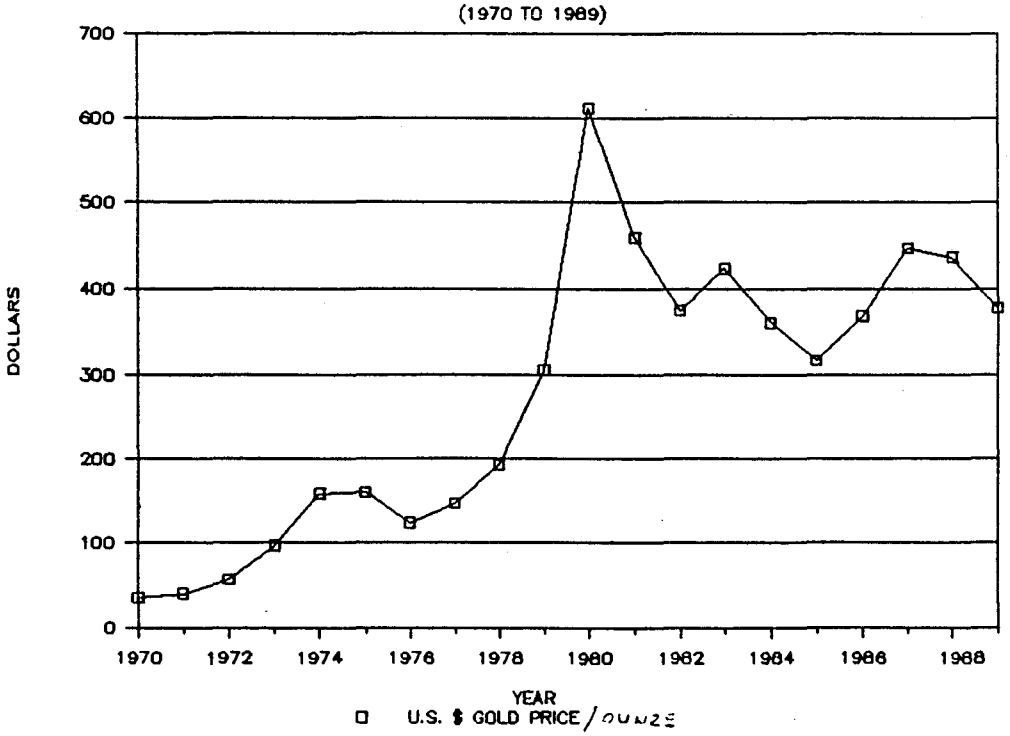
GRAPH 2: NON COMMUNIST GOLD PRODUCTION

1970–1988



GRAPH 3: U.S. DOLLAR GOLD PRICES

(1970 TO 1989)



The fourth explosion in world gold production is currently taking place. Since the gold price was allowed to float in 1971, gold mining has become highly profitable. It has been estimated that 80% of the exploration budgets of today's mining companies are now devoted to finding gold.[3] This has resulted in a dramatic increase in annual gold production. It is estimated that in 1988 annual non communist gold production reached a record high of approximately 1550 tonnes.[4] This compares with the average of 1000 tonnes per year that occurred between 1890 and 1980.

As seen in Graph 2, the increase in non communist gold production has occurred despite a significant decline in South Africa production. Dramatic increases in gold production have been seen in Canada, the U.S., Latin America and Australia. By comparison South African gold production as a percentage of the total has fallen by more than 30% since 1970 (See Graph 1). Bache (1987) has

---

3. See Green (1987).
4. Total world gold production is estimated to have been approximately 1700 tonnes.

estimated that in the past seven years, reserves of more than 7000 tonnes of gold (non communist) have been discovered.[5]

If non South African gold production continues to increase, the question arises, who will buy this gold and more importantly at what price can it be absorbed? As seen from Graph 3, despite the dramatic increase in gold production since 1980, the nominal U.S. dollar gold price has remained relatively stable fluctuating around the $400.00 U.S. mark.

The continued strength in the nominal price of gold over the last 10 years has been due two factors.[6] While fabrication demand was relatively strong over the period, gold prices were buoyed by high investment and official reserve gold demand. Clearly the concern is that if production continues to increase and if investors and speculators lose interest in gold as an investment vehicle, the price of gold could fall significantly.

---

5. Bache (1987) p. 147-159. He added that the estimate was understated as the Sierra Paleda deposits in Brazil and Hemlo deposits in Canada have as yet not been fully explored.
6. See Appendix A for detailed supply and demand statistics for the period 1968-1987.

While many opinions and beliefs, many erroneous, have arisen concerning gold market fundamentals, very little systematic economic analysis has been awarded the subject. The intention of this study is to correct and expand on many of the theories and notions concerning the fundamental supply and demand factors influencing the physical gold market.

What makes this study unique is its scope of analysis and its attention to the supply side of the gold market. One of the largest and most extensive historical gold supply and demand databases has been compiled. A model of South Africa production is developed and unlike other gold studies, supply variables are incorporated in several reduced form gold pricing models. In addition, this paper theoretically and empirically identifies the major factors influencing gold demand and supply; identifies long and short term supply and demand curves for various components; presents several reduced form gold pricing models using each to forecast gold prices under a variety of assumptions.

The dissertation is structured as follows. Chapter 2 reviews theoretical gold market model literature and previous empirical work undertaken on gold supply and demand.

Chapters 3 and 4, respectively, focus on the supply and demand determinants of gold. Chapter 5 reports the empirical test results of the Supply and Demand analysis. Chapter 6 presents several reduced form gold pricing models and several gold price forecasts. Chapter 7 summarizes the findings of this paper.

CHAPTER 2

LITERATURE REVIEW

To gain insight on how the gold market has operated over the last 100 years a review of the major theoretical models dealing with the determination of the relative price of gold under the gold standard, the gold exchange standard and the post-1971 era is required.

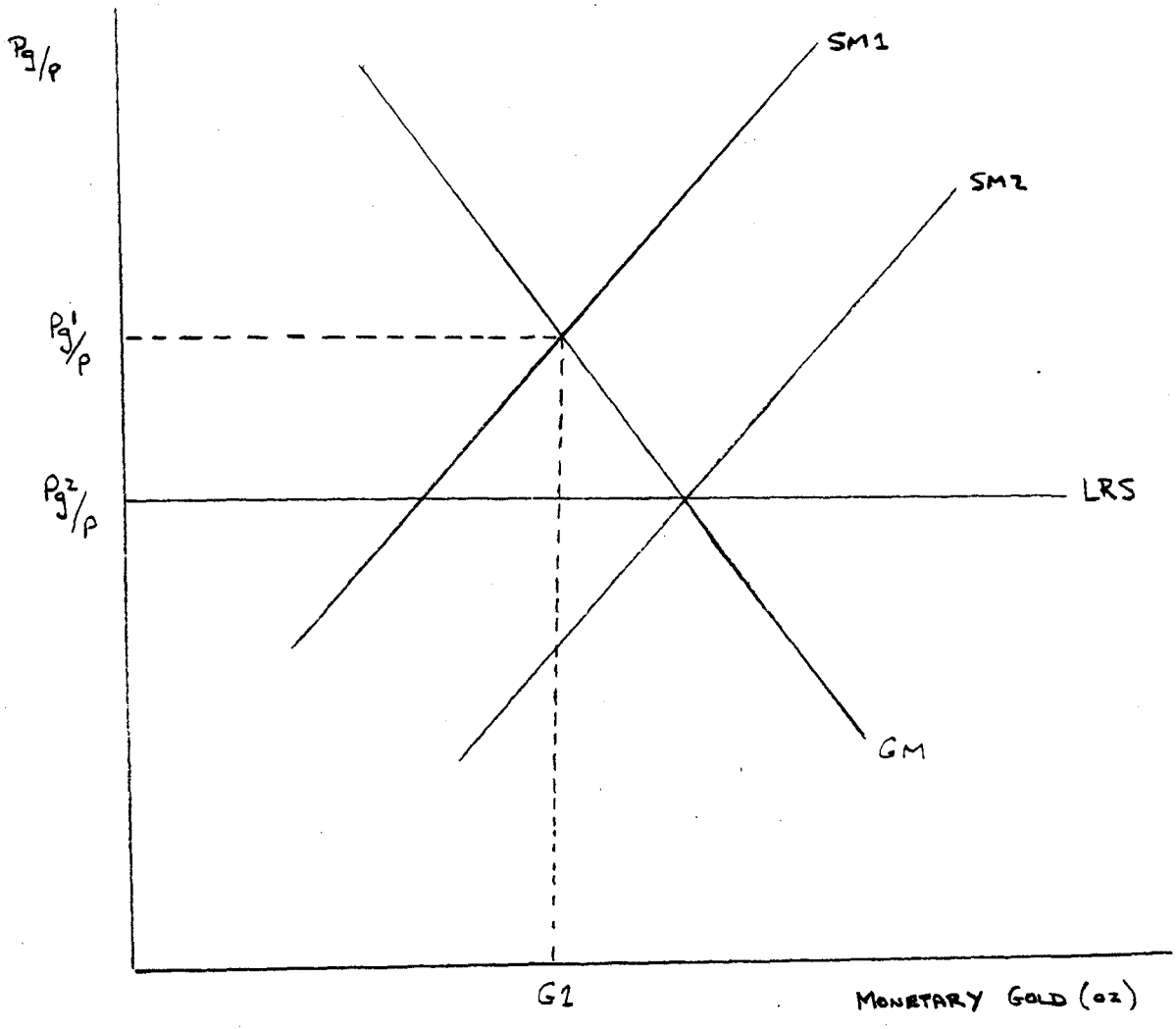
During the gold standard and to a lesser degree in the gold exchange standard, gold was a monetary metal in which the price of gold was fixed and the central banks were required to purchase the excess supply after non-monetary gold demand was satisfied. Figure 1 displays the basic gold standard supply and demand relationships as perceived by classical theorists.[7]

Pg/P is the real price of gold where Pg is the nominal fixed price of gold and P is the commodity price level. The real price of gold at time 1 (Pg1/P) is determined by the intersection of the short run supply curve SM1 and the demand

---

7. This model is similar to the one presented by Barro (1979) except his depicts flow equilibrium. See also Niehans (1978) (p. 156-165). It should be noted that Figure 3 portrays stock equilibrium. While the impact of flow equilibrium is important the figure is used to illustrate simply the determinants of the relative gold price.

Figure 1. SUPPLY OF AND DEMAND FOR MONETARY GOLD



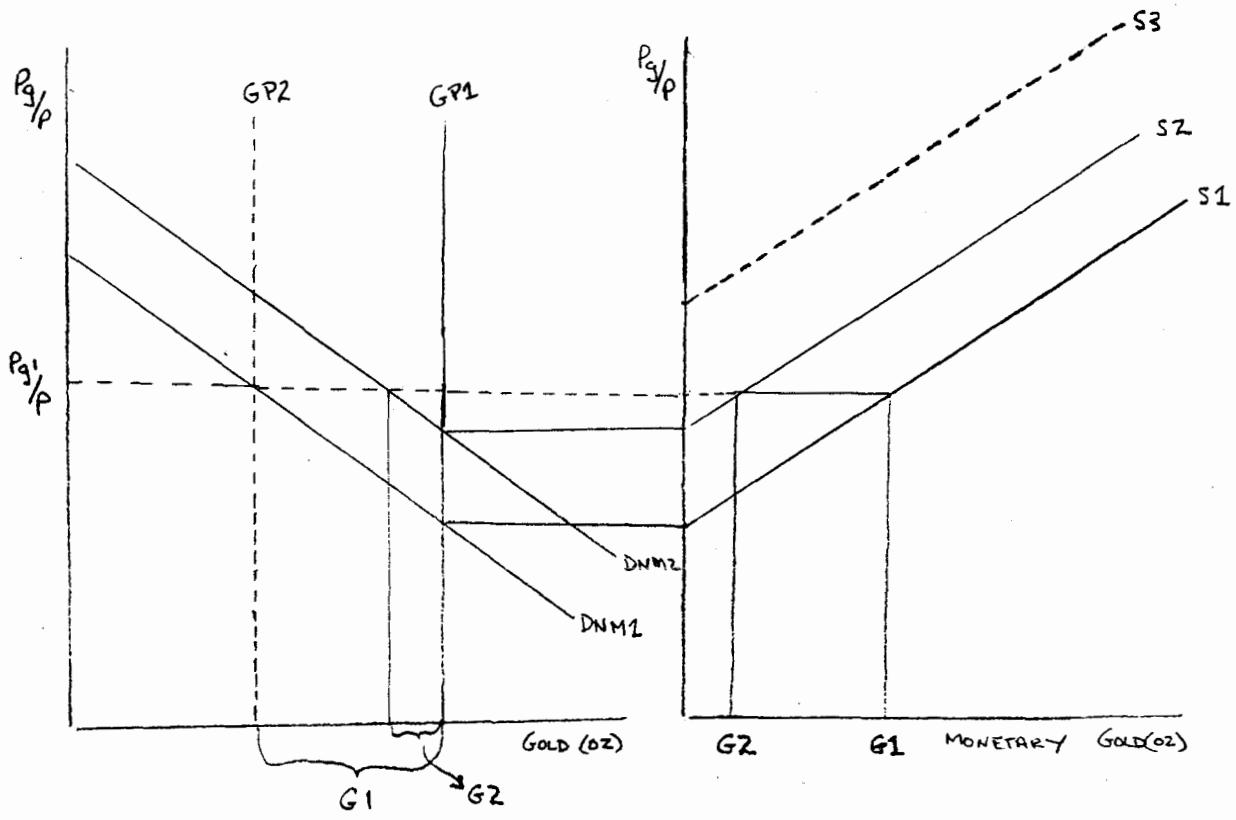
curve GM. The short run monetary supply curve is upward sloping due to non-monetary stocks of gold (Industrial, Ornamental).[8] As the real value of gold increases the non-monetary demand decreases leaving more available for monetary purposes. Assuming price Pg1/p the amount of monetary gold (G1) available is equal to the gold production (GP1) at time 1 minus the demand for non-monetary gold (DNM1) at time 1. (See Figure 2).

Assuming that gold production (GP1) is fixed in period 1, shifts in the demand for non-monetary gold (DNM1 to DNM2) because of changes in fashion, income, industrial or technological changes would shift S1 upward to the left to S2. If gold production falls in period 2 to GP2, then the monetary supply curve would shift upward to the left to S3, and the amount of monetary gold available at Pg1/p would be zero.

---

8. See Barro (1979). In most classical models it is assumed there is no speculative demand component for gold. The public never fears a suspension or devaluation as Pg is fixed. Fremling's (1986) model of the gold standard expanded on the classical and assumed that gold was not only held for industrial uses but for speculative purposes. As gold is an excellent store of wealth and is highly liquid, Fremling assumed that gold would be demanded for speculative reasons. As a result, in the short run, non-monetary gold demand is a function of not only those variables previously outlined but of real interest rates which represent the opportunity cost of gold held and the expected depreciation of the currency relative to gold.

FIGURE 2: Derivation of Monetary Supply Curve



Returning to Figure 1, the demand curve for monetary gold (GM) is determined by the following factors. The first, the demand for money, is explained by the quantity theory of money. For an increase in real income the demand curve (GM) would shift to the right. The second, the ratio of nominal gold stocks to nominal money stocks, is determined by the public preferences with respect to monetary assets and banking reserve requirements. The last factor determining GM is the nominal price of gold. Due to the quantity theory of money the demand curve slopes downward because as the real value of gold falls the demand for money balances increases.

With respect to gold production, classical theorists viewed gold producers as revenue maximizers, each of whom regarded the nominal price of gold (Pg) and the price level (P) as exogenous. This resulted in the marginal cost of the rate of gold production being equal to the real price of gold. This implied a supply function of newly produced gold of the form

$$gs = gs(Pg/P)$$

where gs is the supply of newly produced gold. As it was

argued that gold was not an exhaustible resource and costs in the long run were constant, the long run supply curve (LRS) was assumed to be perfectly elastic.[9]

Therefore the equilibrium determined by the short run supply curve at time 1 (SM1) and the demand curve (GM) would be temporary, as it is above the long run supply curve. Real prices above Pg2/p would result in new mines starting up and existing firms increasing production. This would result in the short-run supply curve shifting downward to the right. During this inflationary period the real price of gold would fall until the real price of gold had fallen back to Pg2/p.

Assuming a constant cost supply curve meant that non-monetary factors such as changes in income and fashion could not affect the real gold price in the long-run. Supply was a function of the real price of gold with the nominal price of gold set by the government. Bordo and Ellson (1986) combined the classical model with an exhaustible resource model. In the classical model, as already noted, gold production was

---

9. Possibly because of ever increasing gold supplies during the 19th century, classical economists in large part ignored the question of exhaustion. See Rockoff (1984). However, Bordo (1982) noted that classical economists such as Cantillon, Hume, Ricardo, and Mills all expressed concern over the availability of gold. In addition, Bordo noted that Adam Smith had suggested that in the long run the world stock of money and its exchange value would be determined by the continued richness of gold mines.

strictly a function of the real price of gold. Treating gold as a durable finite resource meant that production was now not only a function of the real price of gold but also of the cost characteristics of production and the amount of gold mined previously. In addition, as the Hotelling rule states that the real price of an exhaustible resource will increase at the real rate of interest, production would also be a function of the interest rate.[10]

Recognizing the fact that the exhaustible resource model had failed to capture gold price movements since the price of gold was allowed to float and Central Banks were no longer required to purchase excess gold, Salant and Henderson (1978) identified three important features of the gold market which were omitted from the resource model.

1) Extraction costs have not been constant and have increased significantly.

2) Government sales of gold stocks are very large and may significantly effect gold demand and therefore price.

3) In the resource model, speculators will only hold gold if the gold price is increasing at the rate of interest. Salant and Henderson (1978) also suggested that individuals may derive non-monetary services or returns from gold which

---

10. See Levhari and Pindyck (1981) for a detailed discussion on the pricing of durable exhaustible resources.

may often outweigh the rate of interest.

Having identified the problems with classical/resource gold models, Salant and Henderson's (1978) model, with the exception of including the possibility of government gold sales, contained all the assumptions of the simple resource model, paying limited attention to the supply side of the market.

The model of the gold sector in a world without monetary gold, developed by Flood and Garber (1980), was similar to the one developed by Salant and Henderson (1978) but with several modifications. Flood and Garber (1980) described the gold market as follows.

$$(1) \quad WS = C(t) + I(t)$$

$$(2) \quad \dot{C}(t) = V(C^*(P(t) - C(t)) \qquad C^{*\prime} < 0$$

$$(3) \quad \dot{P}(t) = rP(t) \qquad \text{for } I(t) \neq 0$$

Equation (1) says that the total world gold stock (WS), available is held either for investment purposes (I(t)) or for non-speculative reasons (C(t)). (C(t) also includes the amount of gold in the ground). Equation (2) describes how desired non-speculative demand (C*(Pt)) which is negatively

related to the relative gold price (P(t)), adjusts to actual non-speculative holdings. In this equation, V is the speed of adjustment. Equation (3) states that the relative price of gold must at least increase by the real rate of interest (r) to be held for speculative purposes. For example, if $\dot{P}(t)/P(t) < r$ there would be no demand for speculative gold holdings, and as a result the gold price would fall.

This model differed from Salant and Henderson's in that it allowed for non-speculative gold to return to speculative stocks through dishoarding (Equation 2). Flood and Garber's model was however similar to that of Salant and Henderson's in that it assumed gold to be costlessly produced. In each model, gold is assumed to initially exist in pure bar form.

While the preceding theoretical models have helped to increase our understanding of how the gold market functions, they have failed to depict how the gold market actually operates and how prices are determined. Certainly with flexible gold prices, demand by individuals is a complex mixture of motives: hedging, hoarding, speculative and portfolio diversification. Likewise, gold supply is difficult to estimate due to the uncertainty regarding the discovery of new ore bodies, the use of lower-grade ore

stockpiles, a country's balance of payments situation, costs of production and the expected future price of gold.

Combining the above problems with the unavailability of quality supply and demand gold statistics, very little empirical work has been undertaken in estimating price elasticities of gold supply and demand. Instead, what most gold studies have done is to estimate equilibrium price using a simple reduced form model. Baker and Van Tassel (1985) used such a procedure to estimate the price of gold. They found that changes in the price of gold could be explained by changes in commodity prices which proxied world industrial output, changes in the U.S. rate of inflation, the U.S. exchange rate and the expected rate of inflation. The nominal interest rate variable was found to be insignificant. The inclusion of these variables was explained as follows.

1) Commodity Prices - Due to the unavailability of a suitable index for world industrial production, a commodity price index was chosen. As world output increases then gold prices should increase, gold being primarily a commodity.

2) U.S. Inflation Rate - As some individuals view gold as an inflation hedge, then as inflation increases the demand for gold will increase.[11] In addition, the higher the inflation rate, the lower the value of the U.S. dollar

resulting in a higher dollar value gold price.

3) The U.S. Exchange Rate - Dollar investments are an alternative investment to gold, therefore, the stronger the dollar the less gold that will be demanded.

4) Nominal Interest Rates - The higher the interest rate the higher the opportunity cost of holding gold. This reduces investment demand for gold and causes prices to fall.[12]

5) Speculative demand - As the price of gold increases, speculative demand will push prices up higher than would have otherwise resulted.

Baker and Van Tassel's results for the period 1973 to 1984 are given below.

Monthly Change in the Price of Gold =

-30.62 + 69.05 (-1.22) (1.97)	Speculative dummy variable
+ 6.50 (2.67)	Year over year change in U.S. CPI
- 1.10 (-0.40)	90-day U.S. T-Bill rate
+ 0.79 (4.50)	Monthly rate of change in the commodity price index
- 2.01 (-4.21)	Monthly rate of change in the SDR's per dollar exchange rate

---

11. The concept of gold as an inflation hedge will be discussed in greater detail in the following chapters.
12. Baker and Van Tassel should have used real interest rates.

$N = 144 \qquad R^2 = 0.30 \qquad DW = 1.66$

Sherman (1986), also estimated gold prices using a reduced form model. His equation however included several different independent variables from the ones used by Baker and Van Tassel. These included:

1) Log World Liquidity - World liquidity was used as a proxy for expected future nominal income both real and nominal components.

2) Real Eurodollar Interest Rate - This variable indicated the opportunity cost of holding gold versus other financial assets. An increase in the real interest rate decreases the desirability of gold resulting in lower gold prices.

3) Unanticipated Inflation - If unanticipated inflation is positive there will be a portfolio shift towards gold and if negative, towards interest earning assets. This variable attempted to explain investor demand.

4) Political Tension Index - This variable reflected gold's role as a precautionary asset in times of political tension. An increase in global tension will cause individuals to shift into gold thereby increasing its price. The return these individuals receive is in the form of safety and liquidity.

Sherman's empirical results for the period January 1972 to March 1984 were as follows.

Log Nominal Gold Price =

7.212 + (30.44)	0.848 (2.06) Log World Liquidity Lagged One Month
- 1.303 (-4.59)	Log U.S. Exchange Rate
- 0.017 (-3.26)	Real Eurodollar Rate Lagged One Month
+ 0.050 (2.03)	Unanticipated Inflation
- 0.002 (-0.15)	Log Tension Index

$N = 140 \qquad R^2 = 0.991 \qquad DW = 1.55$

With the exception of the political tension index all variable signs were as expected and significant.

In terms of specific demand and supply studies, Sherman (1986) used very simple dated price/quantity scatter diagrams to estimate supply and demand elasticities. Sherman's study however, suffered seriously from an identification problem particularly since only twelve years of data were involved. In addition, his study failed to consider any other variables, such as currency changes, interest rates, inflation, changes in income and political tension. All of these factors have been shown to impact the gold market.

Furthermore, Sherman failed to give any theory supporting his results. Very briefly, Sherman found the following results.

Gold Supply

Aggregate gold supply was found to be a highly inelastic function of the dollar gold price. The elasticity of new mine production, which comprises 80% of aggregate gold supply, becomes more and more inelastic through the period 1979-1983. This implies that a large increase in mine production will have little or no effect on the price of gold if the demand curve is elastic.

Fabricated Gold Demand

The Fabricated gold demand curve was a linear, downward sloping demand curve with a price elasticity of approximately -1.

Non-Fabricated Gold Demand

The Investment demand curve was found to be upward sloping. Sherman also concluded that investment demand was the most volatile demand component.

Sherman (1986) concluded that the gold market was demand driven. Shifts in the aggregate gold demand impact the nominal gold price rather than the physical quantity of gold. In contrast, shifts in the supply curve will impact the physical quantity of gold rather than the nominal gold price. Only substantial shifts in the supply curve will significantly affect the price.

Conclusion

What the preceding gold market literature has indicated is that current understanding of how the gold market operates is based on several, often contradictory models. Classical theorists, in general, viewed the long run supply of gold as perfectly elastic meaning, that variables affecting gold demand would have little or no effect in the long run real gold price level. On the other hand, both Baker and Van Tassel (1985) and Sherman (1985) viewed the price of gold as being determined soley by variables which affect the demand side of the market. With gold supply believed to be highly inelastic and the aggregate demand schedule relatively elastic, any change in the price of gold was viewed as being demand driven. This is evidenced in how each of the authors have modelled their reduced form gold price equations.

This paper will build on both the theoretical models and simple reduced form econometric models of gold price determination. While the simpler models do not enable us to answer a variety of questions concerning the gold market they allow us to focus on some of the major determinants of supply and demand.

Chapter 3 will focus on the supply side of the gold market, describing gold supply and analyzing in detail the possible major determinants affecting gold production. In Chapter 4 a similar form of analysis will be undertaken for gold demand.

CHAPTER 3

GOLD SUPPLY

Since gold is a nonperishable storable commodity, annual gold supply therefore consists of new mine production and reductions of stock. As a result, the world's supply of gold comes from four main sources. These are, mine production, reprocessed scrap, private dishoarding and reductions in monetary stocks. Of the four supply components, mine production constitutes the largest annual addition to gold supply. For example in 1987, of gold supplied to the non communist world, non communist gold production comprised 68% of total supply. (See Table 3. [13])

TABLE 3: 1987 NON COMMUNIST WORLD GOLD SUPPLY

	Tonnes	% of Total
Non Communist Mine Production	1373	68%
Net Communist Sales (purchases)	303	15%
Net Official Sales (purchases)	(70)	-3%
Scrap	402	20%
Total Supply	2008	100%

Source: Consolidated Gold Field's "Gold 1988"

---

13. A detailed discussion of why non communist world production and supply figures are used is forthcoming.

SCRAP

The term gold scrap refers to gold derived from jewellery and industrial products which have been fabricated, used and then discarded. The gold content of these products is then recovered and sold back into the market. The supply of gold scrap from products fabricated for industrial purposes primarily in the field of electronics, tends to remain reasonably stable from year to year. On the other hand, scrap recovered from jewellery is highly volatile.

The selling back by the public of old gold jewellery items is a regular feature of the gold market, particularly in Middle Eastern and Asian countries. Trading can take place either because of fashion changes or the shape of the piece has become distorted, which is common of the high purity alloys demanded in these regions of the world.[14]

---

14. Gold jewellery is available in a range of purities which are traditionally labelled in carats. A carat is defined as a unit of fineness for gold equal to a proportion of 1/24th of pure gold. The purity of gold is listed in the following table.

Carat	Purity(%)	Jewellery Origin
24	100	Indian
22	91	Indian
18	75	European
16	67	European
14	58	American
10	41	American

See Sarnoff (1980) page 9.

In addition, jewellery in India and many Middle Eastern countries is an important form of wealth holding. The total level of jewellery scrap available at any one time is therefore dependant on economic circumstances and gold price movements.[15]

While scrap is an important component in determining gold supply, estimates are difficult to determine. Consolidated Gold Field's, who have produced detailed supply and demand gold figures since 1968 have only been able to quantify gold scrap since 1980.

NET OFFICIAL SALES (PURCHASES)

Net official sales or purchases involves the selling or buying of gold by Central Banks, monetary authorities and investment agencies controlled by governments. As seen in Table 3 the official sector purchased 70 tonnes of gold from private sector markets in 1987. As this paper deals with analysing the gold market over the last 97 years several points must be made concerning the official sector's impact on the gold market.

---

15. Gold hoarding will be discussed in detail in Chapter 4.

During the gold and gold exchange standards, when the price of gold was fixed, Central banks were required to purchase any gold that wasn't demanded by the private sector. During the 1914 to 1965 period, with the exception of two years 1918 and 1935, the official sector was a net purchaser (demander) of gold. By comparison, from 1966 to 1971 before the price of gold was allowed to float, Central Banks sold 2,160 tonnes of gold. During this period private gold demand was extremely high as the gold price was low compared to other commodities. In an attempt to relieve the pressure on the price the central authorities sold gold.

During the 1971 to 1987 period, the official sector has been a net seller of gold, decreasing reserves by 324 tonnes. However since 1980, 875 tonnes of gold have been added to official reserves.

Since Central Banks and institutions have been primarily demanders of gold over the observation period, official sales or purchases will be dealt with as a demand component and thus considered in detail in Chapter 4.

NET COMMUNIST SALES (PURCHASES)

Net communist sales (purchases) are sales and purchases of gold by communist countries. In 1987 the Soviet Union was the largest supplier of gold to Western economies and the People's Republic of China the second largest.[16] Since 1954 when net communist sales (purchases) statistics became available, with the exception of a five year period (1966-1970), communist countries have been net sellers of gold.

The reason why the net sales (purchases) statistics rather than gold production figures are used, is that although the Soviet Union is second to South Africa in annual and cumulative gold production, very few statistics are available concerning the Soviet mining industry. Detailed Soviet gold production and ore reserves statistics were last published in 1935.

Up to 1965, the majority of Soviet gold was marketed in the west through the Moscow Norodny Bank of London. Since then, bullion has been sold through the Wazchod Handelsbank of Zurich, a fully owned Moscow Bank. Demand for Soviet gold is high as the bullion refined electrolytically is 999.9

---

16. Consolidated Gold Field's "Gold 1985".

parts per thousand pure gold. This compares to 995 parts per thousand for good delivery bars, and 996 parts per thousand for South African bullion.

GOLD PRODUCTION

The largest component of supply is gold production. As was illustrated in Chapter 1, the picture of world gold production changed significantly in the late nineteenth century. The outstanding event in gold production was the discovery of gold in South Africa in 1886. Since then, South Africa has been the dominant supplier of gold. Table 4 illustrates that since 1492, South Africa, even though it was not a producer of gold before 1886, has produced 47.0% of the world's stock of gold and 57.0% of non communist world gold stock.

TABLE 4: CUMULATIVE GOLD PRODUCTION
(tonnes)

	1492 - 1987	1978 - 1987
South Africa	41,441	5,444
USSR	15,000	3,000
Canada	7,049	749
United States	10,661	660
Latin America	6,272	1,252
Australia	6,913	413
Total	88,336	11,519

Source: Bache (1987) and Consolidated Gold Field's "Gold 1988"

As seen in Table 5, during the 1970's South African gold production constituted 78.5% of total non communist production. In quantity terms South Africa produced approximately 1,000 tonnes of gold annually. Table 5 also indicates that the 1980's have seen a dramatic decrease in South African production as a percentage of total non communist production. In 1987, South African production totalled 44.2% of total mine production down significantly from the 1970's. In tonnage, South African production fell to 607 tonnes. While the drop in percentage of total was due in part to the 400 tonne decline in production from the 1970's it was also due to the significant increase in gold production by other non communist producing countries.

Graph 4 clearly illustrates the increase in production by other gold producing countries. More specifically between 1980 and 1987 the production of gold in Canada increased 133%, in the U.S. 407%, 115% in Latin America, 353% in Australia and 106% in the Far East (see Table 6).[17]

---

17. Output during the 1970's in all countries fell as it became economic to mine lower grade ores. During the 1980's the downward trend reversed with the higher prices of the late 1970's causing exploration and mine openings.

TABLE 5: NON COMMUNIST GOLD PRODUCTION, 1930 - 1987
(% OF TOTAL)

	1930	1940	1950	1960	1970	1980	1987
SOUTH AFRICA	55.2	38.9	52.2	62.3	78.5	70.4	44.2
CANADA	10.8	14.7	15.9	13.5	5.9	5.4	8.8
UNITED STATES	10.8	13.5	9.5	4.9	3.2	3.2	11.3
LATIN AMERICA	5.6	6.7	5.6	3.1	2.8	9.3	13.9
AUSTRALASIA	2.4	5.4	3.7	3.2	2	3.4	10.7
FAR EAST	6.5	8.9	2	2.7	2.6	3.7	5.3
OTHER	8.7	11.9	11.1	10.3	5	4.9	5.8

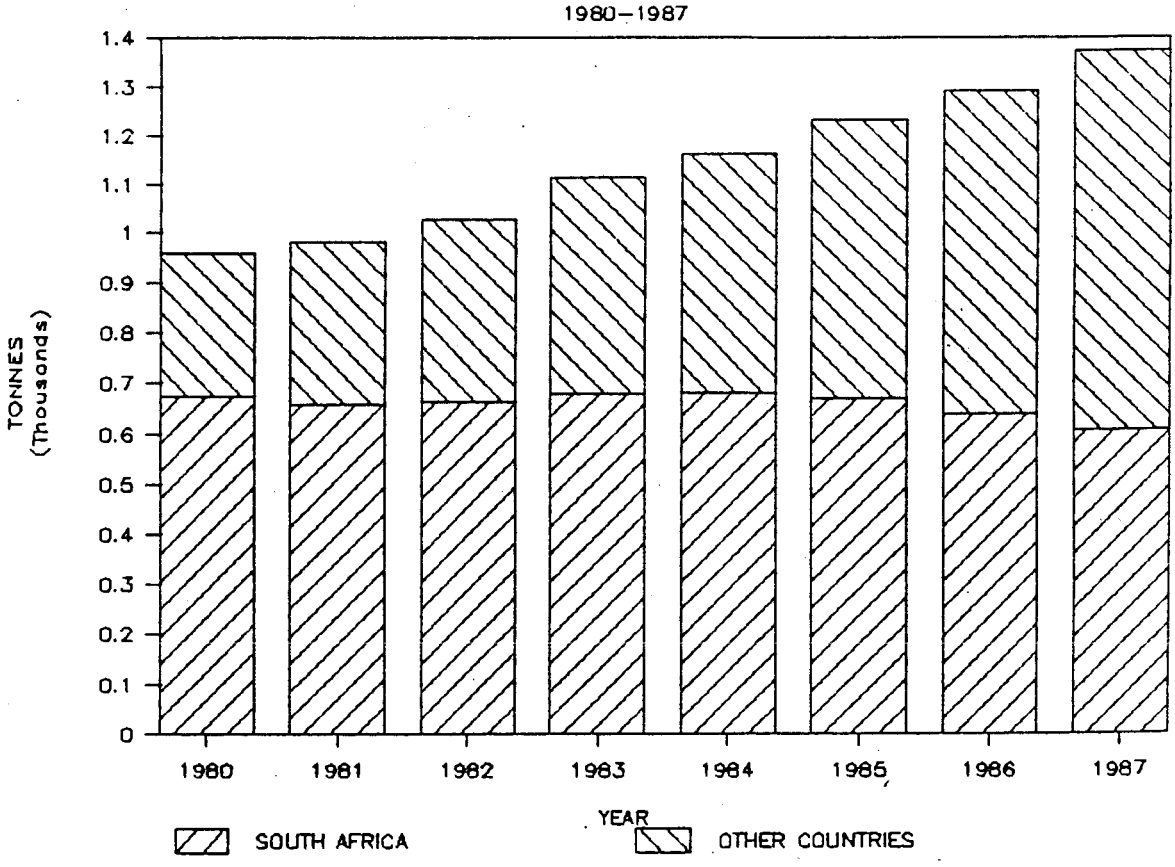
Sources: Gold Delegation(1930), Busschau(1948), Wise(1964), Consolidated Gold Fields
Note: Australasia includes Australia, New Guinea, New Zealand .
Far East includes Japan, Philippines and India.

TABLE 6: NON COMMUNIST GOLD PRODUCTION
TONNES

	1970	1980	1987
SOUTH AFRICA	1000.4	675.1	607
CANADA	74.9	51.6	120.3
UNITED STATES	54.2	30.5	154.9
LATIN AMERICA	34.1	88.7	191.1
AUSTRALASIA	24.7	32.3	146.4
FAR EAST	33.1	35.6	73.4
OTHER	52.2	45.2	80.3
TOTAL	1273.6	959	1373.4

Sources: Various Issues of Consolidated Gold Fields

GRAPH:4 NON COMMUNIST WORLD MINE PRODUCTION

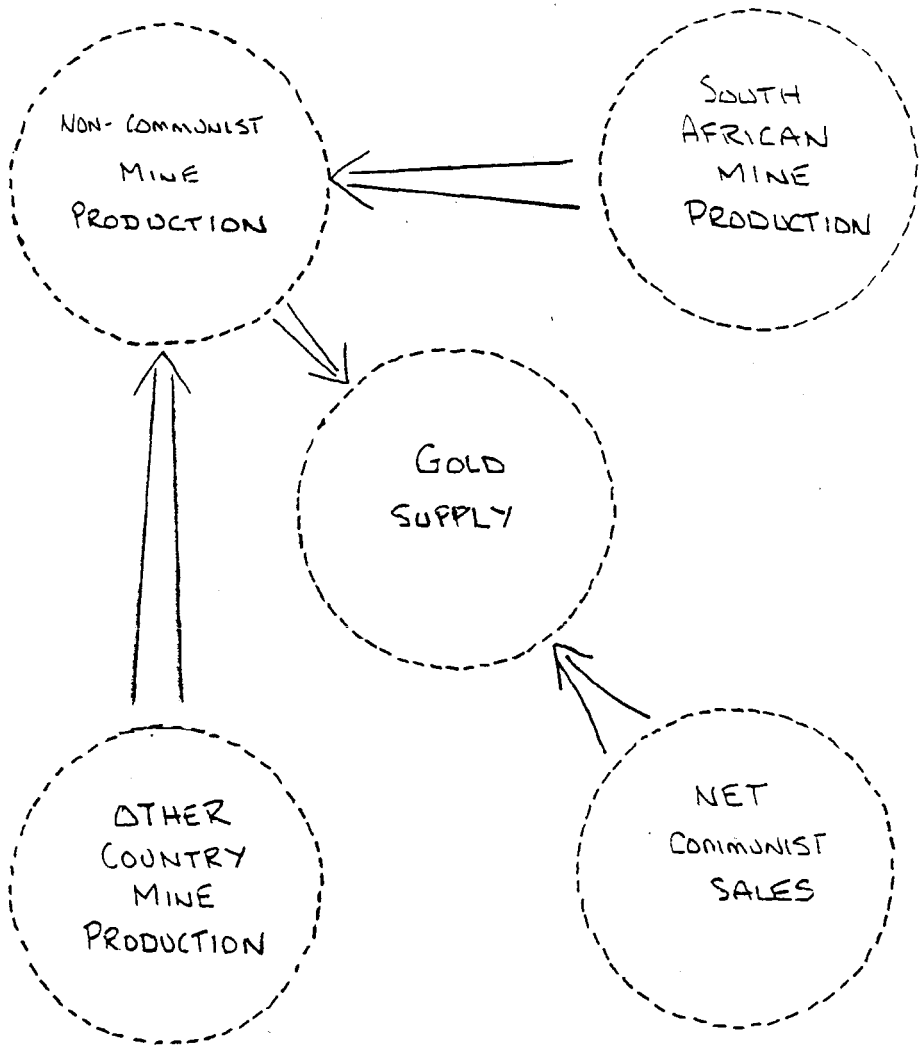


SOURCE: CONSOLIDATED GOLD FIELDS "GOLD 1988"

The structure of non communist world production suggests that as South Africa has been the dominant gold producer in the last 100 years it must be analysed seperately from other countries. To understand how gold production and therefore supply has moved over the last 100 years it is necessary to understand the factors affecting production and costs in South Africa.

Chapter 3 has thus far detailed the major components of gold supply. In this paper, as Soviet gold production figures are not available, annual gold supply will be defined as non communist mine production plus any available figures for net communist sales (purchases). Due to the unavailability of gold scrap data prior to 1980, scrap will not be included in the definition of supply. Figure 3 illustrates the components of gold supply that will be analysed and modelled in this paper. The remainder of this chapter will focus on each of these supply components in detail to determine the major influences on each category.

Figure 3: GOLD SUPPLY DETERMINATION



GOLD SUPPLY DETERMINANTS

Before focussing on the factors that determine gold supply in South Africa and other gold producing countries a simple gold production model will be developed. According to Paish (1938), since 1890 the major cause of changes in gold output have been induced by economic factors such as costs of production or the gold price.[18] These factors have in turn determined the exhaustion rate of existing deposits. As the relationship between mining costs, gold prices and the supply of gold is complex it is best to consider a gold supply model incorporating certain simplifying assumptions.

Consider a new mine in which no money has yet been spent. The optimum rate of mining for the new mine must be determined which gives the largest value of future profits. The following assumptions will be made.

1) The ore deposits are of constant grade, exactly known and equally accessible.
2) The gold price is fixed.
3) Production is subject to increasing and diminishing return.[19]

---

18. See Paish (1938) p.380.
19. See Vogely (1985) p.112.

4) The initial capital costs of the mine are proportional to the determined rate of annual output.
5) Initially the interest rate is zero.
6) Initially profits are undiscounted (UP).

It should also be noted that gold mining differs from other forms of production in that the quantity of gold is fixed or exhaustable.

Not considering initial costs, the optimum rate of mining will be at that point where undiscounted profits are maximized. Undiscounted profits (UP(q)) is the difference between total revenue R(q) and working costs [Cw(q)].

$$UP(q) = R(q) - Cw(q) \qquad (1)$$

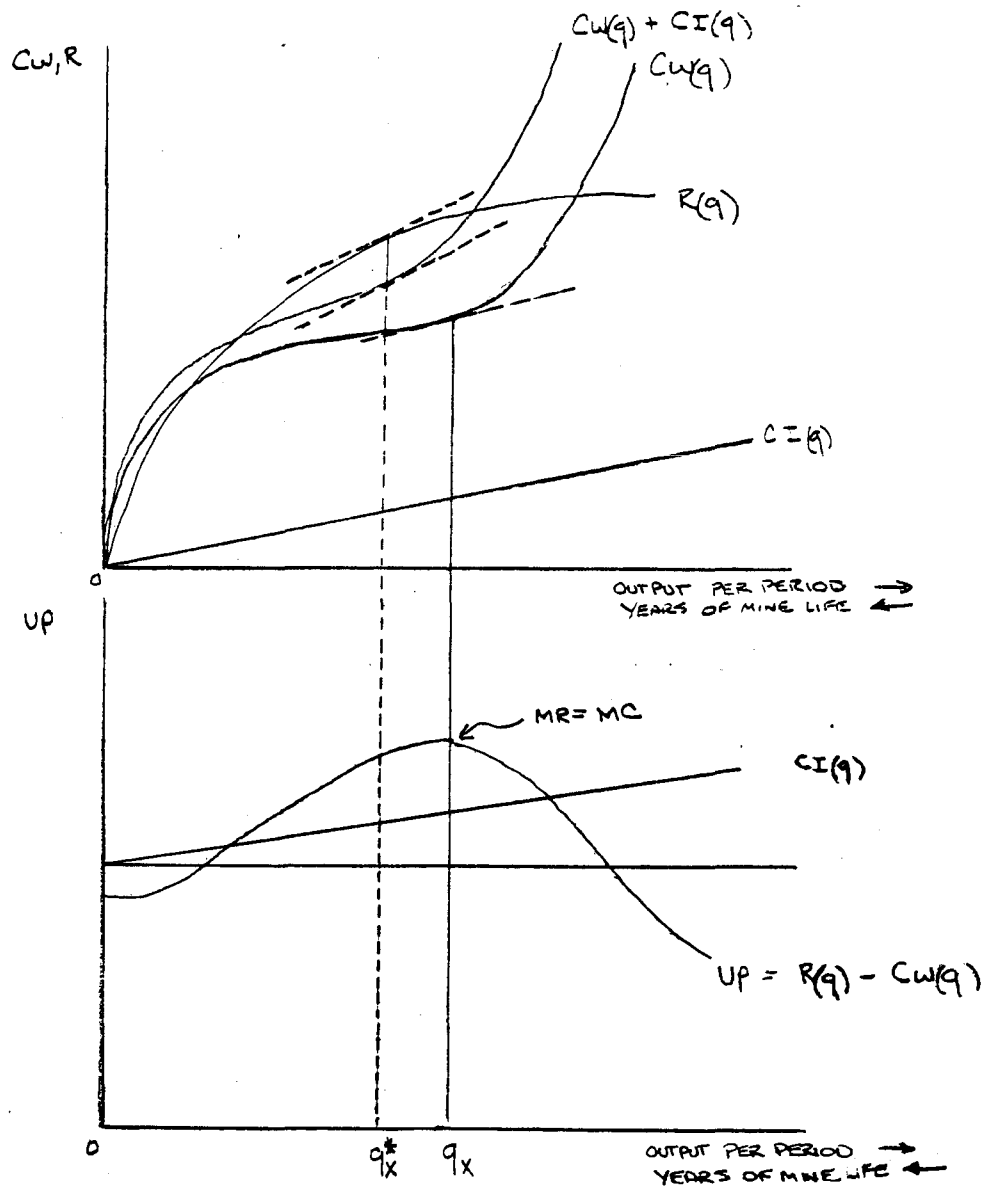
Total revenue is equal to p(q) * q where p is the price of gold and q is the quantity of gold produced. Similarly in producing q certain costs are incurred, Cw(q), and these will also depend on how much is produced. The necessary condition for choosing that value of q which maximizes profits is found by setting the derivatives in equation 1 with respect to q equal to zero.

The first order condition for maximization is

$$dR/dq = dC/dq$$

which is simply equal to marginal revenue (MR) equal to marginal cost (MC). Graphically this is shown in Figure 4.

Figure 4. OPTIMAL RATE OF PRODUCTION

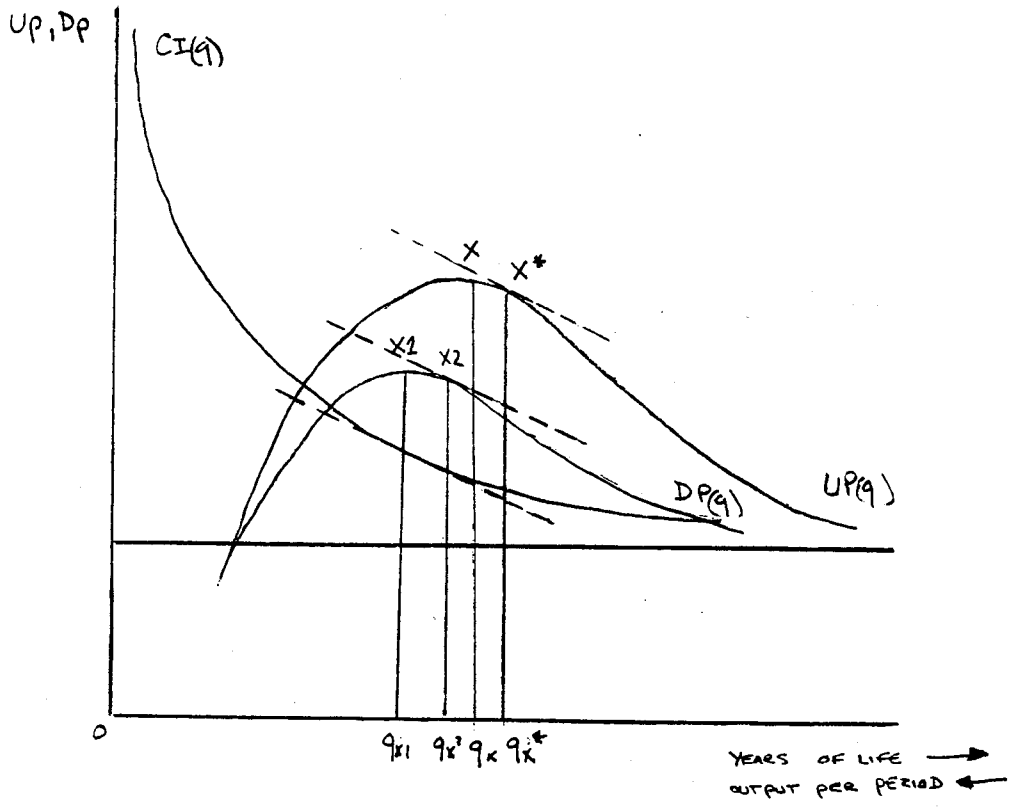


In the absence of any costs other than working costs and with a zero rate of interest the most profitable life of the mine would be that at which undiscounted profits is at its maximum (x). If however initial costs are considered [CI(q)], total costs will be equal to CI(q) + Cw(q). If initial costs are assumed to be directly proportionate to the rate of annual output the CI(q) curve will be a straight line sloping upwards and to the right from the origin. Including initial costs moves the new optimum point qX* to the left of the original point qx decreasing output per period and lengthening the optimum life of the gold mine. Thus as initial or start-up costs decrease or if gold prices rise, the larger will be the most profitable rate of output per period and the shorter will be the optimum life of the mine.

When the zero interest rate assumption is removed discounted present value of net profits [Dp(q)] must be maximized instead of undiscounted profits [UP(q)]. With a positive rate of interest, the more time in exploiting a given asset, the lower will be the present discounted value of future profits. The higher the interest rate, the more it pays to mine as quickly as possible in order not to lose interest.

As seen in Figure 5 the peak of the Dp(q) curve lies to the left of the UP(q) curve. Since discounting is done on an annual basis the scale of the preceding graph must be converted from output per period to years of mine life. As a result the CI(q) curve becomes a rectangular hyperbola. It is evident that the higher the interest rate the shorter will be the optimum life of the mine and the greater the annual output (X1). When including CI(q), X2 lies to the left of X*.

Figure 5. THE INTEREST RATE AND THE OPTIMAL EXTRACTION RATE



The above result is surprising in that contrary to capital theory it implies that the higher the interest rate the greater the demand for capital. However, demand for capital would only increase if all mines were very rich in ore and where the interest rate would not greatly affect the profitability of the asset. Higher interest rates would however deter investment in marginal mining propositions. On balance it would be expected that the affect of a rise in interest rates would be reduced mining investment. Removing the assumption of perfect knowledge concerning mine contents, future costs of production and selling prices would further reduce the impact of interest rates. The greater the degree of risk the smaller will be the affect of movements in the market rate of interest on investment decisions. In general, no matter what the rate of interest, where it is technically necessary, as in the case of deep-level mines, to begin developing by means of a large outlay, development is likely to be delayed until uncertainty is reduced.

Now consider the effect on gold production of changes in working profits which may be caused by changes in the price of gold. The undiscounted profits curve [UP(q)] will shift outward parallel to the old undiscounted profits curve. As the new discounted curve approaches the old curve as the life of the

mine is lenghtened, the new discounted profits curve is not parallel to the old discounted profit curve but is initially flatter and then becomes steeper than the old discounted profit curve. As a result the peak of the new discounted profits curve is slightly to the left of the old curve. The result is that the optimum life of the mine is reduced and therefore annual output increases.

To conclude, assuming homogeneous ore, initial mine investment and discount rates, production will increase as prospective profits increase. Prospective profits will increase due to decreasing costs and higher gold prices.

While the above model gives some insights on factors which affect gold production and supply the assumption of homogeneity of ore is unrealistic. The following section describes how production is determined and how prices and costs effect production under the assumption of various grades of ore. This analysis will be discussed in terms of South African production.

SOUTH AFRICAN PRODUCTION

Where the grade of ore varies theory suggests that extraction policies of mining companies will be determined by the following two factors.[20]

1) If a mine extracts the richest ore first this usually leads to the loss of payable ore of a lower grade as costs of production get higher and higher.
2) Shareholders, mine employees, and the State are usually more concerned with steady income and long-term employment rather than short-run maximization.

In light of these factors it has been the policy of the South African gold mining industry to mine ore of the average grade of payable ore in a mine.[21] South African gold mines are legally required to mine to the average value of each mine's payable ore reserves. Such reserves are determined by the pay limit, the minimum quantity of gold in a ton of rock which will produce enough revenue to cover the costs of mining, processing and marketing the product. Production in a mine is calculated as tonnage of ore milled multiplied by the average grade of ore. The rest of this section will

---

20. See Paish (1958) p.395.

describe in detail the concepts of the pay limit, average grade of ore, and production, culminating with the development of a South African gold production model.

PAY LIMIT

The pay limit is fundamental in the linking of economics and geology to South African gold production. The pay limit measured in grams per ton is the cost per ton of ore milled divided by the gold price per gram. In essence the pay limit is the minimum grade of ore at which costs of production are equal to the gold revenue.

$$\text{PAY LIMIT (grams/ton)} = \text{cost per ton milled (\$/ton)} \;/\; \text{gold price per gram (\$/gram)}$$

The above equation says that if gold prices increase or costs decrease, the pay limit will decline or the quantity of payable ore that a mine has to mine will increase. Suppose a mine has grades of ore ranging from 1 grams/ton to 12

---

21. Each South African gold mine must obtain a lease from the State. The Leases Board approves the pay limit in addition to monitoring operations to ensure conformity. While this method of mining may not optimize the present value of the resource, it does in theory optimize the total profits over a mines life.

grams/ton. If the pay limit is currently 6 grams/ton then the number of payable grades the mine has available are 7 grades, from 6 grams/ton to 12 grams/ton. If gold prices increase and the pay limit falls to 5 grams/ton then the number of payable ore grades will increase from 7 to 8 grades.

AVERAGE GRADE OF ORE

By law each South African mine is required to calculate and then mine to the average grade of its payable ore reserves. Critical to understanding how the average grade is determined is to understand that the composition of the gold ore in the South Africa (Witwatersrand) takes the form of a pyramid with a vast quantity of low grade ore at the base and only a relatively small quantity of high grade ore at the apex. As a result, the average grade of a mine depends on the proportion of payable ore reserves it has at each grade level.[22]

---

22. The term payable ore reserve refers essentially to blocks of ore to which grades, above the selected cut-off grade, have been assigned. See Katzen (1964), Janisch (1986), Consolidated Gold Fields (1981), Kettell (1982), Radetzki (1989), Busschau (1936) and Paish (1938) concerning the economics of South Africa gold production.

The average grade of ore that is mined is given in the following equation. [23]

$$\text{AVERAGE GRADE (grams/ton)} = \sum_{i \geq p}^{N} (OR_i \times GR_i) \quad / \sum_{i \geq p}^{N} OR_i$$

where OR is the ore reserve in tons, GR is the grade of ore in grams per ton and P is the pay limit in grams per ton.

If for example the price of gold increases or working costs fall, the pay limit will fall and this will result in an increase in the quantity of payable ore reserves. As seen from the above equation the increase in the payable reserves will cause the average grade of ore to decrease. The pay limit and the average grade of ore are therefore positively related. The degree to which they are positively related is questionable however. It is usually the case that a mine plans many years in advance what the pay limit will be and then calculates the long run average grade of or to which it will mine. With volatile gold prices, and therefore pay limits, it is difficult to see how a mine could continually be changing the average grade of ore it mines even though it is required to under the terms of its lease.

---

23. Obviously there are an unlimited number of combinations of the proportion of different grades of ore, which could be mined to get the over all average grade required.

PRODUCTION

South Africa gold production is determined by the following equation.

S.A. PRODUCTION (grams) = AVERAGE GRADE (gram/ton)
X TONS OF ORE MILLED

Tons of ore milled like the average grade of ore is dependent on costs and gold prices. However, while cost decreases or gold price increases cause an decrease in the average grade of ore the same changes induce an increase in tonnage of ore milled. As a result, a change in the average grade of ore is often offset by an opposite effect in tonnage milled.

The degree to which each effect is greater depends on the following factors. In the short term, it is often the case that the average grade of ore is sensitive to cost and price changes. On the other hand tonnage milled may remain relatively unchanged in the short term and will depend on the accessibility of the ore. Where the gold is in alluvial deposits or shallow mines, the time needed for expansion may be quite short. In deep mines, it may be a number of years

before new ore can be accessed. In general, in the long term as more equipment, labour, and capital are added tonnage milled will increase. The sensitivity of tonnage milled to cost and price changes is therefore determined by the elasticity of supply for labour and capital and the start-up time of mining investment.

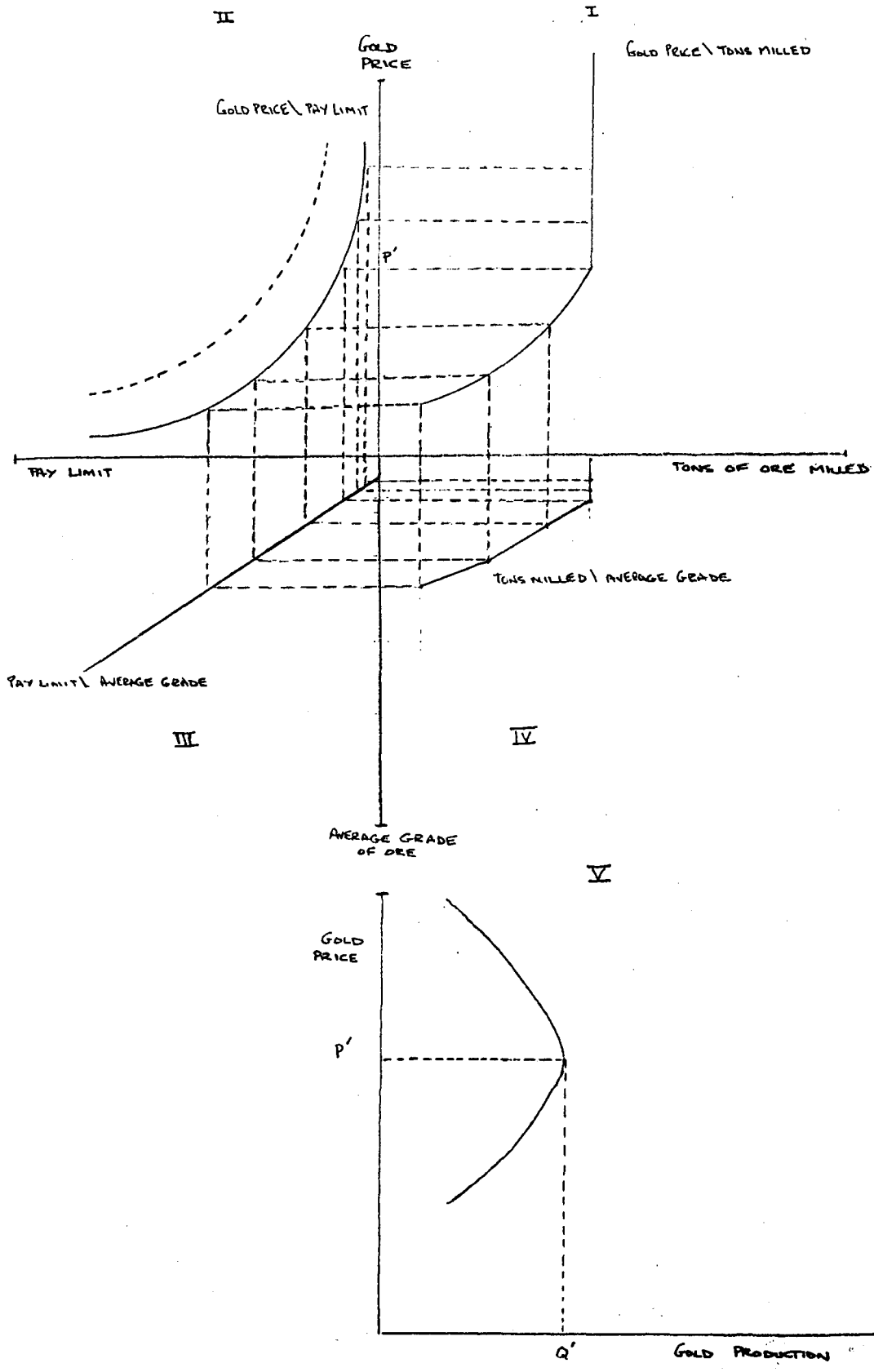
It may be the case therefore, that during gold price increases, that South African gold production may decrease as higher gold prices cause the pay limit and the average grade of ore to decline. Where the addition of large quantities of payable ore is very large, the fall in the average grade of ore may be sharp. If tonnage milled increases by less than the fall in grade, gold production may decline. On the other hand, when costs increase, the increase in grade will tend to offset the fall in tonnage milled so that gold output will not fall to the same extent as tonnage milled. It may be the case that a sharp increase in costs or decline in gold price could lead to an increase and not a decrease in the supply of gold.

To clarify the above interrelationships a five quadrant model is developed below illustrating each of the above factors.(See Figure 6).

Quadrant I illustrates the gold price versus tons milled relationship. It is assumed that over a certain portion of gold prices the price, tonnage milled relationship is positive. In the short and medium term however, at a certain price the mine finds that it is mining at capacity and can no longer increase tonnage milled with further price increases. For a cost increase the price \ tons milled curve shifts in to the left so that at every price level the amount of ore milled is less than at the lower cost.

Quadrant II illustrates the price \ pay limit curve relationship. As the definition of the pay limit is cost per ton milled divided by the gold price, the gold price pay limit relationship can be illustrated by a rectangular hyperbola. That is, for very high gold prices the pay limit approaches zero and for very low gold prices the pay limit approaches infinity. The gold price \ pay limit curve shifts outward to the left with an increase in costs. At every price increased costs increase the pay limit.

Figure 6: A MODEL OF SOUTH AFRICAN GOLD PRODUCTION



Quadrant III illustrates the average grade \ pay limit relationship. It has been shown that the pay limit and average grade of ore are positively related and this is illustrated in the average grade \ pay limit line. Where the line intersects the average grade of ore axis will depend on the mines or industries quantities and proportions of low and high grade ore reserves. The slope of the average grade \ pay limit line also depends on the quantities and proportions of low and high grade ore reserves. A mine with lower ore grades will have a flatter average grade \ pay limit curve than a mine with higher ore grades.

Given a certain price and making assumptions concerning costs and ore reserves, gold production can be determined. This is illustrated in the tons milled \ average grade relationship. To determine gold production, the average grade of ore and tonnage milled must be multiplied together. Quadrant V illustrates the production \ price (supply) relationship.[24] It is shown that in the short and medium term,

for gold prices above P,' production falls while for prices below P' production increases.[25]

As seen from Figure 6, a cost increase, assuming constant gold prices, causes tonnage milled to drop and the average grade of ore to increase. Depending of the sensitivity of quadrants 1 and 2 to cost increases, gold production may increase, decrease, or remain unchanged.

The relationships in quadrants 1, 2, and 3 were then empirically tested. Figures in parentheses are the t-statistics and the observation period covers the years 1950 to 1987. [26]

---

24. Marsh (1983) found that the elasticity of the short run South African supply curve was approximately -0.5 and the long run elasticity approximately 1.0.

25. If we assume the following equations,
PAY = C / P where PAY is equal to the pay limit, C is equal to the costs per ton, and P is the price of gold.
G = a + dg/dpay Pay where G is the average grade, dg/dpay is the slope of the line, and a is the intercept.
TM = CAP - 1 / P - C is the equation for tonnage milled (TM). CAP is capacity of the mine and C is the cost of production. Gold Production (PROD) is equal to
PROD = (a+dg/dpay C/P) (CAP -1/P - C) and

$$dProd/dP = dg/dpay\ C/P^2\ (-CAP + 2/P + C) + a/P^2)$$

The above equation indicates that for large values of P, dPROD/dP becomes negative.

QUADRANT I:

TONS MILLED = 85.036 + .021 * REAL GOLD PRICES

(1.056) (1.050)

As expected, the coefficient giving the relationship between real gold prices and tonnage milled is not significantly different from zero.

QUADRANT II:

PAY LIMIT = 6.957 - .045 * REAL GOLD PRICES

(7.096) (-3.699)

Real gold prices and the pay limit, over the period, are significantly negatively related.

QUADRANT III:

AVERAGE GRADE OF ORE = 4.578 + 0.261 * PAYLIM

(1.503) (3.101)

The quadrant 3 equation indicates that a 1 gram/ton increase in the pay limit changes the average grade of ore by .26 grams/ton. The South African pay limit \ average grade curve is therefore relatively flat and suggests that South Africa has depleted its high ore reserves.

---

26. South Africa supply equation results are given in detail in Chapter 5 of this paper.

TABLE 7 : SOUTH AFRICAN GOLD PRODUCTION STATISTICS, (1890-1987)

(A) YEAR	(B) SOUTH AFRICAN GOLD PRODUCTION tonnes	(C) TONNES MILLED millions	(D) AVERAGE GRADE OF ORE g/tonnes	(E) PRICE OF GOLD £/g	(F) COSTS £/tonne milled	(G) PAY LIMIT g/tonne
1890	14.0	0.7	20.0	0.134	1.35	10.1
1891	22.0			0.133		
1892	33.0			0.138		
1893	40.0			0.137		
1894	56.0			0.137		
1895	63.0	3.2	19.7	0.136		
1896	63.0			0.137		
1897	85.0			0.137		
1898	119.0			0.136	1.50	
1899	113.0	7.2	15.7	0.137		
1900	11.0			0.135		
1901	8.0			0.137		
1902	53.0			0.138	1.30	
1903	92.0	7.0	13.1	0.137		
1904	117.0			0.137	1.20	
1905	153.0			0.135		
1906	180.0			0.137		
1907	201.0			0.136		
1908	220.0			0.136		
1909	228.0			0.136	0.85	6.25
1910	235.0	22.6	10.4	0.136	0.90	6.62
1911	257.0	24.9	10.3	0.136	0.90	6.62
1912	284.0	26.8	10.6	0.136	0.95	6.99
1913	274.0	27.1	10.1	0.136	0.90	6.62
1914	261.0	27.2	9.6	0.137	0.85	6.20
1915	263.0	29.5	9.6	0.136	0.85	6.25
1916	289.0	29.5	9.8	0.137	0.90	6.57
1917	281.0	28.1	10.0	0.136	0.95	6.99
1918	262.0	25.7	10.2	0.136	1.10	8.09
1919	259.0	24.9	10.4	0.152	1.15	7.57
1920	259.0	25.4	10.2	0.176	1.30	7.39

TABLE 7: Con't

(A)	(B)	(C)	(D)	(E)	(F)	(G)
1921	254.0	24.0	10.6	0.171	1.30	7.60
1922	219.0	20.5	10.7	0.148	1.20	8.11
1923	285.0	27.7	10.3	0.146	1.00	6.85
1924	298.0	29.5	10.1	0.150	1.00	6.67
1925	299.0	29.6	10.1	0.136	0.95	6.99
1926	310.0	30.7	10.1	0.136	0.95	6.99
1927	315.0	30.6	10.3	0.136	1.00	7.35
1928	322.0	31.9	10.1	0.136	1.00	7.35
1929	323.0	32.0	10.1	0.137	1.00	7.30
1930	333.0	33.0	10.1	0.137	0.95	6.93
1931	338.0	33.8	10.0	0.137	0.95	6.93
1932	359.0	36.6	9.8	0.138	0.95	6.88
1933	343.0	38.5	8.9	0.200	0.95	4.75
1934	326.0	41.8	7.8	0.222	0.95	4.28
1935	335.0	46.5	7.2	0.228	0.95	4.17
1936	353.0	51.9	6.8	0.225	0.95	4.22
1937	365.0	54.5	6.7	0.226	0.95	4.20
1938	378.0	58.1	6.5	0.229	0.95	4.15
1939	399.0	62.3	6.4	0.250	0.95	3.80
1940	438.0	68.4	6.4	0.269	1.00	3.72
1941	448.0	72.3	6.2	0.270	1.05	3.89
1942	439.0	72.0	6.1	0.270	1.05	3.89
1943	398.0	62.2	6.4	0.270	1.10	4.07
1944	392.0	63.2	6.2	0.263	1.15	4.37
1945	380.0	61.3	6.2	0.277	1.20	4.33
1946	371.0	59.8	6.2	0.277	1.30	4.69
1947	348.0	56.1	6.2	0.278	1.35	4.86
1948	360.0	58.1	6.2	0.278	1.30	4.68
1949	364.0	59.7	6.1	0.316	1.35	4.27
1950	363.0	61.5	5.9	0.399	1.50	3.76
1951	358.0	60.7	5.9	0.399	1.60	4.01
1952	368.0	62.4	5.9	0.397	1.70	4.28
1953	371.0	60.8	6.1	0.398	1.85	4.65
1954	412.0	66.5	6.2	0.399	1.95	4.89
1955	454.0	67.8	6.7	0.403	2.05	5.09
1956	494.0	70.6	7.0	0.402	2.15	5.35
1957	530.0	67.9	7.8	0.401	2.30	5.74
1958	549.0	67.8	8.1	0.401	2.35	5.86
1959	624.0	71.7	8.7	0.401	2.25	5.61
1960	665.0	73.9	9.0	0.403	2.30	5.71

TABLE 7: CON'T

(A)	(B)	(C)	(D)	(E)	(F)	(G)
1961	713.0	75.1	9.5	0.403	2.50	6.20
1962	793.0	77.0	10.3	0.401	2.60	6.48
1963	853.0	79.7	10.7	0.402	2.70	6.72
1964	905.0	80.8	11.2	0.404	2.80	6.93
1965	950.0	81.2	11.7	0.403	2.90	7.20
1966	960.0	80.0	12.0	0.403	3.00	7.44
1967	950.0	77.2	12.3	0.404	3.80	9.41
1968	969.0	76.9	12.6	0.507	4.07	8.03
1969	973.0	75.4	12.9	0.534	4.36	8.16
1970	1000.0	75.8	13.2	0.467	4.65	9.96
1971	976.0	74.5	13.1	0.522	4.33	8.30
1972	910.0	72.8	12.5	0.721	4.66	6.46
1973	855.0	76.3	11.2	1.231	5.88	4.78
1974	759.0	75.9	10.0	2.115	8.18	3.87
1975	713.0	75.9	9.4	2.255	9.82	4.35
1976	713.0	77.5	9.2	2.134	12.10	5.67
1977	700.0	76.1	9.2	2.637	15.56	5.90
1978	706.0	79.3	8.9	3.127	16.50	5.28
1979	703.0	85.7	8.2	4.472	17.10	3.82
1980	675.0	87.7	7.7	8.183	19.90	2.43
1981	658.0	90.1	7.3	7.056	24.10	3.42
1982	664.0	94.9	7.0	6.663	24.90	3.74
1983	680.0	100.0	6.8	8.693	30.70	3.53
1984	683.0	103.5	6.6	8.403	29.70	3.53
1985	672.0	106.7	6.3	7.606	24.70	3.25
1986	640.0	110.3	5.8	7.803	27.80	3.56
1987	607.0	110.4	5.5	8.483	35.10	4.14
1988						

Sources: South African gold production figures were obtained from Jackson (1988) and Consolidated Gold Fields "Gold 1988".
Tonnage Milled Statistics were obtained from Katzen(1964), Cousineau and Richardson(1979), various issues of Consolidated Gold Fields, or calculated (coluan D/ coluan B).
Where S.A. gold production and tonnage milled figures were available Average grade of ore was determined by dividing column B by coluan C. Where statistics for tonnage milled were unavailable average grade of ore figures were obtained from Frankel(1967),Cousineau and Richardson(1979) and from various issues of Consolidated Gold Fields.
Price of gold figures were determined from Frankel(1967), and various issues of South Africian Journal of Statistics.
Cost figures wwere obtained from Katzen(1964), the Journal of the South African Institute of Mining and Metallurgy (Aug. 1988), and Consolidated Gold Fields "Gold 1988".
The pay limit was determined by dividing column F by coluan E.

The above results indicate that since tons milled is price insensitive, an increase in the price of gold will lower the pay limit, lower the average grade or ore, and lower gold production. When prices decrease the results indicate production will increase.

Table 7 details historical production statistics for South Africa. A brief discussion of this table will follow, indicating the interdependency of each factor. As seen from Column E in Table 7 the nominal gold price has steadily increased over the 1890 - 1987 period. From 1890 to 1971, the gold price (£/g) increased 249%. Gold price increases or depreciations occurred between 1919 and 1924, in 1933, 1939, 1949 and in 1968. Since the price of gold was allowed to float the nominal price of gold (£/g) has risen from .522 (L/g) in 1971 to a high of 8.483 (£/g) in 1987.[27]

Working costs expressed in £/tonnes milled fell during the early 1900's due to technical innovations and economies of scale. Costs fell from 1.35 (£/tonne milled) in 1890 to 0.85 (L/tonne milled) by 1915. Costs increased during the

---

27. Due to data problems the price of gold was converted to L/g instead of Rands/oz. In terms of Rand/oz, the gold price has risen significantly largely due to the sharp depreciation of the Rand against the U.S. dollar. This has increased the profitability of South African gold mines.

early 1920's but fell to the 0.95 (£/tonne milled) level by 1925 and remained there until 1940. From 1940 through to 1987 working costs have risen dramatically reaching a high of 35.1 £/tonne milled in 1987.

The main constituents of working costs are labour charges, stores and materials, electric power and compressed air and water.[28] Gold is found in South Africa in quartz conglomerates known as reefs. These reefs, found at great depths, vary in thickness from a few inches to several feet. The natural constraints in mining in South Africa are primarily those associated with the depth at which mining has to be carried out, the high temperatures, poor ventilation, water and high rock stresses. These constraints have limited mechanization making South African gold mining labour intensive.[29]

The following table indicates how labour costs as a percentage to total costs have changed over the last 50 years.

---

28. Working costs include all costs charged to the mining and milling of gold ore and are usually expressed as a currency/ton milled or $/oz produced. The latter measure excludes the exchange rate and grade variables. See Consolidated Gold Fields 1987 p.29.
29. See Kettell (1982) p. 16-17 for a description of the South African mining process.

Table 8. SOUTH AFRICAN GOLD MINING LABOUR COST
(% of Total Costs)

1930	46.2%
1945	46.4%
1970	30.8%
1985	23.5%

Source: Katzen (1964) p. 21 and Consolidated Gold Fields "Gold 1985" p.65.

Due to the high percentage of labour, rapid wage increases have been the primary cause for the dramatic increase in production costs during the last decade. Wage increases have been due to increasing inflation, the shortage of skilled manpower and unions.[30] The escalating gold price however has enabled South African mines to accommodate the rise in working cost.

As noted earlier the gold price and mining costs determine the pay limit. As is evidenced by Table 7 the pay limit, in contrast to the steady increase in gold prices and mining cost, has moved in a cyclical manner over the past 100 years. During the late 1800's the pay limit was approximately 10.00 g/tonne. As South African mines became larger, costs fell to where by the mid-1930's the pay limit fell to around 4.00 g/tonne. From the mid-1930's to 1967 the pay limit steadily increased reaching a high of 9.41 g/tonne

---

30. See Consolidated Gold Fields "Gold 1985" p.67.

in 1967. While the price of gold during this period increased 79%, mine working costs rose 300%.

With the implementation of the two-tiered gold pricing system in 1968 the pay limit fell despite continued increases in costs. Currently the pay limit is approximately 4.00 g/tonne.

As the pay limit and average grade are directly related the average grade of payable ore has moved in the same manner as the pay limit. Since 1970 the average grade has fallen from 13.2 g/tonne to 5.5 g/tonne in 1987. From the average grade of ore and pay limit statistics it appears that South Africa maybe running out of easily accessible ore reserves. As stated earlier, the pay limit and therefore the average grade of ore is negatively related to the price of gold and positively related to working costs. Since 1980, while gold prices have remained relatively flat, production costs have risen 76%. Despite this fact the average fell significantly from 7.7 Ł/g to 5.5 Ł/g.

Column C in Table 7 shows the movement in tonnage of ore milled over the last 97 years. In 1935, two years after a significant increase in the gold price, (depreciation of the

£), tonnage milled increased significantly. Gold price increases resulted in the increase in tonnage milled as costs were stable over the period. A similar increase occurred during the late 1930's and early 1940's. Between 1945 and 1972 tonnage milled remained relatively stable, apparently with rising costs offsetting any increase in the gold price. From 1972 tonnage milled increased significantly on the strength of rising gold prices reaching 110.4 million tonnes in 1987.

Over the 97 year period South African gold production has risen from 14 tonnes in 1890 to a high of 1000 tonnes in 1970. Since 1970 gold production has decreased steadily falling to 607 tonnes in 1987. The following table gives an interesting comparison on how different combinations of tonnage milled and the average grade of ore mined can determine gold production.

Table 9. GOLD PRODUCTION DETERMINATION

Year	Tonnage Milled (million tonnes)	Average Grade of Ore (g/tonne)	Production (tonnes)
1987	110.4	5.5	607
1959	71.7	8.7	624

The tonnage of gold produced in 1987 and 1959 was almost

identical however, the manner in which it was produced was very different. In the late 1950's the average grade of ore was significantly higher than the late 1980's. This was due to high gold prices negatively affecting the pay limit and therefore the average ore grade. The large differences in the average grade of ore over the two periods may also suggest that South African has exhausted its high ore grades. In terms of tonnes milled there was a 54% increase from 1959 to 1987.

During the 1980's it is evident that the only reason why South African gold production has remained as high has been due to the significant increase in tonnage milled. If South African gold expansion plateaus and costs remain high, given declining average grades of ore, gold production will continue to fall in the future. It is important to note that South Africa is nearing a critical point, where the pay limit is approaching the average grade of ore. When the pay limit is greater than the average grade of ore, the average mine will not be able to cover costs.

It is evident that South African gold production is highly complex and dependent on many factors. In Chapter 5 factors influencing production will be empirically tested to determine the relative importance of each on production.

NON SOUTH AFRICAN GOLD PRODUCTION[31]

As is illustrated in Graph 5 gold production movements between South Africa and the rest of the non communist world since 1890 have been significantly different. During the period 1890-1950 while South African production was steadily increasing production elsewhere went through two significant cycles. Between 1890 and 1920 production increased from 156 tonnes in 1890 to approximately 420 tonnes in 1910 and then fell steadily to 244 tonnes in 1920. From 1920 to 1945, gold production peaked at 685 tonnes in 1940 and then fell to 276 tonnes in 1945. After World War II, non South African gold production remained relatively constant hovering around the 300 tonnes per year level until the early 1980's when output increased significantly. South African production during this period increased dramatically despite flat or declining real gold prices.

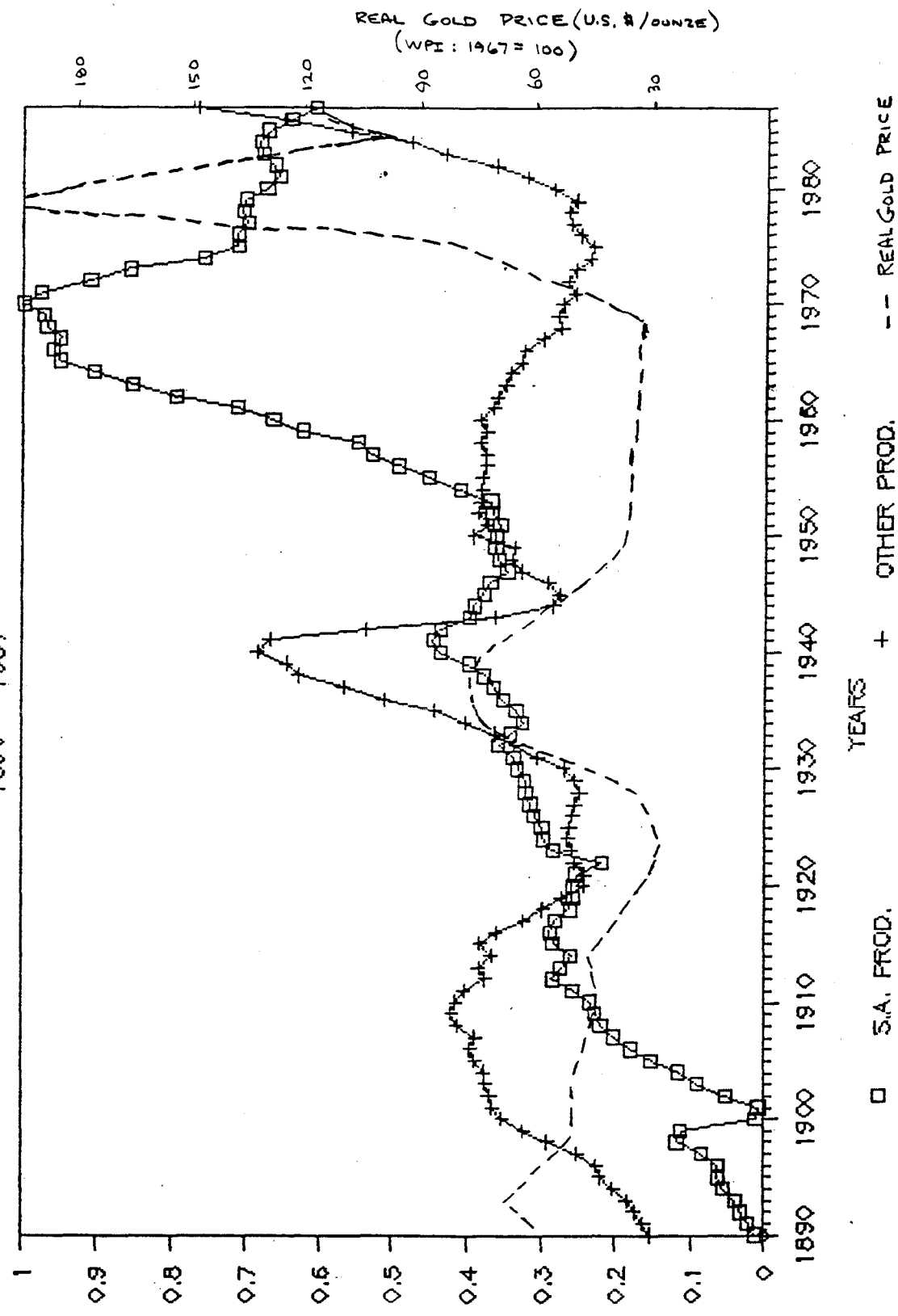
It was shown in the previous section that the main determinants of South African gold production are gold prices

---

31. Non South African production includes production from all non communist countries except South Africa.

GRAPH 5: S.A. AND OTHER COUNTRY PRODUCTION

1890 - 1987



and mining costs. In particular, higher gold prices or lower mining costs increase the pay limit which in turn causes a decrease in the average grade of ore mined. Assuming no increase in the tonnage milled due to full employment or full mine capacity, output would decrease in the short-run. In the long-run the higher price would induce exploration and new mining, thereby increasing tonnage milled helping to increase output.

Graph 5 indicates a negative relationship between gold prices and South African production. The graph also illustrates a positive lagged relationship between real gold prices and non South African gold production. Non South African production therefore appears to follow what was predicted in the simple model of gold production discussed earlier in this chapter. That is, as gold prices increase profits rise causing the most profitable rate of annual output to increase. Price increases therefore will shorten the optimum life of the mine but also increase exploration as has been witnessed in non South African gold production since 1981.

Since 1981, net profits have made gold mining very

profitable. The following table illustrates that production costs have remained relatively stable over the last four years resulting in large profit margins.

Table 10. Non Communist World Excluding South Africa GOLD PROFITS

Year	COSTS (US$/OZ)	GOLD PRICE (US$/OZ)	PROFITS (US$/OZ)
1984	219	361	142
1985	196	317	121
1986	188	360	172
1987	200	447	247

Source: Various Issues of Consolidated Gold Fields "Gold"

While profits for operating mines over the four year period are quite large, Consolidated Gold Fields estimates that the gold price over the last few years is critically close to the costs of bringing a new mine into production.[32]

For mines coming on stream in this decade, Australia's capital expenditure per ounce of capacity was $250, Canada's $350 per ounce and the United States $400 per ounce. During the early 1980's when gold prices were well over the $500 an ounze level and if the above estimates are accurate and

---

32. Consolidated Gold Fields "Gold 1988" p.27.

continue to apply significant exploration and development occurred in which we are now witnessing the results. However with prices falling exploration or development may soon be curtailed and as a result non South African production may decline.

The preceding analysis has indicated that lagged gold prices may have a significant influence in determining non South African gold production. Also it has been shown that non South African production is highly volatile and must be considered seperately from South African gold production.

NET COMMUNIST SALES

The final component of supply which will be analyzed is net communist sales. As was indicated in Table 4 as the Soviet Union is estimated to be the world's second largest mine producer of gold, it would account for the major portion of communist sales to the west. Consolidated Gold Fields (1982) suggested that Soviet sales should be viewed in the same manner as other major mine producers. That is a portion of the gold is kept for domestic purposes and the remainder is added to reserves or sold on the market for currency. As seen in Table 11 net communist sales (purchases) figures were

only available from 1953 onwards. During the period 1953 to 1965 the communist bloc made substantial sales primarily to finance its trade deficit with the West. From 1966 to 1970 the communist bloc was a net purchaser of gold, very likely rebuilding reserves.

Attempts to predict Communist gold sales behavior is extremely difficult because so many unknown factors are involved. Since the early 1970's poor harvests and the need to import expensive technologies, combined with favourable gold prices have encouraged the resumption of strong communist sales.[33] However this relationship is less obvious in 1979 and 1980 when the Soviet trade balance improved and gold sales declined despite record grain imports.

---

33. Boulay and Fells (1982) suggested that while communist sales were extremely difficult to predict three factors have shown some correlation with Communist (Soviet) gold sales.
    1) The need for Western Grain.
    2) Soviet current account balance.
    3) The gold price.

A possible explanation is that during 1979 and 1980, oil prices were extremely high. As oil accounts for more than 50% of the Soviets hard currency earning there was little need for significant gold sales. With lower oil prices in the 1980's, the need of more and more hard currency meant that the Soviets had to sell larger and larger quantities of gold bullion. Table 11 gives detailed supply statistics by component from 1890. Supply of gold to non communist countries is illustrated in Graph 6.

TABLE(1: SUPPLY OF GOLD TO NON COMMUNIST COUNTRIES, 1890-1987

(A) YEAR	(B) SOUTH AFRICAN GOLD PRODUCTION tonnes	(C) OTHER GOLD PRODUCTION tonnes	(D) NON COMMUNIST GOLD PRODUCTION tonnes	(E) NET COMMUNIST sales/purchases	(F) SUPPLY TO NON COMMUNIST COUNTRIES(tonnes)
1890	14.0	156.0	170.0	N/A	170.0
1891	22.0	164.0	186.0	N/A	186.0
1892	33.0	176.0	209.0	N/A	209.0
1893	40.0	185.0	225.0	N/A	225.0
1894	56.0	203.0	259.0	N/A	259.0
1895	63.0	221.0	284.0	N/A	284.0
1896	63.0	226.0	289.0	N/A	299.0
1897	85.0	252.0	337.0	N/A	337.0
1898	119.0	291.0	410.0	N/A	410.0
1899	113.0	325.0	438.0	N/A	438.0
1900	11.0	353.0	364.0	N/A	364.0
1901	8.0	367.0	375.0	N/A	375.0
1902	53.0	371.0	424.0	N/A	424.0
1903	92.0	376.0	468.0	N/A	468.0
1904	117.0	378.0	495.0	N/A	495.0
1905	153.0	390.0	543.0	N/A	543.0
1906	180.0	396.0	576.0	N/A	576.0
1907	201.0	390.0	591.0	N/A	591.0
1908	220.0	414.0	634.0	N/A	634.0
1909	228.0	422.0	650.0	N/A	650.0
1910	235.0	416.0	651.0	N/A	651.0
1911	257.0	404.0	661.0	N/A	661.0
1912	284.0	377.0	661.0	N/A	661.0
1913	274.0	384.0	658.0	N/A	658.0
1914	261.0	368.0	629.0	N/A	629.0
1915	283.0	383.0	666.0	N/A	666.0
1916	289.0	362.0	651.0	N/A	651.0
1917	281.0	324.0	605.0	N/A	605.0
1918	262.0	298.0	560.0	N/A	560.0
1919	259.0	273.0	532.0	N/A	532.0

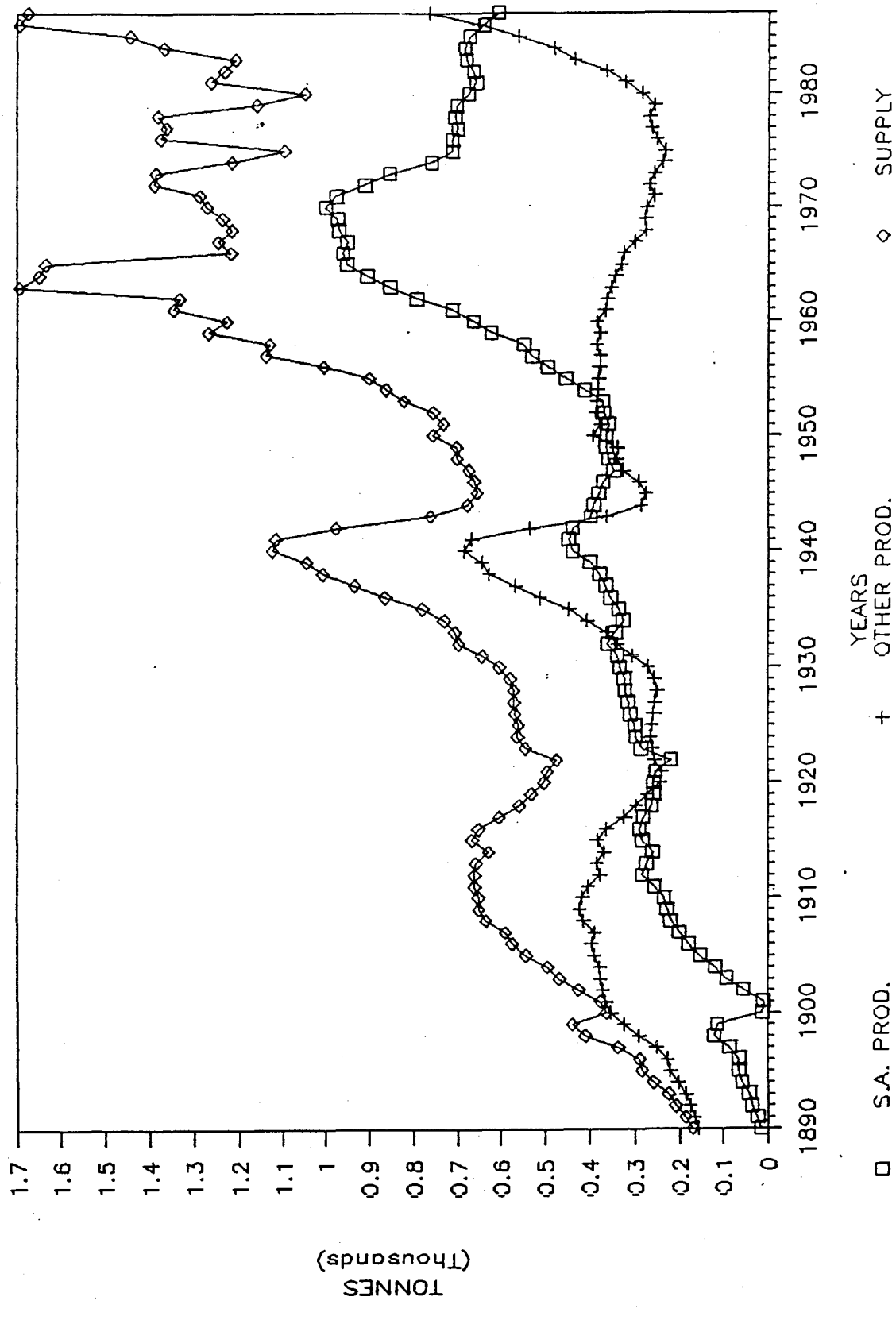
TABLE II: CONT'D

(A)	(B)	(C)	(D)	(E)	(F)
1920	259.0	244.0	503.0	N/A	503.0
1921	254.0	242.0	496.0	N/A	496.0
1922	219.0	256.0	475.0	N/A	475.0
1923	285.0	260.0	545.0	N/A	545.0
1924	298.0	265.0	563.0	N/A	563.0
1925	299.0	263.0	562.0	N/A	562.0
1926	310.0	259.0	569.0	N/A	569.0
1927	315.0	256.0	571.0	N/A	571.0
1928	322.0	250.0	572.0	N/A	572.0
1929	323.0	256.0	579.0	N/A	579.0
1930	333.0	270.4	603.4	N/A	603.4
1931	338.0	305.9	643.9	N/A	643.9
1932	359.0	337.7	696.7	N/A	696.7
1933	343.0	363.1	706.1	N/A	706.1
1934	326.0	404.9	730.9	N/A	730.9
1935	335.0	445.7	780.7	N/A	780.7
1936	353.0	511.7	864.7	N/A	864.7
1937	365.0	568.1	933.1	N/A	933.1
1938	378.0	629.8	1007.8	N/A	1007.8
1939	399.0	646.1	1045.1	N/A	1045.1
1940	438.0	684.9	1122.9	N/A	1122.9
1941	448.0	668.6	1116.6	N/A	1116.6
1942	439.0	537.7	976.7	N/A	976.7
1943	398.0	364.1	762.1	N/A	762.1
1944	392.0	286.1	678.1	N/A	678.1
1945	380.0	276.3	656.3	N/A	656.3
1946	371.0	291.5	662.5	N/A	662.5
1947	348.0	327.0	675.0	N/A	675.0
1948	360.0	342.0	702.0	N/A	702.0
1949	364.0	339.0	703.0	N/A	703.0
1950	363.0	392.0	755.0	N/A	755.0
1951	358.0	375.0	733.0	N/A	733.0
1952	368.0	387.0	755.0	N/A	755.0
1953	371.0	384.0	755.0	67.0	822.0
1954	412.0	383.0	795.0	67.0	862.0
1955	454.0	381.0	835.0	67.0	902.0
1956	494.0	377.0	871.0	133.0	1004.0
1957	530.0	376.0	906.0	231.0	1137.0
1958	549.0	384.0	933.0	196.0	1129.0
1959	624.0	376.0	1000.0	266.0	1266.0

TABLE II : CONT'D

(A)	(B)	(C)	(D)	(E)	(F)
1960	665.0	384.0	1049.0	177.0	1226.0
1961	713.0	367.0	1080.0	266.0	1346.0
1962	793.0	362.0	1155.0	178.0	1333.0
1963	853.0	351.0	1204.0	489.0	1693.0
1964	905.0	344.0	1249.0	400.0	1649.0
1965	950.0	330.0	1280.0	355.0	1635.0
1966	960.0	325.0	1285.0	-67.0	1218.0
1967	950.0	300.0	1250.0	-5.0	1245.0
1968	969.0	276.0	1245.0	-29.0	1216.0
1969	973.0	279.0	1252.0	-15.0	1237.0
1970	1000.0	273.0	1273.0	-3.0	1270.0
1971	976.0	257.0	1233.0	54.0	1287.0
1972	910.0	267.0	1177.0	213.0	1390.0
1973	855.0	256.0	1111.0	275.0	1386.0
1974	759.0	237.0	996.0	220.0	1216.0
1975	713.0	233.0	946.0	149.0	1095.0
1976	713.0	251.0	964.0	412.0	1376.0
1977	700.0	262.0	962.0	401.0	1363.0
1978	706.0	266.0	972.0	410.0	1382.0
1979	703.0	256.0	959.0	199.0	1158.0
1980	675.0	284.0	959.0	90.0	1049.0
1981	658.0	323.0	981.0	280.0	1261.0
1982	664.0	364.0	1028.0	203.0	1231.0
1983	680.0	434.0	1114.0	93.0	1207.0
1984	683.0	479.0	1162.0	205.0	1367.0
1985	672.0	561.0	1233.0	210.0	1443.0
1986	640.0	651.0	1291.0	402.0	1693.0
1987	607.0	766.0	1373.0	303.0	1676.0

Sources: South African gold production was obtained from Jackson(1988).
Total non communist gold production was estimated from the following sources.
Tonnage estimates from 1890 to 1929 were calculated from the Interim Report of the Gold Delegation by the League of Nations (1930). It was assumed that over the period communist production totalled 5% of the total and therefore was subtracted from the total.(See League of Nations(1930) p.63)
These figures were converted from monetary pounds to ounces by dividing by 4.23 pounds per troy ounze and then converted to tonnes. Non communist estimates for the years between 1930 and 1948 were calculated from Busschau(1949). These figures were also converted to tonnes(see conversion table, Appendix B). Various issues of Consolidated Gold Fields were used to calculate non communist production from 1950 to 1987.
Other production was calculated by subtracting column D from column C.
Net communist sales/purchases were taken from Consolidated Gold Fields "Gold 1988".
Supply to non communist countries was calculated by summing columns D and E.


GRAPH 6: NON COMMUNIST GOLD SUPPLY
1890 – 1987
TONNES
(Thousands)
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
YEARS
□ S.A. PROD.
+ OTHER PROD.
◇ SUPPLY

CHAPTER 4

THE DEMAND FOR GOLD

Gold has the distinction of being partly a commodity, partly decorative, and partly money. The last fact more than all the others makes analysing gold demand extremely complex. The historic reputation of gold was founded on unique properties which made it a useful medium of exchange and an excellent store of value. For centuries gold has served as a highly liquid temporary abode of purchasing power. It has served as an insurance policy for those individuals facing uncertain political, economic and social conditions. It has been demanded in countries such as India and the Middle East for traditional reasons. Finally gold has been both a national and international money, but during the last hundred years it has gradually been withdrawn from domestic circulation. However, gold continues to be an important monetary asset. Even with the explosion of foreign exchange holdings in the seventies official gold valued at market prices continues to constitute a major component of official reserves.[34]

---

34. Statistics will be given later in this chapter.

In terms of a commodity gold has many industrial applications. Gold is used in dentistry and is of special importance for the electronics industry where it is an exceedingly good conductor of electricity and heat. The largest demand for gold comes through the demand for carat jewellery and the arts. Gold is used in jewellery and the arts because of its beauty, its resistance to tarnish, its relative ease of working and its intrinsic value. Given the variety of uses it is clear that predicting the course of gold demand is difficult.

The prevailing hypothesis is that industrial, a portion of jewellery and monetary demand are susceptible to changes in the business cycle, and to changes in the price of gold.[35] On the other hand it is difficult to predict the movements of investment and speculative demand. These demands are often subject to unpredictable variations which arise from political, economic and financial changes and the accompanying changes in interest and inflation rates.

The demand for gold can be classified into these broad categories.

---

35. See Quadrio-Curizio and Curizio (1982).

1) Total Gold Fabrication Demand

This category includes fabrication of gold for jewellery, dentistry and electronics purposes. For reasons which will be discussed in greater detail later in the paper an attempt has been made to seperate developed country fabrication and developing country fabrication. Jewellery in developing countries often represents a form of investment or insurance and is not affected by the same factors as demand for jewellery in developed countries.

2) Official Reserve Demand

As stressed earlier, gold has had a very long standing as a monetary asset. Despite the period in the mid 1970's when there was an attempt to demonetize gold, it has always been an important reserve. This category includes transactions by central banks, monetary authorities and investment agencies controlled by governments.[36]

3) Private Investment Demand

For centuries gold has served as an investment vehicle. However the motives for private stockpiling are complex. They include hedging and speculation. This category includes demand for gold medals, medallions, coins

---

36. See Consolidated Gold Fields, "Gold 1977".

and bullion.

As was the case in the previous chapter on supply detailed statistics have been compiled for gold demand covering the period 1890-1987. The sources of the categories are detailed at the bottom of Table 12. The following sections describe in detail each of the above demand components identifying and verifying the importance of various demand determinants.

GOLD FABRICATION DEMAND

Table 12 indicates total gold fabrication demand is an extremely important component of total demand. Over the 97 year period (1890-1987) total gold fabrication as a percentage of total supply to non communist countries has ranged from a high of 99% in the early 1970's to a low of -56% in 1932. The table illustrates that total gold fabrication demand fell significantly during 6 periods: World War I (1914-18), the 1920 stock market crash (1920-21), the 1930 depression (1930-39), World War II (1940-43) and the 1974 and 1980 recessions. During the 1980's total gold fabrication demand has averaged approximately 66% of total supply as compared to 40% during the 1890's.

TABLE12: DEMAND FOR GOLD, 1890 - 1987
tonnes

(A) YEAR	(B) SUPPLY TO NON-COMMUNIST COUNTRIES	(C) DEVELOPING COUNTRY GOLD FABRICATION	(D) DEVELOPED COUNTRY GOLD FABRICATION	(E) TOTAL GOLD FABRICATION	(F) OFFICAL RESERVES	(G) PRIVATE INVESTMENT RESIDUAL	(H) REAL GOLD PRICE
1890	170.0	35.7	73.3	109.0			71.3
1891	186.0	27.9	71.1	99.0			71.8
1892	209.0	-2.1	71.1	69.0			76.8
1893	225.0	4.5	72.5	77.0			74.9
1894	259.0	-13.0	75.0	62:0			83.7
1895	284.0	28.4	85.6	114.0			82.0
1896	289.0	31.8	87.2	119.0			86.1
1897	337.0	37.1	74.9	112.0			86.1
1898	410.0	45.1	93.9	139.0			82.7
1899	438.0	74.5	105.5	180.0			76.8
1900	364.0	36.4	109.6	146.0			71.5
1901	375.0	33.8	112.3	146.0			72.5
1902	424.0	80.6	106.4	187.0			68.0
1903	468.0	88.9	122.1	211.0			67.1
1904	495.0	113.9	109.2	223.0			67.1
1905	543.0	38.0	120.0	158.0			66.7
1906	576.0	144.0	133.0	277.0			64.8
1907	591.0	124.1	141.9	266.0			61.5
1908	634.0	31.7	127.3	159.0			63.6
1909	650.0	130.0	143.0	273.0			59.2
1910	651.0	169.3	162.7	332.0			56.9
1911	661.0	198.3	164.7	363.0			61.7
1912	661.0	211.5	178.5	390.0			57.9
1913	658.0	118.4	191.6	310.0			57.4
1914	629.0	12.6	144.4	157.0	1137.0	-665.0	58.9
1915	666.0	-13.3	120.3	107.0	1348.0	-789.0	57.6
1916	651.0	52.1	123.9	176.0	584.0	-109.0	46.9
1917	605.0	157.3	108.7	266.0	777.0	-438.0	34.1
1918	560.0	-16.8	117.8	101.0	-497.0	956.0	30.5
1919	532.0	276.6	165.4	442.0	0.0	90.0	28.9

TABLE 12: CON'T

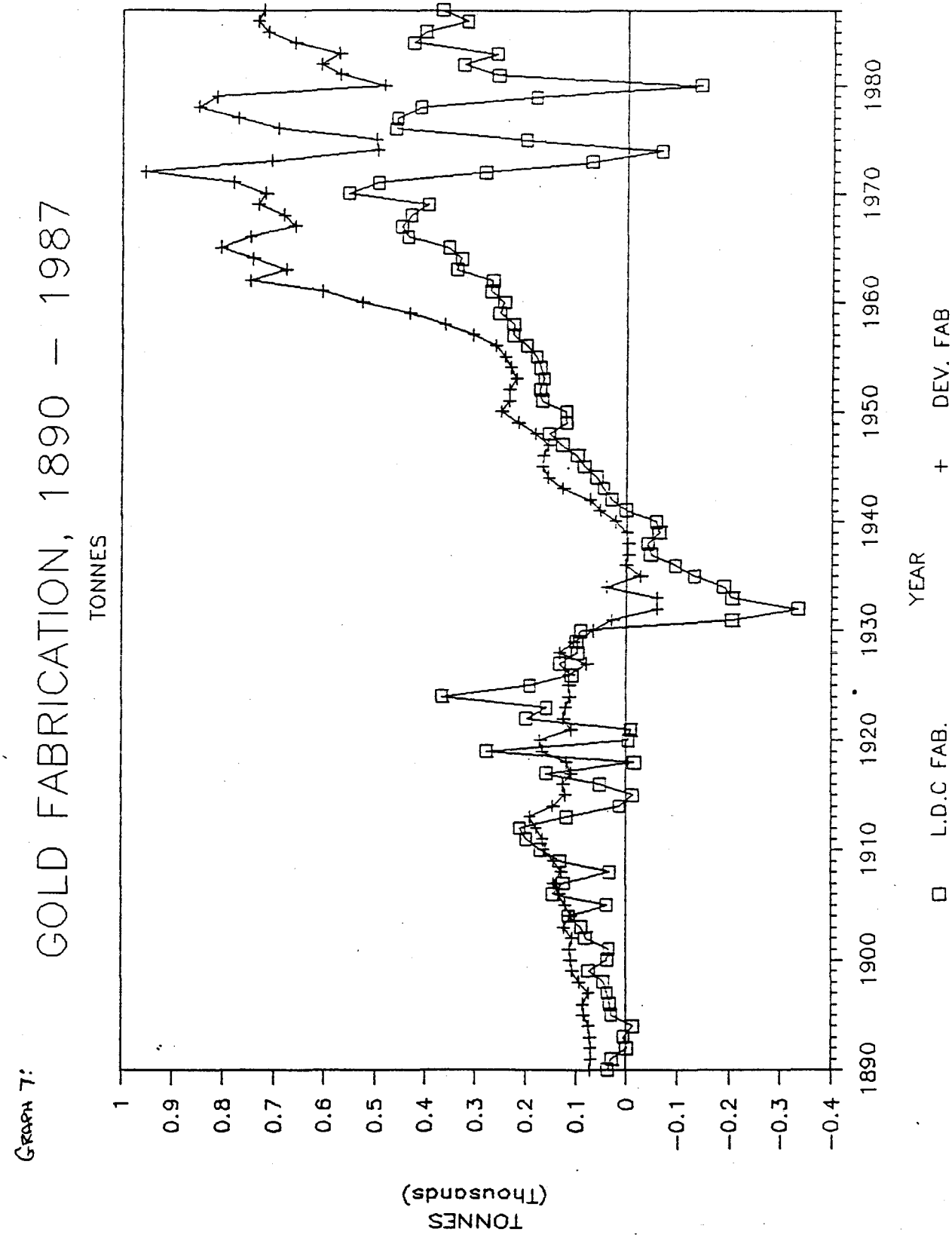
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1920	503.0	-5.0	171.0	166.0	677.0	-340.0	25.9
1921	496.0	-9.9	108.9	99.0	1180.0	-783.0	41.0
1922	475.0	199.5	123.5	323.0	565.0	-413.0	41.4
1923	545.0	158.1	120.0	278.0	355.0	-88.0	39.8
1924	563.0	366.0	112.1	478.0	489.0	-404.0	40.9
1925	562.0	191.1	112.9	304.0	31.0	227.0	38.7
1926	569.0	108.1	113.9	222.0	355.0	-8.0	40.1
1927	571.0	131.3	79.7	211.0	540.0	-180.0	41.9
1928	572.0	97.2	131.8	229.0	699.0	-356.0	41.3
1929	579.0	98.4	104.6	203.0	419.0	-43.0	42.1
1930	603.0	90.5	66.6	157.0	917.0	-471.0	46.4
1931	644.0	-206.1	28.1	-178.0	571.0	251.0	55.0
1932	697.0	-334.6	-58.4	-393.0	913.0	177.0	61.5
1933	706.0	-204.7	-58.3	-263.0	109.0	860.0	77.8
1934	731.0	-190.1	39.1	-151.0	1360.0	-478.0	90.5
1935	781.0	-132.8	-26.2	-159.0	-152.0	1092.0	84.8
1936	865.0	-95.2	1.2	-94.0	559.0	400.0	83.9
1937	933.0	-46.7	-3.3	-50.0	894.0	89.0	78.7
1938	1008.0	-40.3	-3.7	-44.0	1503.0	-451.0	86.4
1939	1045.0	-62.7	-0.3	-63.0	184.0	924.0	87.9
1940	1123.0	-56.2	22.2	-34.0	2889.0	-1732.0	86.4
1941	1117.0	0.0	54.0	54.0	640.0	423.0	77.6
1942	977.0	29.3	73.7	103.0	908.0	-34.0	68.8
1943	762.0	45.7	126.3	172.0	908.0	-318.0	65.3
1944	678.0	61.0	155.0	216.0	908.0	-446.0	65.3
1945	656.0	85.3	167.7	253.0	908.0	-505.0	64.1
1946	663.0	99.5	165.6	265.0	273.0	125.0	56.2
1947	675.0	128.3	155.8	284.0	410.0	-19.0	45.8
1948	702.0	154.4	182.6	337.0	369.0	-4.0	42.3
1949	703.0	119.5	217.5	337.0	396.0	-30.0	44.5
1950	755.0	120.8	249.2	370.0	288.0	97.0	42.8
1951	733.0	168.6	234.4	403.0	235.0	95.0	38.4
1952	755.0	173.7	234.4	408.0	205.0	142.0	39.5
1953	822.0	164.4	221.6	386.0	404.0	32.0	40.1
1954	862.0	172.4	232.6	405.0	595.0	-138.0	40.0
1955	902.0	180.4	243.6	424.0	591.0	-113.0	39.9
1956	1004.0	200.8	261.2	462.0	435.0	107.0	38.6
1957	1137.0	227.4	306.6	534.0	614.0	-11.0	37.6
1958	1129.0	225.8	361.2	587.0	605.0	-63.0	37.0
1959	1266.0	253.2	430.8	684.0	671.0	-89.0	36.9

TABLE 12: CON'T

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1960	1226.0	245.2	526.8	772.0	262.0	192.0	36.9
1961	1346.0	269.2	605.8	875.0	538.0	-67.0	37.0
1962	1333.0	266.6	746.4	1013.0	329.0	-9.0	36.9
1963	1693.0	338.6	677.4	1016.0	729.0	-52.0	37.0
1964	1649.0	329.8	742.2	1072.0	631.0	-54.0	37.0
1965	1635.0	355.0	806.0	1161.0	196.0	278.0	36.2
1966	1218.0	435.0	747.0	1182.0	-40.0	76.0	35.1
1967	1245.0	448.0	660.0	1108.0	-1404.0	1541.0	35.0
1968	1216.0	429.0	682.0	1111.0	-620.0	725.0	37.7
1969	1237.0	395.0	732.0	1127.0	90.0	20.0	38.6
1970	1270.0	554.0	717.0	1271.0	236.0	-237.0	32.6
1971	1287.0	496.0	780.0	1276.0	-96.0	107.0	35.8
1972	1390.0	282.0	954.5	1236.5	151.0	2.5	48.8
1973	1386.0	72.0	706.0	778.0	-6.0	614.0	72.3
1974	1216.0	-66.0	499.0	433.0	-20.0	803.0	99.5
1975	1095.0	203.0	501.0	704.0	-9.0	400.0	92.0
1976	1376.0	461.0	693.0	1154.0	-58.0	280.0	68.2
1977	1363.0	458.0	772.0	1230.0	-269.0	402.0	76.3
1978	1382.0	411.0	849.0	1260.0	-362.0	484.0	92.4
1979	1158.0	183.0	813.0	996.0	-544.0	706.0	130.7
1980	1049.0	-143.0	484.0	341.0	230.0	478.0	228.4
1981	1261.0	258.0	571.0	829.0	276.0	156.0	157.0
1982	1231.0	327.0	609.0	936.0	85.0	210.0	125.6
1983	1207.0	261.0	574.0	835.0	-142.0	514.0	140.2
1984	1367.0	425.0	661.0	1086.0	-85.0	366.0	116.6
1985	1443.0	402.0	714.0	1116.0	132.0	195.0	102.9
1986	1693.0	319.0	733.0	1052.0	143.0	498.0	122.9
1987	1676.0	370.0	722.0	1092.0	70.0	514.0	144.8

Sources: See Table 11 of this paper for the sources of non communist gold supply.
Developing country gold fabrication estimates were determined from the following sources.
Over the 1890 - 1928 period developing country fabrication was calculated from the Interim Report of the Gold Delegation by the League of Nations(1930). Columns for India and China and Egypt were used to construct the estimates.
From 1929 - 1944 estimates were obtained from Busschau (1949 p.150).
From 1945-1951 estimates were obtained from the Statistical Compendium of the Report to the Congress of the Commission on the Role of Gold in the Domestic and International Monetary Systems (Gold Commission Report) (1982).
Estimates for the period 1952 - 1968 were determined from Hinshaw(1967 p. 116).
...ious issues of Consolidated Gold Fields were used to determine the 1969 - 1987 estimates.
...tal Gold Fabrication estimates were obtained from the same sources for the same time periods as the developing country gold fabrication estimates.
Developed country gold Fabrication estimates were calculated by subtracting column E from C. Official reserve estimates were obtained for the 1914 - 1947 period from Table SC-8 of the Gold Commission Report (1982 p. 199). The remaining years were taken from Consolidated Gold Fields " Gold 1988 ".
Private Investment Residual was calculated by subtracting columns E and F from B.
The Real Gold Price was taken from the Gold Commission Report (1982 p.220).
They determined the real gold price by dividing the price of gold per U.S$ ounze by the U.S. wholesale price index (1967 = 100).

GRAPH 7:


GOLD FABRICATION, 1890 – 1987
TONNES
(Thousands)
TONNES
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
YEAR
□ L.D.C FAB.
+ DEV. FAB

Disaggregating total gold fabrication demand into developing and developed country gold fabrication demand shows that developed country fabrication demand is less downward volatile than developing country demand. (See Graph 7) Developing country gold fabrication demand as a percentage of total supply ranged from a high of 64% in 1924 to a low of -32% in 1932. In recent years developing country fabrication demand has averaged approximately 23% of total supply up significantly from 10% during the 1890's.

Developed country fabrication demand as a percentage of total supply has ranged from a high of 77% in 1972 to a low of -8% in 1932. With the exception of the 1932 to 1939 period developed country fabrication demand has been positive. On the other hand developing country demand was negative in 1892, 1894, 1915, 1918, 1920-21, 1931-1940, 1974, 1980.

The preceeding results strongly suggest that both subcomponents of total fabrication demand are either influenced in differing degrees by similar factors or influenced by different factors. As a result developed and developing country gold fabrication demand must be considered separately.

Developed Country Gold Fabrication Demand

Jewellery fabrication is the largest component of total developed gold fabrication demand.[37] Since 1968 when jewellery figures became available, jewellery fabrication as a percentage of developed country gold fabrication demand has remained relatively stable averaging approximately 70% per year over the 1968 to 1987 period. The remaining 30% per year has gone into primarily dentistry and electronics.[38]

Over the 1890 to 1987 period, as a jewellery breakdown is unavailable and as dentistry uses and to a greater extent electronic uses were relatively small over the 97 year period it will be assumed that the majority of developed country gold fabrication demand is comprised of jewellery demand. Prior to reviewing the possible determinants of developed country gold fabrication a general theory of mineral demand will be given.

Typically the role of minerals is as inputs of production used to produce final goods for consumers.[39] This type of indirect demand is referred to as a derived

---

37. The jewellery figures refer to the fabrication of gold in the country in which the process takes place, regardless of the country in which the product may eventually be sold.
38. Various Issues of Consolidated Gold Fields "Gold".

demand. Unlike most minerals however gold derived demand constitutes a very small fraction of total demand. Gold is demanded for wealth, jewellery purposes and health related uses. Demand for the majority of gold fabrication therefore can be studied within the theoretical framework of individual choice.

Basic to the theory of consumer demand is the notion of utility or overall satisfaction derived from a product. A person's utility is affected not only by consumption of commodities but also by psychological attitudes, personal experiences and the general cultural environment. Given a certain income it is assumed that individuals make choices that yield the greatest utility possible.[40] In order to maximize utility given a budget constraint an individual allocates available funds so that the marginal rate of substitution (MRS) between goods is equal to the ratio of market prices. From the above framework individual demand functions can be determined of the general form

$$Xi = Di\ (P1, P2, \ldots. Pn, I, \text{Other Factors})$$

---

39. See Vogely p.161-179
40. It is assumed that individuals have full information and that they obey certain basic assumptions of rationality in their choices. See Eaton & Eaton (1988) p.40-45.

The above equation states that Xi, the quantity of the ith good demanded, is a function of all prices (P1,P2,...Pn), income (I), and other factors such as tastes and preferences.

Such a function allows comparative static experiments to be performed. These experiments examine the consequences of a change in one of the determinants of demand on quantities chosen.

A change in the good's price and the associated change in the quantity of the good demanded is a movement along the demand curve. Change in the other determinants of demand cause a shift in position of the curve. For example, a rightward shift in an individual's demand can be caused by an increase in income, or increase in a substitute price, a decrease in a compliments price, and a favourable change in tastes and preferences. For example, when in 1927 it was found that a solution containing small amounts of gold helped to reduce rheumatoid arthritis, it would be expected that the demand curve for gold would have shifted outwards to the right.[41]

Individual demand curve functions are then horizontally

---

41. See Kettell (1982) p.112.

summed to create a market curve. Unlike individual demand functions in some cases the direction in which the market demand curve will shift is ambiguous. If some individual's demand curves shift outward while others shift inward, the resultant effect on market demand will be uncertain. Generally however the market demand curve is assumed to be downward sloping and shift in the same fashion as the individual's demand curve.

As a way of measuring the responsiveness of demand to various influences the concept of elasticity is important. Elasticity is the degree of change in the quantity demanded of a product due to changes in factors such as prices, income and the prices of compliments and substitutes. Identifying demand elasticity allows for powerful statements to be made concerning the behavior of the market. For example as was stated earlier in the paper, Sherman (1986) in a very simple demand and supply study on gold found that the total fabricated gold demand curve is downward sloping with a price elasticity of roughly -1. That is a 1 percent increase in the U.S. dollar price of gold will result in a 1 percent decrease in the demand for fabricated gold products.[42].

---

42. See Sherman (1986) p.54-63.

Determinants of Developed Country Gold Fabrication Demand

In developed countries it is jewellery at the lower end of the carat scale that provides the greatest demand for gold.[43] As a consequence gold is not demanded as a store of value or for investment purposes but rather primarily for consumption reasons.[44] Therefore developed country gold fabrication demand should be determined by factors which were discussed earlier in the theory of individual choice. As a luxury good, jewellery demand should be negatively related to increasing gold prices. If tastes and fashion turn against gold to other metals, particularly silver, then less gold will be demanded. The effect of the price of substitutes on the quantity of gold demand for fabrication would be expected to be positive. Finally income or wealth and the quantity of gold demand would be positively related.

Developing Country Gold Fabrication Demand and Its Determinants

As was the case in developed country fabrication demand jewellery constitutes the largest portion of developing

---

43. Kettell (1982) page 105 estimates that 80% of gold trade in Britain is in 9 carat gold.
44. See Cousineau and Richardson (1979) p. 26-27.

country gold fabrication demand. Unlike developed countries however high carat low mark-up jewellery is an important form of savings in developing countries.[45] The major reason for holding gold as a form of savings is due largely to its liquidity properties.

In many developing countries, particularly India, gold forms an integral part of social custom. Traditions such as inheritance laws and the right of a woman to own and hold precious metals and gems seperately from her husband's property are important. Also where the government has authorized the holding of gold in the form of bars and where banking systems, savings schemes and stock markets are not available or not trusted, gold jewellery is extremely important.

While the primary motive for holding jewellery in developed countries is fashion driven, the basic motive for holding gold jewellery in developing countries is fear and uncertainty. Fear of loss and fear of being illiquid.[46] As a consequence it is expected that the determinants of developing country fabrication demand will be significantly

---

45. In developed countries mark-ups in excess of 100% are commonly charged by jewellers while in developing countries the premium is normally not higher than 10%. See Consolidated Gold Fields (1982) p.39.

different from those of developed country demand.

The hoarder purchases gold primarily because of uncertainty and fear of being illiquid. Consider a risk averse individual who is concerned with his level of income in each possible future reality. To ensure that he is protected against all future states he will save a portion of his income. The individual however must ensure that these savings retain their purchasing power and are highly liquid. For example, if a serious illness arises in a family in a developing country, the family will need immediate resources to pay for care.[47] Assuming the family is risk averse it will attempt to minimize the risk of being illiquid and therefore minimize the risk of serious loss in the family. But the question arises as to why the individual's savings take the form of gold? Why not hold currency, stocks, silver, wheat, bonds, etc.? Apparently hoarders attach a higher liquidity return to gold than to other commodities. Before addressing the question of the liquidity return it may be beneficial to analyse the hoarder's demand for insurance and therefore gold.

---

46. See Machlup (1969, p.339)
47. For the hoarder it is assumed that he views these factors as gambles or lotteries. See J. Hirschliefer (1970, p.217).

Consider a risk averse individual in a developing country, where banking services are limited or suspect. Suppose an individual's utility as a function of wealth (w_o), can be expressed as

$$U = U(w_o).$$

The individual faces a risk of loss due to sickness, theft, taxation, fire of

$$U = U(w_o - L)$$

where -L is the loss in wealth resulting from the occurrence of the bad event and NL is the no loss prospect. The individual therefore faces the following risky prospect.

$$(p,\ 1-p:\ -L,\ NL)$$

where $1 < p < 0$.

This prospect offers NL with probability p and -L with probability 1-p. The expected utility of the risky prospect to someone with initial wealth w is

$$p\ U(w_o - L) + (1-p)U(w_o)$$

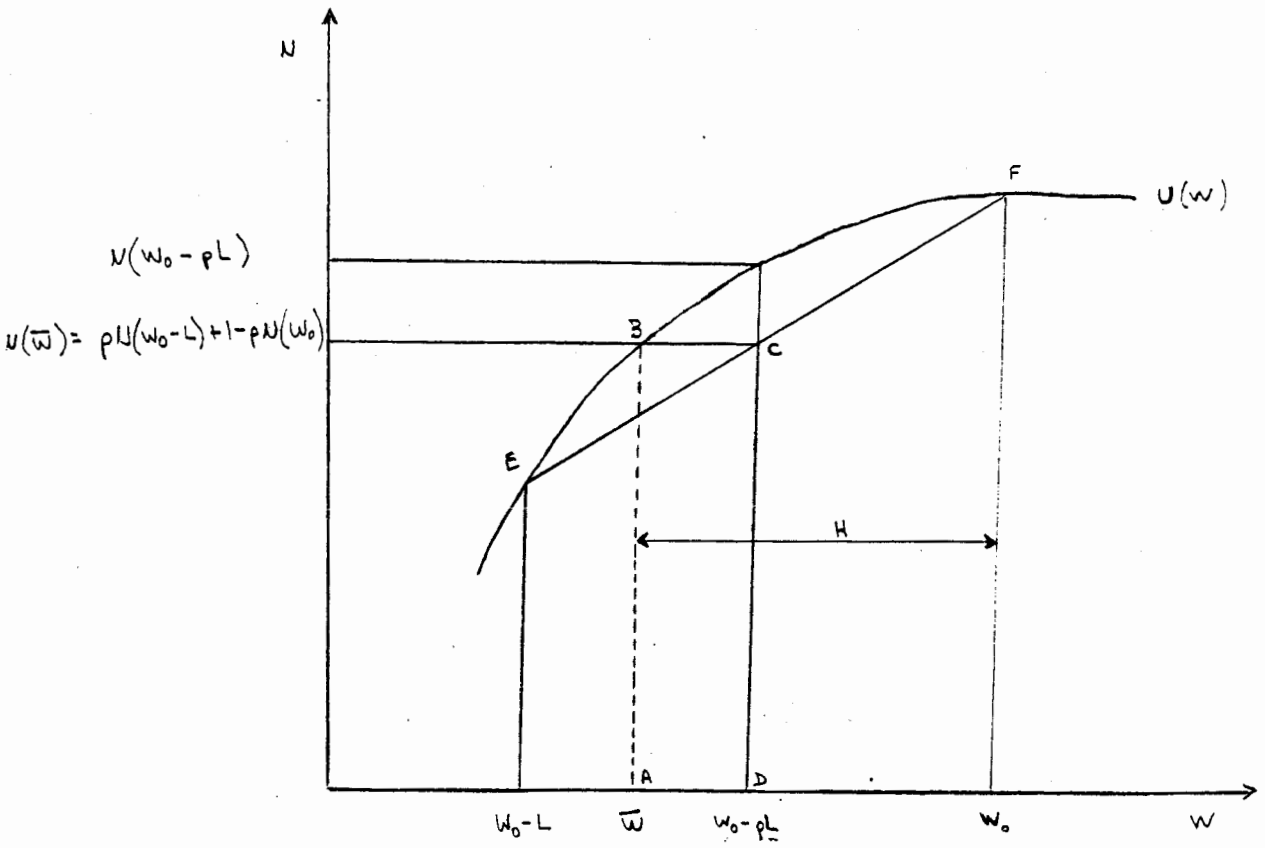
where $NL = 0$.

and the expected value is

$$p\ (w_o - L) + (1-p)w_o = w - pL$$

Assuming risk averse preferences the individual's expected utility in the absence of gold hoarding is shown in Figure 7.

Figure 7: THE DEMAND FOR GOLD AS AN INSURANCE ASSET



The certainty equivalent of the risky prospect is

$$U(w_o) = pU(w_o-L) + 1-pU(w_o).$$

This is the point where the individual is indifferent between the riskless prospect and the risky one. The line segment BA is equal to CD, the expected utility of the risky prospect that the individual would have in the absence of gold hoarding.

Now consider gold hoarding. Hoarding gold acts as an insurance policy in the event of loss. How much gold will the individual in this case purchase rather than bear the risk of loss? As seen from Figure 7, the individual will demand a dollar amount of gold equal to the distance H. This no risk wealth level is equal to w_o-H and the expected utility associated with it is $U(w_o-H)$ which is equal to $U(\bar{w})$ the certainty equivalent.

Next, consider an individual who does not hoard gold but instead holds a riskless asset such as government bonds as loss insurance. In developing countries while there is interest attached to government bonds there are liquidity costs such as time and paperwork associated with bonds that must be taken into account when funds are urgently needed.

As seen from Figure 7, the maximum amount that the individual will pay to reduce the risk is H. Any amount greater than H the individual would be willing to take his chances with the risky prospect. For the individual to hold government bonds instead of gold means that what the individual pays for the bond plus the liquidity costs must be equal to or less than the distance H, valued in gold plus the foregone interest that might have been earned on the bond. If the interest rate on the risk free bond is high and the liquidity costs are low then the individual would hold bonds instead of gold. If interest rates are low and liquidity costs relatively high then the individual would hold gold. Therefore if an individual holds gold the liquidity return is greater than the interest that might have been earned on the bond.[48] If it is assumed the hoarder expects little long-term change in the purchasing power of gold the following equation determines whether or not he will hoard gold.[49]

$$G + i < Bp + LC$$

---

48. It is assumed that the price of the bond is equal to H. Also, when considering large quantities of gold, storage and transportation costs must be considered. An individual in this instance will hold gold if the bond price plus the liquidity costs is greater than the distance H valued in terms of gold plus the interest foregone and storage and transportation costs (LC).

$$G + i + T < Bp + LC$$

49. Jastram (1977, p.175) concludes that the purchasing power of gold is constant in the long-run.

where G = the distance H valued in terms of Gold

i = nominal interest rate on the bond

Bp = price of the bond

LC = liquidity costs.

The right hand side of the equation is the cost of holding the bond and G + i is the cost of holding gold.

As an example of how high the non-monetary liquidity return on gold can be, in 1965, India initiated a program to wean Indian society from its gold hoarding habit. Individuals were offered Gold Defense Bonds in exchange for gold. These bonds were offered at a rate of interest of 7% and were exempt from wealth and capital gains tax. Upon maturity, gold was to be repaid to the bond holder. The program failed dismally in enticing gold out of the system.[50] It failed because the liquidity return of holding gold was larger than the 7% interest on the bonds combined with the returns associated with the tax savings.

The model just described, is a one period model which assumes that the individual wanting gold and not another asset such as bonds, does not already have a stock of gold to which he is adding. What happens in periods N+1 when the

---

50. See Green (1968, p.179).

hoarder already has an initial stock of gold? What factors affect how much will be added to his gold stock? Consider Figure 8.

Suppose in period 2 the risk averse hoarder's non-gold wealth increases by $w_o - w_1$ with the loss outcome and the probability (p) remaining constant. The expected utility of this new risky prospect is

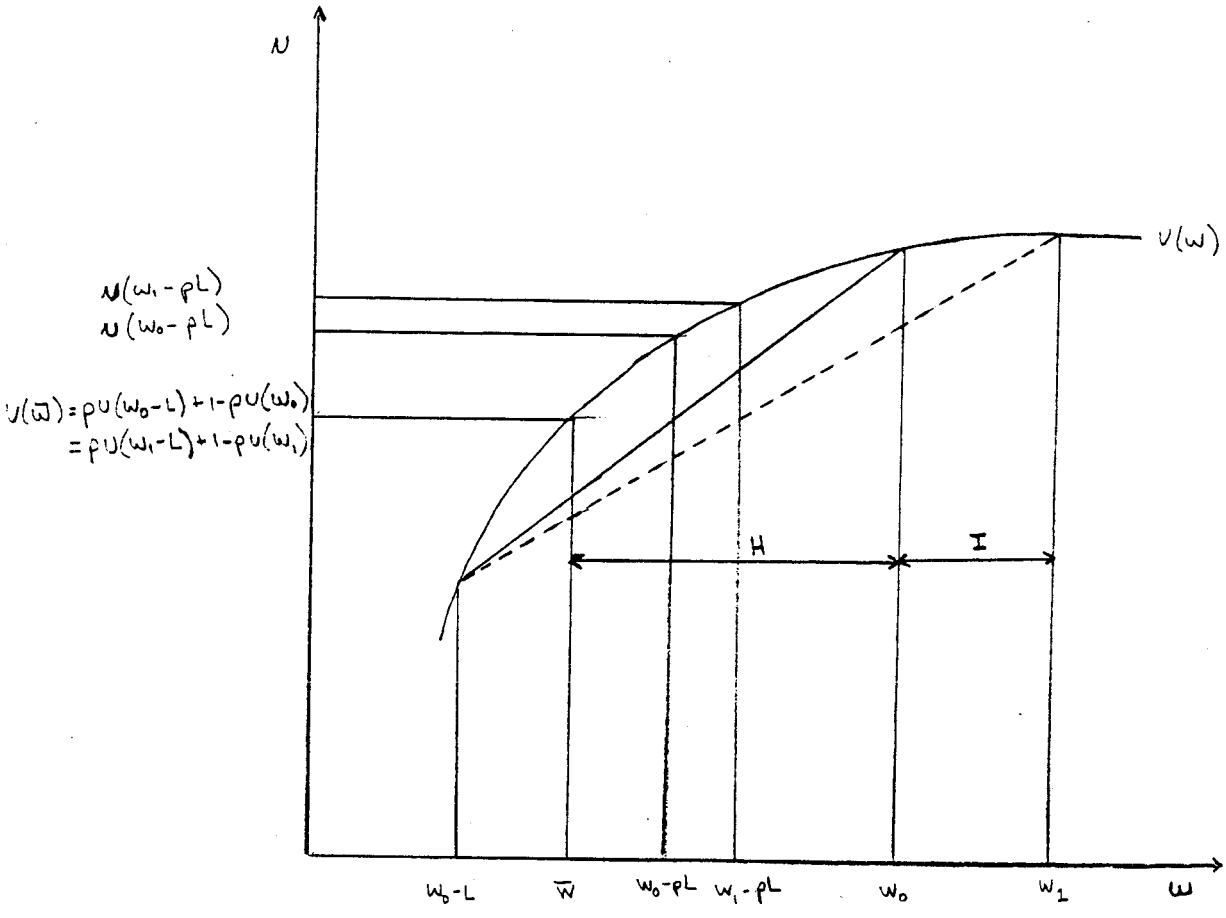
$$pU(w_1-L) + (1-p)U(w_1)$$

and the expected value is

$$p(w_1-L) + (1-p)w_1 = w_1 - PL.$$

The dollar amount of gold the individual will purchase rather than be faced with the new risky prospect is distance H + I. But the hoarder has already purchased distance H the previous period. He now only has to purchase distance I to reach the point where he is indifferent between the now riskless prospect and the new risky one. It is clear that an increase in wealth $(w_o - w_1)$ with the loss outcome, probabilities and gold prices remaining constant, means that the hoarder will demand a value of gold equal to H + I where I is the new addition to the individual's gold stock.

Figure 8. WEALTH CHANGES AND THE DEMAND FOR GOLD



Now consider that either the relative price of gold P/Pg (where P is the commodity price index and Pg is the fixed price of gold) or the market price of gold Pg is free to move.[51] Suppose that the price of gold has increased from period 1 to period 2. As a result the value of the hoarder's gold stock will have risen. If the price of gold increases by an amount equal to I then the hoarder will not purchase any additional gold in period 2. If prices increase by an amount greater than I then the hoarder will dishoard an amount equal to

Value of Gold Stock - H - I = Dishoarding.

Likewise if gold prices fall, a greater than distance I value of gold will be demanded until H + I is reached.

To conclude, it is anticipated that the gold price will be an important variable in determining developing country gold fabrication. However it may be secondary to the hoarder's level of income or wealth and his social, political and economic environment.

---

51. The fixed price of gold corresponds to the Gold Standard to Bretton Woods periods and the market price corresponds to the post 1971 period.

OFFICIAL RESERVE DEMAND

The role of gold in the international monetary system has been extremely important for centuries. The history of gold as money dates back more than 5,000 years to Ancient Egypt and the civilizations of Mesopotamia.[52] In the last 97 years gold in the international monetary system has gone through six distinct phases.[53]

1) The Classical Gold Standard Mechanism

The period 1879 to 1914 is considered the Gold Standard era. While Great Britain in 1821 was the first country to meet the formal conditions of the gold standard mechanism, most Western European economies and the U.S. did not formally move to a gold standard until the 1870's. In all cases the transition by most countries took different forms nor was it consciously planned.

Very briefly, there were several important rules of the 1879 to 1914 gold standard system:

---

52. See Anika (1983) p.27.
53. Note that in Table 12 official reserve statistics were unavailable prior to 1913.

a) Convertibility of domestic money into gold. More specifically the gold standard was a gold coinage standard.[54] In this system gold coins circulated domestically and were interchangeable with notes at the central bank, which held a gold reserve to maintain and safeguard interchangeability. As a currency's value was stated in terms of a fixed amount of gold, this meant that the exchange rate between currencies was also fixed.

b) Participating countries had to allow the free import and export of gold. The gold standard was a system of international balance of payments adjustment.

c) The money supply for each country had to be linked automatically to the movement of gold in and out of the country.

With the main feature of the gold standard being that a nation's money was stated in terms of a fixed amount of gold, this ensured that the price of gold across nations would remain relatively uniform. National price levels were determined by the Quantity Theory of Money. That is, the price level was determined by a country's stock of monetary gold which in turn was determined by the nation's income and money holding characteristics. As a result, the theory of

---

54. Otherwise known as a gold specie standard.

the gold standard was one of equalization of prices internationally. If any disturbance to a country's prices occurred, the market value of gold would be affected; gold flows would occur affecting the country's money supply and level of prices.

In theory, the gold standard was to do the following:

a) Provide a generally accepted medium for the holding of international reserves.

b) Provide a method of adjustment of disequilibrium in the balance of payments of particular countries.

c) Impose constraints on the growth of the domestic money stock of participating countries and the price level.

d) Confine fluctuations in the exchange rates within narrow limits set by the cost of transporting gold.

e) Ensure that domestic and world prices were relatively stable.

2) The Gold Bullion Standard

The international gold standard fell apart as a result of World War I. During this period many countries attempted to remove gold coins from circulation eliminating the

possibility of exportation abroad. After the war monetary instability prompted the restoration of the international gold standard. Many countries were faced with severe inflation the most striking example being Germany in 1923, where the German mark was reduced to one million-millionth of its former value.

Germany returned to the gold standard in 1924; the United Kingdom in 1925; France in 1927; and the United States in 1919. As before, central banks bought and sold gold at fixed prices, and gold was allowed to move freely internationally. However in this instance most countries, with the exception of the U.S., operated on a gold bullion standard rather than a specie standard. Countries under the bullion standard redeemed money in gold bars of large denomination only and often there were restrictions limiting gold sales to individuals wanting it for export or industrial use. Of more importance however, was the fact that many central banks, in an attempt to economize on gold were now holding a significant proportion of their reserve in the form of foreign exchange. In 1913 foreign exchange accounted for 12% of total reserves for 15 European central banks. By 1924, the percentage of 24 European central banks had risen to 27% and by 1928 foreign exchange accounted for 42% of

reserves.

The gold bullion standard soon ended with the Great Depression of 1930. In 1931, a series of continental bank failures led to heavy withdrawals from the London money market forcing the Bank of England to announce that its gold reserves had fallen significantly and therefore they could not maintain the gold standard. The pound was allowed to float downward, creating losses for the central banks that held their reserves in London. Pressures then shifted to other countries, forcing most of them off the gold standard.

The U.S. was one of the few countries which remained on the gold standard during the depression period. (See Table 13). However in 1933, a significant modification was made to the U.S. gold standard. No longer were private individuals allowed to hold gold coin, gold bullion or gold certificates. This put the U.S. on a limited gold bullion standard, under which redemption in gold was restricted to dollars held by foreign banks and licensed private users. At the same time the U.S. devalued the dollar by increasing the price of gold from $20.67, as established in 1834, to $35.00 an ounce. The devaluations of national currencies in relation to gold was significant in that it had the effect of endowing gold with

capital gains value and a resultant positive rate of return, which tended to exceed that available in foreign currencies. In response countries had to take action to protect gold reserves.

Table 13: MONETARY STANDARD POSITION OF SELECTED WORLD ECONOMIES
(January 1st, 1933)

Off the Gold Standard and with Depreciated Currencies		Nominally on the Gold Standard with Old Parities Maintained Through Official Control	On Full Gold Standard
Without Official Control	With Official Control		
Australia	Argentina	Austria	Albania
British India	Bolivia	Bulgaria	Belgium
British Malaya	Brazil	Czechoslovakia	Danzig
Canada	Chile	Estonia	East Indies
Egypt	Columbia	Germany	France
Finland	Denmark	Hungary	Italy
Great Britain	Ecuador	Latvia	Lithuania
Irish Free State	Greece	Romania	Netherlands
Mexico	Japan	Yugoslavia	Poland
New Zealand	Persia		Switzerland
Norway	Portugal		U.S.
Palestine	Spain		
Peru	Turkey		
Siam	Uruguay		
Sweden			
Union of South Africa			

Source: Busschau (1949, p.156)

The attempted restoration of the gold standard in the 1920's did not meet the test of consistency. Exchange rates were pegged on an ad hoc basis and price adjustments in

countries with payment deficits often did not occur. In addition, looser ties between money and gold allowed countries to follow independent monetary policies and each country was substituting more and more reserve currencies of gold creating additional monetary instability.

3) The Gold Exchange Standard

With the end of World War II there was a need for monetary order, however without the rigidities and inconsistencies of the previous gold bullion standard. The consensus by most countries was to ensure the convertibility of currencies between countries and to avoid significant exchange rate fluctuations.

Out of these concerns, a new monetary organization was created at Bretton Woods, New Hampshire, called the International Monetary Fund (IMF). Members of the IMF were required to do the following:

a) Declare fixed parities for their currencies either in terms of gold or of U.S. dollars.

b) The U.S. Treasury continued to buy and sell gold at $35 an ounce with foreign central banks and licensed users.

But other countries were no longer required to join the U.S. in making their currencies convertible into gold.

c) The IMF was to provide the necessary machinery to correct for temporary balance of payment swings. Each member country paid into the IMF an amount of gold plus its own currency equal to a quota that was roughly proportionate to its economic size.

d) The requirement of maintaining a fixed parity for a currency could be fulfilled by stabilizing its dollar value within +/- 1% of parity through central bank intervention in the foreign exchange market.

As a result, the gold exchange system was similar to the gold standard but now the U.S. assumed Britain's earlier role as the main reserve currency country. Because of vast inflows of gold during the 1930's, the U.S. was in an excellent position to act as the world's banker.

4) Demise of the Gold Exchange Standard

Two important reasons resulted in the demise of the gold exchange standard. An essential feature of a reserve currency is that holders must have confidence in it and the

Bretton Woods system required the international reserves be created by U.S. deficits. But continuing and large deficits by the U.S. led to a glut of U.S. dollars and a loss of dollar confidence. The increase in dollar liabilities coincided with the drain on U.S. gold reserves and these liabilities exceeded U.S. gold holdings for the first time in 1964. (See Table 14). The U.S. tried to keep down the deficit, through foreign investment restrictions, currency swaps, etc. but with no positive effect. As a result, speculative private demand for gold soared in expectation of a dollar devaluation.

Table 14: FOREIGN LIABILITIES AND U.S. GOLD STOCK
1959 to 1970
($ billion, end of period)

	Liabilities(1)	Gold Stocks(2)
1959	10.12	19.51
1960	11.09	17.80
1961	11.83	16.95
1962	12.91	16.06
1963	14.43	15.60
1964	15.79	15.47
1965	15.83	14.07
1966	14.90	13.24
1967	18.19	12.07
1968	17.34	10.89
1969	15.99	11.86
1970	23.77	11.07

Source: International Financial Statistics, IMF

1) Liabilities of central banks and governments only.
2) Gold valued at $35.00 oz.

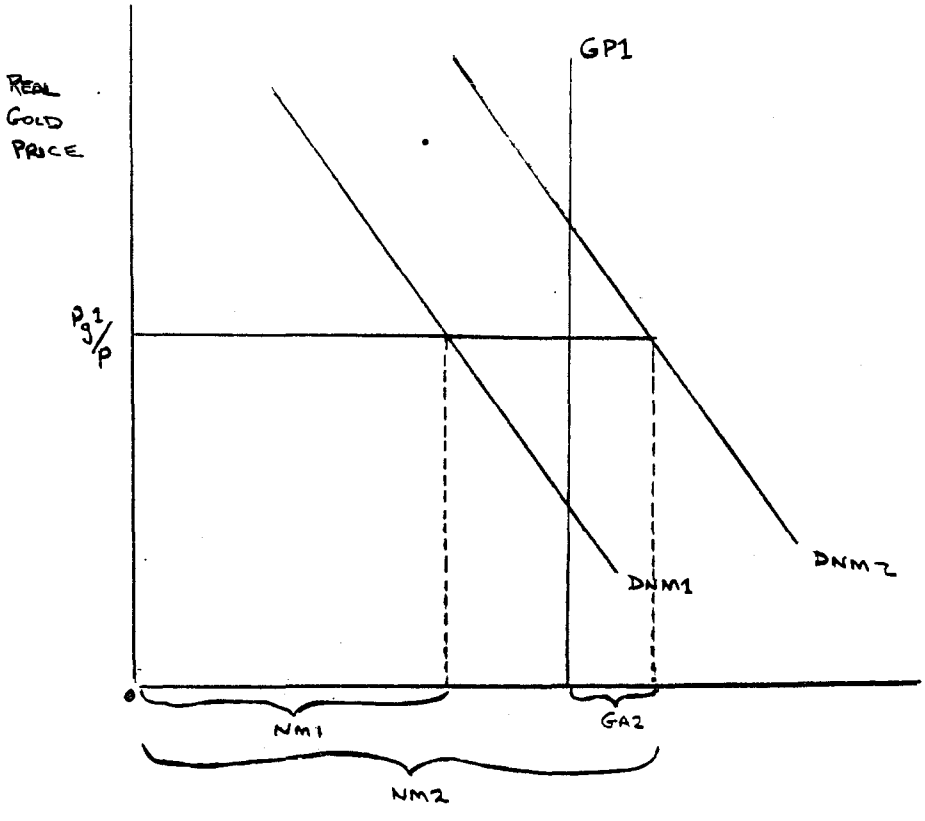
In addition to the increase in speculative demand gold in expectation of a dollar devaluation, gold was now significantly underpriced in relation to other commodities. This encouraged gold hoarding resulting in little gold available for monetary use. By 1966 annual non-monetary market demand accounted for all of the gold supplied. Only once before since 1920 had this occurred. See Table 12. Figure 9 illustrates what occurred in 1966. As before DNM1 is the non-monetary gold demand curve at time 1 and GP1 is the amount of gold supplied at period 1. Pg1/p denotes the real price of gold. In period one at Pg1/p the amount of gold demand for non-monetary purposes is NM1. If non-monetary demand increases, the DNM1 shifts out to DNM2. If it is assumed that gold production remains unchanged at GP1, at Pg1/p the amount of non-monetary gold demanded is NM2 with official agencies having to supply an additional amount GA2. In an effort to limit private demand pressures on gold, the U.S., the United Kingdom, Switzerland, Belgium, France, Germany, Italy and the Netherlands formed the Gold Pool. From 1967 until early 1968 the gold pool sold over 2000 tonnes of gold in an attempt to stabilize the price of gold in private markets. See Table 12.[55]

---

55. Clearly the obvious solution would have been to raise the official price of gold, however this was strongly opposed by the U.S. They argued that the resulting increase in reserves would increase inflation.

Unable to keep up with the private demand for gold the Gold Pool was disbanded in March 1968. It was replaced by a two tier gold price system, one price on private markets determined by supply and demand and another price for central banks to remain at the previous fixed level of $35.00 per ounce. Also in that year, the U.S. eliminated the requirement that the Federal Reserve hold gold certificates equal to at least 25% of the value of Federal Reserve notes, thereby freeing all Treasury gold for international use.

Figure 9: Increasing Non-Monetary Gold Demand



Continued worsening balance of trade deficits and capital account imbalances due partly to rising inflation in the U.S. and to rapid productivity increases abroad resulted in increased international liquidity and U.S. obligations abroad. To private holders of dollars a depreciation of the dollar was inevitable, although countries with payment surpluses could have revalued their currencies upward to correct the disequilibrium.[56]

What resulted was a massive outflow of U.S. dollars during the summer of 1971. In response to this, the U.S. suspended gold convertibility in August 15, 1971.[57] This severed the link of the dollar from gold and declared that the U.S. would no longer meet its international obligations with gold. All currencies were free to float independent of the dollar and the price of gold in the market was free from official intervention.

5) Attempt to Demonetize Gold

As the monetary stock of gold could not keep up with reserve demand it was blamed in large part for the poor state

---

56. These countries were reluctant to revalue because of the impact on their export sector.
57. See Grubel (1981 p.479-485) for a detailed explanation of the shortcomings of the Gold Exchange Standard.

of the world economy. Monetary officials as a result began to look on gold as an encumbrance and set out to demonitize it. Although in 1971, the U.S. ended gold convertibility of its currency the two tier gold system continued to exist. In 1973 the two tier system was terminated resolving the issue of market price sales in the market.

In 1974 a committee set up by the International Monetary Fund (IMF) entitled the Group of Twenty set out several proposals regarding the future sale of gold. Very briefly these are as follows:

- the SDR (Special Drawing Rights) should become the central reserve asset,
- the official price of gold should be abolished,
- the role of both gold and reserve currencies should be reduced,
- the IMF should reduce its gold holdings through market sales.

As a result of the Group of Twenty recommendations in 1974 the SDR became valued not in gold but in terms of a group of currencies and individual countries were allowed to value gold which had been pledged as collateral for loans at market price. In 1974 the U.S. removed the ban on U.S.

individuals holding gold, allowing citizens the opportunity to buy and sell gold. This was significant in that it created a futures market greatly increasing the investment opportunities associated with gold. Most importantly, beginning in 1976 the IMF and U.S. began auctioning off a portion of their gold holdings. From 1976 to 1979 net official sales of gold totalled 1,233 tonnes of gold. This increase in supply did nothing however to lower the gold price. The reason for this substantial price increase was due to the fact that private market participants feeling that substantial gold sales would fuel inflation sought protection by purchasing real assets such as gold. In 1979 the IMF and the U.S. stopped regular gold sales for fear of creating monetary instability.

6) The Role of Gold in the 1980's

The mood to demonetize gold after 1979 disappeared. The resulting picture regarding the official function of gold is now complex if not puzzling. Gold no longer stands as the official currency valuation, is no longer used in the settlement of imbalance between central banks, is generally no longer related to money creation and central banks no

longer buy much gold. However official gold holdings remain important in the international financial system as they amount to approximately 38,400 tonnes or 539,000 million dollars. A possible reason why Central bankers continue to hold vast amounts of gold is that gold is beyond the control of one nation. Therefore nations can operate under a substantial measure of autonomy and independence in their own monetary and fiscal matters.

As seen in Table 15 gold as a percentage of International Reserves has fallen significantly despite being valued at market prices since the early 1900's. In 1987 gold comprised 39.5% of international reserves down significantly from 91.4% in 1937. In general during the 1980's central banks have largely husbanded their gold stocks buying or selling little, holding it for safety and liquidity purposes. (See Table 12).

However a growing number of central banks are valuing their gold reserves based on some formula linked to current market prices. In addition gold reserves are being used more widely as collateral for international loans and developing countries are purchasing gold when prices are low and selling when gold prices are high to acquire needed foreign exchange.

Table 15: GOLD IN INTERNATIONAL RESERVES (1913 - 1987)[58]
(%)

	1913	1928	1937	1950	1960	1970	1980	1984	1987
Official Gold as a % of International Reserves[59]	85.4	75.7	91.4	68.8	63.6	41.3	57.8	42.2	39.5
Distribution of official gold among main groups of countries									
- Industrial countries				90.9	90.8	86.5	83.0	83.6	83.6
- Oil exporting countries				2.2	1.9	3.2	4.3	4.6	4.6
- Non-oil exporting countries				6.9	7.3	10.3	12.7	11.8	11.8
				100.0	100.0	100.0	100.0	100.0	100.0

Sources: IMF and Triffin (1964).

---

58. Gold valued at $20.67 an ounce for 1913 and 1928, at $35 for 1937, and at market prices from 1950-1987.
Sources: IMF and Triffin (1964).
59. International official reserves = gold + foreign exchange + SDR's + reserve position in the Fund.

Determinants of Official Reserve Demand

Clearly over the last 100 years the role of gold in the international monetary system has changed dramatically. As was seen in Chapter 2, Rockoff (1984), in his analysis of the supply and demand for monetary gold, theorized that during the gold standard monetary gold demand would be determined by three factors: the demand for money; the price of gold and ratio of the stock of gold to the stock of money.[60] The above relationships have not been empirically tested due to the unavailability of data.

However, empirical testing of the demand not for gold reserves solely but for international reserves has been undertaken for periods only since 1950. Bahmani-Oskooee (1987) found that the variability of international receipts, the imports of a country and the price of gold were among the main explanatory variables in the international reserves demand function.[61]

The rational for including each factor is as follows.

---

60. See Chapter 2
61. For a detailed summary of empirical studies pertaining to demand for reserves see Bahmani-Oskooee (1987).

1) Variability of international receipts is a measure of the fluctuations in external transactions. Therefore the higher the fluctuations the greater the demand for reserves and therefore gold.
2) Increasing imports of a country implies increased demand for reserves.
3) A higher gold price revalues the gold component of total reserves, thus leading to a lower demand for international reserves.

Testing nineteen industrial countries over the 1973-81 period Bahmani-Oskooee (1987) found all three of the explanatory variables to have the expected signs and to be significant at the 99% level.

PRIVATE INVESTMENT DEMAND

As was stated earlier private investment demand is a residual of supply to non communist countries minus developed and developing country fabrication demand and official reserve demand. Investment demand includes the demand for gold medals, medallions, coins and bullion.

Each of the above alternative forms of gold investments

has its own set of characteristics.

1) Physical Gold Bullion

Usually the larger the bar the more acceptable and liquid however with this comes storage problems.

2) Bullion Delivery Order

A delivery order is a document that gives the owner the ownership of physical gold. As bullion remains in a recognized precious metal warehouse of the investors choice, the associated storage costs are relatively small. As a delivery order is totally liquid, it is therefore a highly convenient method of holding gold.

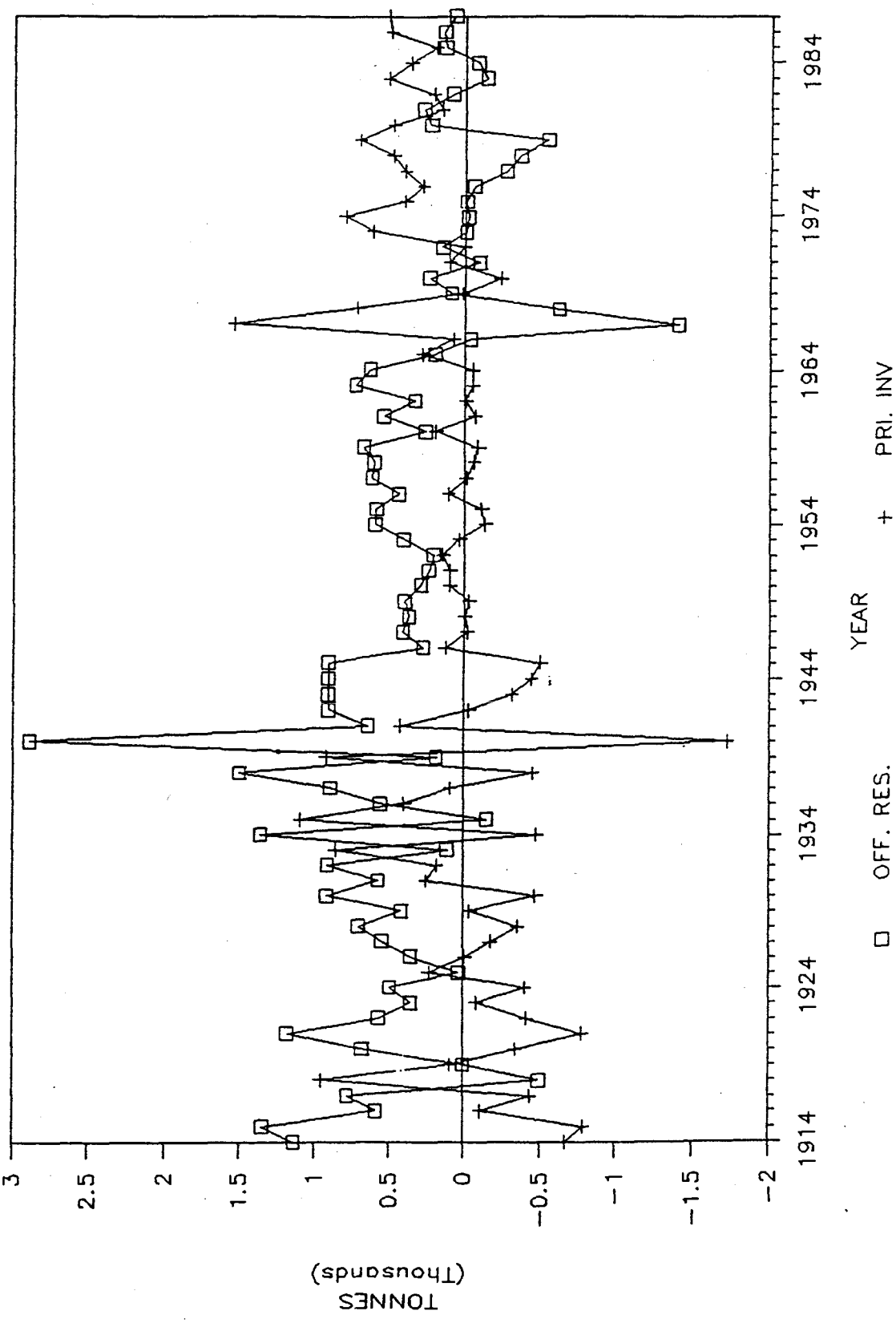
3) Bullion Certificates

Bullion remains in the broker's vault. The investor therefore has limited storage risk and is provided with a highly liquid investment.

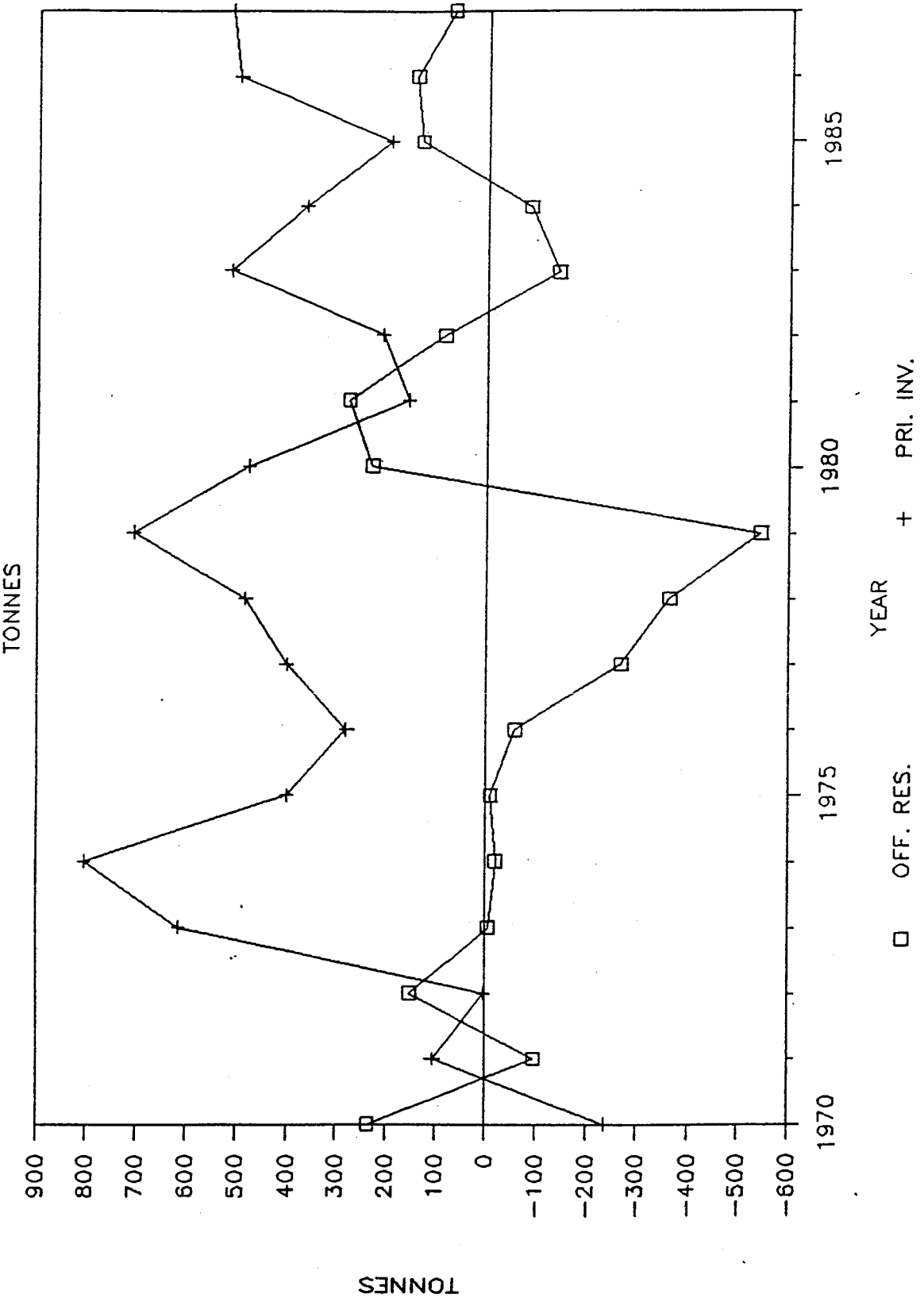
4) Gold Coins

Storage of coins is relatively easy. While there is a slightly wider spread between the bid and asked prices of coins than bullion, coins are still highly liquid.

GRAPH 8: OFF. RESERVES AND PRIVATE INVESTMENT



GRAPH 9: OFF. RESERVES AND PRIVATE INVESTMENT



Graphs 8 and 9 illustrate how volatile private investment demand has been over the last 73 years. What is also striking is the magnitude of disinvestment and investment that has occurred in certain periods.[62] For example, from 1914 to 1918 over 2000 tonnes of gold were sold by private individuals. In contrast from 1965 to 1969, 2640 tonnes of gold were bought by the private investor. Since gold prices were allowed to float in 1971 in no year has there been negative investment however demand has remained volatile ranging from a low of 2.5 tonnes demanded in 1972 to a high of 803 tonnes in 1974.

Since the Gold Standard, the investment properties of gold have changed significantly. During the gold standard and gold exchange standard, investors could exchange their domestic money at a fixed rate for gold which was effectively a package of pure hedges against several bad general states.[63] Gold had two general sources of income contingent on extreme bad states. In states of war, monetary breakdown, or social disorder gold would assume all the functions of money and so long as a major part of the world's currencies remained on gold, international purchasing power would

---

62. Also included in the graph is official reserves. It is interesting to see that the private investment demand and official reserve demand curves are mirror images of each other up until 1971.

remain fairly constant. As seen in Table 12, between 1914 and 1930 a massive amount of disinvestment in the world was occurring. This was due primarily to World War I, the 1920 stock market crash and the 1930 depression.

In terms of purchasing power, column H in Table 12 shows that during this period the real price of gold was also falling which contributed further to private disinvestment. Beginning in approximately 1930 the purchasing power of gold and therefore the real return of holding gold started to increase causing an increase in private gold investment. Investment continued until 1940 and the breakout of World War II. From 1950 to 1966 investment demand remained extremely weak due in large part to the low real purchasing power of gold.[64] In general over the 1914 to 1965 period as gold was not a good inflation hedge gold was purchased by private individuals primarily as protection against extreme bad

---

63. Let x* represent a bad state of the world which is one extreme value of state-variable x. A pure hedge is income which is a function only of the value of x and which rises the nearer is x to x*. An impure hedge promises high income in most state variables in which x moves to x*. As an example pertaining to gold, while it may be thought that gold yields its highest income in the state of total war and its lowest value in total peace, the income is a function not only of the value of the belligerency variable, but also of other state-variables that exist. Gold would probably yield a higher income in the combined states of war - hyperinflation - boom than in war - price stability - moderate economic activity and a war - increased gold production or large discovery of gold state.

states of the world.[65] With the dollar's break with gold beginning in 1968 the motives for holding gold sharply changed. (See Graph 8).

1) Speculative Motive

First of all with the price of gold allowed to float investors now had the opportunity of capital gains from the appreciation of gold. As seen from Table 16 the average real rate of return for gold against alternative U.S. assets have been mixed.

Table 16: ANNUAL REAL RATES OF RETURN FOR ALTERNATIVE ASSETS, 1975-1985

Year	U.S. Treasury Bill	Standard & Poors 500 Stock Stock Index	U.S. Real Estate	U.S. Future Funds	Gold
1975	-1.1	28.3	6.0	3.5	-29.7
1976	0.3	18.2	4.7	-25.6	-8.5
1977	-1.6	-13.1	4.0	55.3	14.8
1978	-1.7	- 2.3	5.3	19.3	25.7
1979	-2.6	4.5	4.7	40.9	104.6
1980	-1.0	17.9	0.8	13.4	0.1
1981	5.3	-12.8	-3.7	7.8	-37.7
1982	6.4	16.8	3.8	-4.7	10.0
1983	4.8	18.1	3.2	-13.9	-19.6
1984	5.7	2.2	0.7	3.3	-22.3
1985	3.7	27.2	5.7	10.1	3.0
ARITH. MEAN	1.6	9.5	3.2	9.9	3.7
GEO. MEAN	0.1	8.5	3.1	7.8	-1.6
STAND. DEV.	3.5	14.7	2.9	22.9	38.8

Source: Irwin & Landa (1987)

---

64. See Jastram (1977) for a detailed examination of the historical purchasing power of gold.
65. Brown (1982) outlines a theory of Hedge Investment.

While gold has the third highest average return of the five assets it has the highest volatility, 38.9% almost twice as high as the futures Funds asset.

These types of buyers are influenced by world economic circumstance, political developments, particularly in the Middle East and South Africa, the price of energy, inflationary tendencies, the value of the U.S. dollar, and real interest rates. With respect to the last three factors one would expect interest rates to affect the gold price in two ways. The first, as interest rates rise, the opportunity cost of holding gold increases causing portfolio shifting out of gold. Second, an increase in U.S. interest rates will lead to an increase in value of the the dollar which in turn will lead to a lower gold price. This is primarily due to two reasons. Dollar denominated assets are an alternative investment to gold and a rise in the value of the U.S. dollar will lead to a fall in the dollar gold price, if the price of gold is stable in foreign currency. With respect to inflation, the real price of gold should continue to go up because it is a depleting resource. Hence, the gold price should rise by a suitably chosen price index. Investors recognize that the above factors affect the demand and supply for gold and therefore the price.

2) Gold as an Inflation Hedge

With gold prices floating gold now becomes an inflation hedge. The notion that gold since 1971 has been a powerful hedge against inflation has been confirmed by Aliber (1982), Van Tassal (1982) and Jastram (1977). Table 16 shows that over the 1975 to 1985 period the average real rate of return was 3.7% but over the 1971 to 1986 period the average real rate of return was approximately 10%. Further evidence of how gold prices and inflation move in the same direction is given in Tables 17 and 18.

TABLE 17: NOMINAL GOLD RETURNS FOR VARIOUS COUNTRIES DURING PERIODS OF ACCELERATING AND DECELERATING INFLATION
(Cumulative Rate of Return,% Per Year)

Country	Accelerating Inflation		Decelerating Inflation	
	1971-1974	1977-1980	1975-1976	1981-1986
U.S.	43.3	40.0	-14.6	-6.4
Canada	42.4	44.2	-12.8	-4.1
Japan	38.8	32.4	-15.4	-10.6
Germany	32.9	34.3	-16.0	-6.4
Switzerland	30.0	31.1	-17.7	-7.7
U.K.	43.9	30.8	2.2	1.7

Source: IMF Statistics.

TABLE 18: REAL GOLD RETURNS FOR VARIOUS COUNTRIES DURING PERIODS OF ACCELERATING AND DECELERATING INFLATION (Cumulative Rate of Return,% Per Year)

Country	Accelerating Inflation		Decelerating Inflation	
	1971-1974	1977-1980	1975-1976	1981-1986
U.S.	33.4	29.9	-21.5	-8.3
Canada	33.2	33.1	-21.0	-8.9
Japan	27.0	25.3	-19.4	-9.1
Germany	26.2	30.3	-20.1	-9.3
Switzerland	21.8	30.7	-16.2	-9.5
U.K.	25.1	24.6	-17.5	-4.8

Source: IMF Statistics.

Table 17 illustrates that during periods of accelerating inflation the average annual nominal gold return was significant. The average annual nominal return over the two periods was 37.0% The local gold price appreciated relatively uniformily across all countries during accelerating inflation periods. In the decelerating inflation periods all countries with the exception of the United Kingdom suffered losses in nominal terms. The average rate of return decline in all countries except the U.K. was 11.2%. In the U.K. gold return increased an average of 2.0% per year during periods of decelerating inflation.

In real terms the picture is substantially the same.[66] (Table 18). The average annual real return over the two periods was 28.4%. Once again the local gold price appreciated relatively uniformily across the countries despite broadly varying inflation. During periods of decelerating inflation all countries experienced modest annual declines in real gold returns. What is striking about Table 18 is the similarity in declines between all countries over the 1981 - 1986 period.

The safety or security return that hedgers received from holding gold during the 1981-1986 period is given in Table 19. The security return is equal to the real gold return minus the opportunity cost of holding gold which has been defined as a country's Treasury Bill rate.[67] The average gold security return for the six industrialized countries was -16.3% This means that hedgers purchasing gold over this period were willing to give up a return of 16.3% in order to safeguard against inflation, war, currency devaluation, etc.

---

66. The Wholesale commodity price index was used to calculate real gold returns. The WPI instead of the CPI was used so as to be consistent with Jastram's 1976 study.
67. The security return is an underestimate as it excludes transactions and storage costs.

Table 19: Hedging Security Returns for the 1981-1986 Period % per year

Country	Average Gold Real Return	T-Bill Rate	Gold Security Return
United States	-8.3%	9.4%	-17.7%
Canada	-8.9%	11.7%	-20.6%
Japan	-9.1%	5.2%	-14.3%
Germany	-9.3%	6.5%	-15.8%
Switzerland	-9.5%	4.3%	-13.8%
United Kingdom	-4.8%	10.9%	-15.7%

Source: IMF International Financial Statistics

It has been shown that as inflation and gold prices move in the same direction that gold is an inflation hedge. But to be truely an inflation hedge gold must appreciate over the period during which it is held at a rate at least as great as the sum of the real rate of interest and the rate of inflation. If the real rate of interest rises as was the case during the 1980's holders will divest themselves of gold. If the expected rate of inflation rises, other things being equal, investors will increase their holdings of gold as an asset. If the market rate of interest rises, the demand for gold will rise only commensurate with the extent to which inflationary expectations are fully incorporated in the nominal interest rate.

3) Gold as a Portfolio Diversifier.

With fluctuating gold prices, investors began demanding gold as a portfolio diversifier. The theoretical models of portfolio selection developed by Markowitz (1952) and Tobin (1958) demonstrated that gains existed from national portfolio diversification. Very simply, the degree to which diversification can reduce risk depends upon the correlation among asset returns. If security returns are perfectly correlated, no amount of diversification can affect risk. A number of additional authors, Alder and Dumas (1975), Grubel (1968), Grubel and Fadner (1971), Lessard (1974), Levy and Sarnat (1970) have extended the Markowitz/Tobin model to show that further gains can and do exist when portfolios are internationally diversified.

For an asset to be included on a portfolio therefore the expected returns of the asset should be negatively correlated with portfolio return. Correlation coefficients for seven general asset groups including gold are presented in Table 20.[68]

---

68. The following results are consistent with previous studies, particularly Irwin & Landa (1987), Aggarwal and Soenen (1985), Sherman (1986), Ibbotson, Siegal and Love (1985).

Table 20: CORRELATION COEFFICIENTS
(Nominal Returns)

	Gold	World Cash	US Equities	US Bonds	Foreign Equities	Foreign Bonds	US Real Estate
Gold	1.000						
World Cash	0.074	1.000					
US Equities	-0.288	-0.322	1.000				
US Bonds	-0.482	-0.198	0.289	1.000			
Foreign Equities	-0.284	-0.378	0.961	0.125	1.000		
Foreign Bonds	-0.039	-0.284	0.045	0.068	0.156	1.000	
US Real Estate	0.697	0.047	0.082	-0.449	0.088	0.077	1.000

Sources: Asset category returns were obtained from Ibbotson, Siegal and Love (1985)

The above table shows that gold returns are negatively correlated with U.S. equity, U.S. Bond, foreign equity and foreign bond returns. Gold returns are highly correlated with U.S. real estate returns and to a lesser degree with world cash. This latter result is expected as gold is sometimes considered a form of cash and therefore should be somewhat correlated. Gold's low correlation against equities and bonds strongly suggests that gold will reduce return volatility in portfolios and therefore will be demanded as a portfolio diversifier. The relative stability in private investment demand since 1971, despite fluctuating inflation and political situations, suggests that the diversifier motive has added underlying strength to investment demand in

the 1970's and 1980's.

CONCLUSION

The previous chapters have analysed in detail the major supply and demand components for gold. The analyses has covered approximately 100 years, to show how the supply and demand for gold has functioned under a system of gold price maintenance and non-gold price maintenance. Of more importance, in light of the recent dramatic increase in gold production by non South African countries, this study pays special attention to how gold supply is determined and its affect on price. It has been shown that the classical economist believed the long run supply curve for gold as highly elastic with demand having little affect on the real price of gold. Current studies estimating gold prices have assumed the supply curve highly inelastic and the demand curve elastic. Therefore for supply changes to significantly affect price there has to be a substantial change in supply. As a result, it has been assumed that nominal gold prices are entirely demand driven.

To summarize the following chapters clearly in two diagrams, Figure 10 illustrates how the supply and demand for non-monetary gold, with the residual going to satisfy government demand, affects and influences real gold prices under a fixed gold price regime. The arrows indicate the major causal directions. Figure 11 summarizes the major factors affecting and influencing nominal gold prices under a flexible gold price system. Once again the arrows indicate principal causal directions.

FIGURE 10: PRICE MAINTENANCE GOLD MARKET

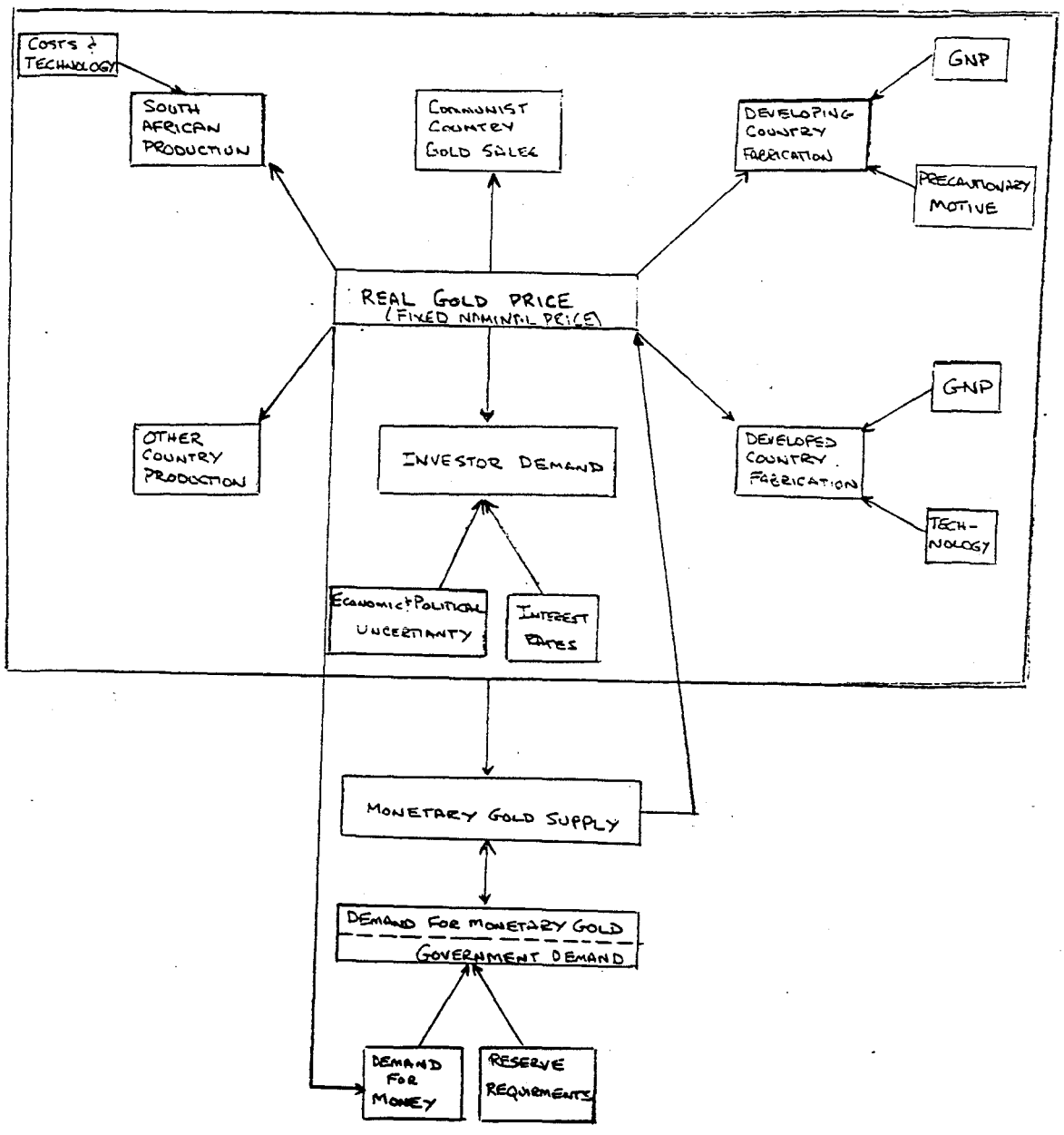
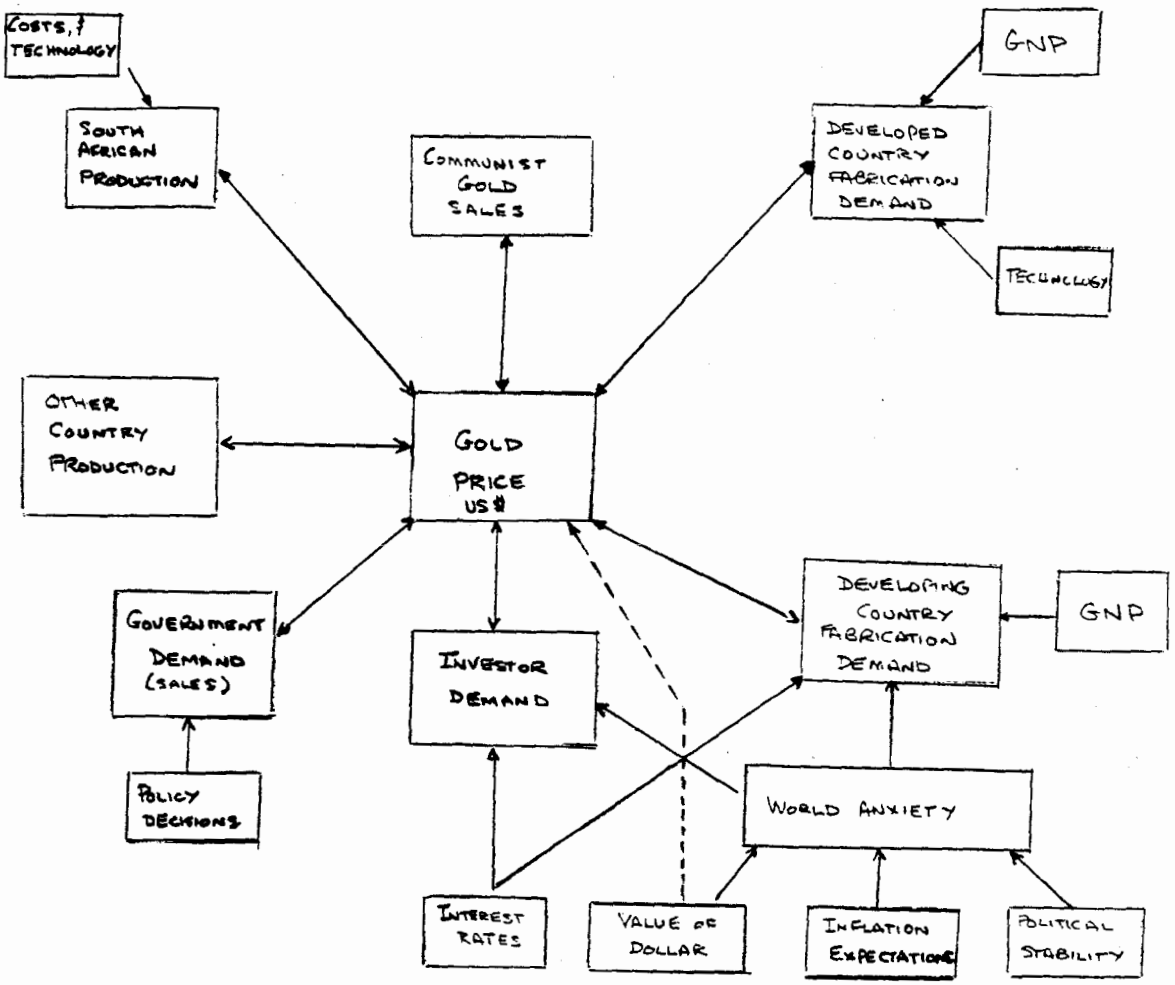


FIGURE 11: FLEXIBLE GOLD PRICE MARKET



CHAPTER 5

GOLD SUPPLY AND DEMAND CURVE ESTIMATION

The previous sections have detailed theoretically how the major supply and demand groups have operated over the last 100 years, in addition to identifying key explanatory variables for each category. This Chapter estimates supply equations for South African Production, Other Country Production, and Net Communist Sales/ Purchases. Demand equations are estimated for Developed Country Gold Fabrication, Developing Country Gold Fabrication, Official Reserve demand, and Private Investment demand.

SUPPLY MODEL

The following supply equations have been estimated using a stock adjustment distributed lag model which is very similar a Koyck or geometric lag model.[69]

The long-run supply curve is given as follows, where the

---

69. For a more advanced discussion of distributed lag models see Dhrymes (1971), Griliches (1954) and Nerlove (1972).

(1) $$St^* = @ + BPt + et$$

amount of gold supplied (metric tons) in year t is St, the current price received by the producers is Pt and et is the error term. B represents the long run effect of price on supply.

It is assumed that in any one period producers do not or cannot immediately adjust supply to the optimal or desired supply, St*. Therefore, in any given period the value of St may not be equal to St*. If we assume that supply changes by some fraction u, of the optimal change in any one year, then the adjustment process can be written as follows.

(2) $$St - St-1 = u(St^* - St-1) , \qquad 0<u<1$$

Substituting for St* into equation (2) and solving for St yields,

(3) $$St = u@ + uBPt + (1-u)St-1 + uet$$

Equation 3 gives the supply stock adjustment model. In the equation, the short run effect of price on supply is given by

uB, and the long run effect is given by B.

STOCK ADJUSTMENT MODEL ESTIMATION

Estimation of equation (3) poses some problems. As the equation contains a lagged dependent variable, simply estimating the equation using ordinary least squares (OLS) will lead to biased parameter estimates and inconsistency in the error term if it is autocorrelated.

To get around these problems, equation (3) is estimated using a method similar to the one devised by Fair(1970). Fair's method is an autocorrelated adjusted Two Stage Least Squares (2SLS) technique.[70] It is assumed that the error term is first order autocorrelated, because such disturbances

---

70. The Fair estimation method requires the following. The instruments used must at least include the current and once lagged predetermined variables and the lagged values of all endogenous variables. The endogenous variables (the right hand side variables) are regressed on the chosen instruments. The fitted values for the endogenous variables are then used as regressors in the OLS equation. To correct for autocorrelation the above step is repeated for various values of p between minus one and one, choosing the p that yields the smallest sum of squared residuals. See Fair (1970). In this dissertation other instrumental variables were included in each equation estimation in addition to those required by the Fair Method.

often occur when lagged dependent variables are used.[71] The error term wt, is represented by

(4) $$wt = pwt_{-1} + et$$

where et is assumed to have zero expected value and that all disturbances have uniform variance and are uncorrelated. The correlation coefficient between the errors in time period t and errors in time period t-1 is measured by p. When p equals zero, no first order serial correlation is present while a large value of p indicates its' existence.

ESTIMATION OF SOUTH AFRICAN SUPPLY

Prior to reviewing the estimation results, the instrumental variables used, in addition to those required under the Fair method were determined as follows.

As detailed earlier, one of the most important determinants of South Africa gold production (SAPROD) is the pay limit (PAYLIM). The pay limit is defined as the cost per

---

71. Pindyck and Rubinfeld (1976) suggest that while the error specification does not follow directly from the stock adjustment model, they however feel that this error specification should be given "serious consideration" as lagged dependent variables result in autocorrelation.

ton milled divided by the price of gold per gram. By law South African mines must mine at the average grade of ore. The average grade of ore is the average of the grades of ore greater then or equal to the paylimit. South Africa gold production is then calculated as the average grade of ore multiplied by the tons of ore milled. [72]

When regressed against South African production the pay limit is expected to be positive. The greater the pay limit the greater the average grade of ore. If it is assumed that tonnage milled remains constant, South African production will increase. The sign of the exogenously determined PAYLIM variable is therefore expected to be positive.

Additional explanatory variables tested were tonnage milled (TONMILL), the real rate of interest (INT) and time (TIME). (See Chapter 3 for a detailed discussion on each of the above explanatory variables.)

The sign of tonnage milled (TONMILL) is expected to be positive as the greater the amount of ore milled the greater the production of gold. As earlier stated, theory suggests

---

72. See Chapter 3 for a detailed explanation of South African gold production.

that the higher the interest rate (INT) the shorter will be the optimum life of producing mines and therefore the greater the annual output. However, in the long run high interest rates would cause aggregate mining investment to decline resulting in fewer new mines coming on stream. As a result it is expected that long run production will fall with increasing interest rates. The interest rate variable used was the real U.K 90-day treasury bill rate. The data were obtained from the London & Cambridge Economic Service and the IMF's International Financial Statistics.

Finally, a time (TIME) variable was included as a proxy for technical advance and as an indication of the remaining stock of gold in the ground.

South African production (SAPROD) was regressed on the above variables over various time periods. The results are listed below. The t-statistics are given in parentheses. To correct for autocorrelation, equations were estimated using a Cochrane-Orcutt process.[73]

YEARS: 1915 TO 1987

(5) SAPROD=85.66+14.04PAYLIM+5.42TONMILL-0.17INT-1.02TIME
(0.355) (3.102) (4.543) (-0.253) (-0.338)

R^2 = .35 RHO = .991 D.W.= 1.10 SER = 26.74

YEARS: 1968 TO 1987

(6) SAPROD=2234.43+10.04PAYLIM+2.55TONMILL+1.51INT-19.852TIME
(5.782) (1.625) (0.948) (0.846) (-3.355)

R^2 = .70 RHO = .816 D.W.= 1.02 SER = 27.63

YEARS: 1915 TO 1967

(7) SAPROD=-158.06+10.65PAYLIM+6.26TONMILL-0.25INT+6.46TIME
(-0.679) (1.761) (5.372) (-0.422) (2.150)

R^2 = .54 RHO = .994 D.W.= 0.79 SER = 20.98

Concentrating on the 1915 to 1987 results, as predicted the pay limit and the tonnage milled variables were positively related to South African production. Over the period PAYLIM and TONMILL appear to be relatively important explanatory

---

73. Regression Results: Explanatory Notes. For further information see Kennedy (1985).

$\bar{R}^2$ is a descriptive measure of the goodness fit of the regression. It explains the proportion of the total variation in the dependent variable explained by the regression.

SER is the standard error of the regression. It is a summary measure of the size of the prediction errors within the sample period. It has the same units as the dependent variable.

DW is the Durbin-Watson test statistic for serial correlation. A value near 2 suggests no serial correlation. A DW value of less then 1.5 implies positive serial correlation. The Cochrane-Orcutt method was used to correct for serial correlation. This procedure performs an iterative search for the best estimate of RHO. The best RHO is the one that yields the lowest sum of squared residuals.

variables in determining South African production. The time variable, while negative over the 1915 to 1987 period, was positive during the 1915 to 1967 period but was significantly negative over the 1968 to 1987 period. These results suggest that South African production has declined due a lack of technical advances and or gold discoveries. Finally, the interest variable was negatively related to production over the 1915 to 1987 period. However, over the 1968 to 1987 period, results indicate that interest rates and South African production were positively related.

Denoting annual South African mine production (metric tons) by SAPROD, and the U.S. dollar gold price (per ounze) deflated by the U.S. wholesale price index (1930 =100) by RGOLDP, the estimated South Africa supply equation is [74]

---

74. The observation period used in most cases was from 1950 to 1987 . Demand and supply data was available from 1915, however it was felt that the data prior to 1950 was not as reliable as the post 1950's figures. Real gold prices were used in estimating equations, as prior to 1971 the price of gold was fixed in nominal terms. See Appendix D for real gold prices. Regressions using both the real price of gold deflated by the U.S. wholesale price index and the U.S. CPI were undertaken. In all cases the results were similar using either index. Only the results using the WPI deflated gold price will therefore be documented.

(8) SAPROD = 250.15 - 1.666RGOLDP + 0.734 SAPROD(-1)
(4.432) (-4.724) (10.979)

R^2 = .924 RHO = 0.203 Years: 1950 - 1987

The figures in parentheses under the equation are the t-statistics.

The instrumental variables used in estimating the above equation in addition those required by the Fair Method were the lagged value of the pay limit and the lagged value of tonnage milled.

The results of equation (8) indicate that the speed of adjustment in South African production is relatively slow. Only roughly a quarter (1.00 - .734 = .266) of the distance between optimal production and actual production is closed each year. As was predicted earlier, price is inversely related to production. Measured at the point of means for the period the short run supply elasticity is -0.10 while the long run elasticity is approximately -0.38.

ESTIMATION OF OTHER COUNTRY SUPPLY

Instrumental variables tested for use in the Other Country Production (OTHPROD) supply equation are detailed below.

It is estimated by Consolidated Gold Fields that Other Country production, measured in metric tons, is determined largely by past gold prices. Consolidated Gold Fields estimates it takes roughly seven years from when a deposit is found to when full production begins. It is therefore expected that real gold prices lagged seven years (RGOLDP(-7)) should be positively related to production. Once again an interest rate variable was tested. USINT is the real U.S. 90-day treasury bill rate. This series was taken from the London and Cambridge Economic Service and the IMF's International Financial Statistics. This series was used instead of a world rate due to the unavailability of a World series prior to 1960. As noted above, the expected sign of USINT is difficult to estimate. The time variable, TIME, was used for the same reasons as previously discussed in the South Africa section.

Other Country production (OTHPROD) was regressed on the above variables over various time periods. The results are listed below.

YEARS: 1915 TO 1987

(9) OTHPROD = 209.28 + 2.56RGOLDP(-7) + 0.42USINT + 2.04TIME
(1.243) (3.663) (0.414) (0.825)

R^2 = .19 RHO = .953 D.W.= 0.61 SER = 38.74

YEARS: 1968 TO 1987

(10) OTHPROD = -713.47 + 2.51RGOLDP(-7) + 6.98USINT + 12.03TIME
(-1.234) (3.758) (1.646) (1.815)

R^2 = .64 RHO = .966 D.W.= 0.88 SER = 30.79

YEARS: 1915 TO 1967

(11) OTHPROD = 345.90 + 1.53RGOLDP(-7) + 0.13USINT - 0.47TIME
(1.912) (0.768) (0.124) (-0.155)

R^2 = .10 RHO = .934 D.W.= 0.58 SER = 40.60

Over the period 1915 to 1987 the real gold price lagged seven years is as expected, positive. The interest rate and time variables are insignificant. The time variable, regressed over the 1967 to 1987 period indicates that production has increased through time as a result of new discoveries and or technology. Over the same period interest rates and production are positively related.

The above results indicate that the real gold price variable lagged seven years should be considered as a possible

additional instrumental variable in the Other Country Production supply equation. Estimating the supply equation using the Fair method yields the following results.

(12) OTHPROD =15.05 + 0.94RGOLDP + 0.933OTHPROD(-1)
(0.333) (2.584) (16.895)

R^2 = .865 RHO = 0.573 Years: 1950 - 1987

The speed of adjustment in Other Country Production is significantly less than that of South African production. Roughly only 7% of the gap between optimal and actual production is closed each year. Clearly the adjustment speed is extremely slow in the short run. This fact is reflected in the large difference between short and long run elasticities. Measured at the means the short run elasticity is approximately 0.14. In the short run the supply curve for Other Country production is highly inelastic. The long run elasticity on the other hand is approximately 2.00 indicating that the long run elasticity of the Other Country supply curve is relatively price sensitive.

The slow adjustment speed by Other Country Production means that if gold demand decreases suddenly, Other Country production would remain high for a considerable period of time. These two effects would cause significant downward

pressure on gold prices.

ESTIMATION OF NET COMMUNIST SUPPLY

In estimating the Net Communist supply (NETCOMM) curve no additional instrumental variables were used than those required by the Fair method. The Net Communist supply results are given in equation (13).

(13) NETCOMM = 100.16 - 0.375RGOLDP + 0.729NETCOMM(-1)
(1.815) (-0.469) (3.985)

R^2 = .525 RHO = 0.070 Years: 1960 - 1987

The estimation results indicate that the speed of adjustment of Net Communist supply is very similar to that of South African supply. Approximately 27% of the gap between desired production and actual production is closed each year. In addition, the price elasticity results are almost identical to South Africa. At the point of means, the short run price elasticity of supply is -0.1 whereas the long run supply price elasticity is approximately -0.37. Net Communist supply is price insensitive in the long and short runs.

As in the South African case, real gold prices were

negatively related to Net Communist supply. As was detailed earlier, this result was expected as higher gold prices usually occur during periods of increasing inflation and high oil prices. During periods of high oil prices the Soviets seem to prefer to sell oil rather then gold to secure hard currency. During the 1980's as the price of oil fell the Soviets had to sell more and more gold to satisfy their hard currency needs. These gold sales have continued despite falling gold prices.

DEMAND MODEL

As stated earlier, typically minerals are used basically as inputs to produce final goods. The input demand for gold however, constitutes a very small fraction of total demand. Primarily, gold is demanded for wealth and fashion purposes.

If gold is demanded for wealth reasons it would be expected that the adjustment between any period could be made completely and that demand is largely dependent upon changes in the expected price. An alternative form of the above stock adjustment model which assumes complete adjustment and adaptive price expectations is the Adaptive Expectations

model. The adaptive expectations model is detailed below.

Suppose the demand curve is given as

$$(14) \quad Dt = @ + BP^{*}t + et$$

where Dt is the amount of gold demanded and $P^{*}t$ in this case denotes the long run expected price. It is assumed that price expectations are altered every period. Changing expectations are determined as an adjustment between the current observed price level and the previous expected value of price.

$$(15) \quad P^{*}t - P^{*}t\text{-}1 = u(Pt - P^{*}t\text{-}1), \quad 0<u<1$$

In the above equation u is no longer the speed of adjustment of supply or in this case demand, which is now assumed to be complete, but rather the speed of adjustment of price expectations. Equation (15) is equivalent to equation (16).

$$(16) \quad P^{*}t = uPt + (1-u)P^{*}t\text{-}1$$

Solving for $P^{*}t\text{-}1$ and then substituting both $P^{*}t$ and $P^{*}t\text{-}1$ into equation (14) yields

$$(17) \quad Dt = @u + uBPt + (1-u)Dt-1 + uet$$

It is obvious that equations (17) and (3) are equivalent however the assumptions made in determining each are clearly different. In equation (17) it is assumed that demand adjusts completely each period, hence u is no longer the speed of adjustment of demand but rather the speed of adjustment of price expectations. Once again B describes the long run effect and uB the short run effect.

The same assumptions and method described in detail earlier to estimate the supply curves were used to estimate each of the following demand components.

ESTIMATION OF DEVELOPED COUNTRY GOLD FABRICATION DEMAND

In addition to those instrumental variables required by the Fair method, the real price of silver (RSIL) and real U.S. GNP (RGNP) growth were tested to determine if they should be included as instrumental variables in the Developed Country gold fabrication (DEVFAB) demand equation.

The real price of silver (RSIL) can be viewed as a

substitute for gold. The higher the price of silver relative to that of gold the greater will be the fabrication demand by developed countries. It however may be the case that both gold and silver prices move together. Therefore silver prices may act as a proxy for gold prices and as a result be negatively related to Developed Country gold fabrication demand. The expected sign of RSIL is therefore difficult to determine.

U.S. real GNP growth (RGNP) was used as a proxy for developed country world growth due the unavailability of data prior to 1960. It is expected that RGNP and Developed Country gold fabrication demand will be positively related. Income increases will promote demand increases for jewelry and artistic works made of gold. U.S. real growth data was obtained from the London and Cambridge Economic Service and the IMF's International Financial Statistics. See Chapter 4 for a detailed theoretical discussion on the determinants of Developed Country gold fabrication demand.

Developed Country gold fabrication demand, measured in metric tons, was regressed on RGNP and RSIL over various time horizons. The results are presented below.

YEARS: 1915 TO 1987

(18) DEVFAB = 19.04 + 0.827RGNP - 0.438RSIL
(0.190) (5.515) (-4.723)

R^2 = .42 RHO = .895 D.W.= 1.63 SER = 63.12

YEARS: 1968 TO 1987

(19) DEVFAB = 613.39 + 0.227RGNP - 0.446RSIL
(0.190) (0.872) (-2.925)

R^2 = .32 RHO = .534 D.W.= 1.43 SER = 93.46

YEARS: 1915 TO 1967

(20) DEVFAB = -74.20 + 0.982RGNP + 0.081RSIL
(-0.660) (4.467) (0.222)

R^2 = .29 RHO = .926 D.W.= 1.68 SER = 43.88

The results over the 1915 to 1987 period are more or less as expected. RGNP and RSIL respectively, are positively and negatively related to fabrication demand. The sign of RSIL indicates that silver and gold prices are highly positively correlated.

In addition to those variables required by the Fair method the lagged value of RGNP was included as an instrumental variable in estimating the Developed Country gold fabrication demand equation.

(21) DEVFAB = 750.720 - 2.006RGOLDP + 0.277DEVFAB(-1)
(5.827) (-1.924) (1.820)

R^2 = .230 RHO = 0.604 Years: 1950 - 1987

As expected the sign of RGOLDP is negative. At the point of means for the period, the short run price elasticity of demand is approximately -0.15. The long run elasticity of demand is approximately -0.2. The results suggest that Developed Country gold fabrication demand is relatively price inelastic in both the long and short runs. The DEVFAB(-1) coefficient indicates that approximately three quarters of the gap between actual and expected gold prices is adjusted for each year. This relatively high speed of adjustment in price expectations is reflected in the small difference between short and long run demand elasticities.

ESTIMATION OF DEVELOPING COUNTRY GOLD FABRICATION DEMAND

It was noted in Chapter 4 of this paper, individuals in Developing Countries demand fabricated gold (LDCFAB) for many reasons other than the fashion motive. Individuals in Developing Countries demand gold primarily for liquidity, security, insurance and investment purposes. Gold in developing countries continues to be an important store of

value. As many developing countries restrict individuals from holding gold in the form of bullion or coin, individuals get around these restrictions by purchasing high carat gold jewelry. The following set of possible additional instrumental variables are given below.

It is expected that since gold is often viewed as an inflation hedge, as inflation increases the demand for gold will increase.[75] Due the unavailability of world data prior to 1960 the annual rate of change in the U.S. consumer price index (CPIR) was used as a world proxy. These statistics were taken from the London and Cambridge Economic Service and the IMF's International Financial Statistics.

The value of the exchange rate variable (EXCH) is likely to be important for the following reasons. As gold is denominated in U.S. dollars, an appreciation in the dollar will lead to an decrease in the dollar gold price, if the price of gold is stable in foreign currency. In addition, as the dollar is an important alternative investment asset, then as the dollar appreciates, dollar denominated assets will appreciate increasing the opportunity cost of holding gold.

---

75. If it is assumed that the inflation rate is positively related to the price of gold then a decrease in the amount of gold demanded may result.

Therefore, as the dollar appreciates there will be a movement away from gold to dollar denominated assets. Due the unavailability of a U.S. trade weighted exchange rate series prior to 1970 the British Pounds per U.S. Dollar exchange rate was used. The series was taken from the London and Cambridge Economic Service and IMF's International Financial Statistics.

The higher the interest rate (INT) the higher the oppportunity cost of holding gold and the lower the demand. The interest used was the real U.S. 90-day treasury bill rate. This rate was used as a proxy for world rates due the unavailability of data.

The precautionary motive for holding gold, as discussed in Chapter 4 is extremely important in Developing Countries. An increase in global tensions will increase gold prices as individuals increase gold demand. Individuals in developing countries continue to rely on gold as money. Gold's store of value increases the greater the uncertainty in the world's political, economic, and financial system. In order to capture this precautionary motive a world conflict variable (CON) was constructed. CON is an annual series of the total number of wars or internal conflicts which have occurred in the World. A war or internal conflict is defined as a

conflict or a war where 1000 or more war related deaths occur per year. The series was constructed from data compiled by Sivard (1987). It is expected that the greater the number of wars or conflicts in the world, the greater the demand for gold.

It is expected that as income increases, the demand for fabricated gold will increase, as gold is an important form of savings in Developing Countries. Once again the variable RGNP was used as a proxy for real economic growth in Developing Countries.

LDCFAB, measured in metric tons, was regressed against the above explanatory variables over several time horizons. The results are shown below.

YEARS: 1915 TO 1987

(22) LDCFAB=-51.73+708.71EXCH-41.4INT-8.21CON+0.39RGNP-38.34CPIR
(-0.47) (1.722) (-3.20) (-1.07) (1.718) (-2.96)

R^2 = .25 RHO = .766 D.W.= 2.04 SER =107.32

YEARS: 1968 TO 1987

(23) LDCFAB=665.35+1831.80EXCH+12.05INT-72.37CON-0.30RGNP-11.93CPIR
(3.090) (3.044) (0.550) (-2.967) (-0.700) (-0.764)

R^2 = .68 RHO = .231 D.W.= 1.91 SER =107.05

YEARS: 1915 TO 1967

(24) LDCFAB=-170.57-463.08EXCH+42.02INT+0.08CON+0.90RGNP+47.42CPIR
(-1.860) (-0.93) (3.833) (0.010) (5.040) (4.051)

R^2 = .67 RHO = .675 D.W.= 1.98 SER =100.16

Concentrating on the 1915 to 1987 period, the sign of EXCH is positive implying that exchange rate increases, which cause the price of gold to fall, increase the demand for gold. The signs of both the interest rate and real growth variables were as predicted. However, the signs of the inflation rate variable and the world conflict variable were opposite to that predicted. The results indicate that developing countries do not purchase gold as an inflation hedge. The negative sign of the conflict variable suggests that during times of world conflict developing countries have been reducing their gold

holdings instead of increasing them.

Measured in metric tons, Developing Country gold fabrication demand (LDCFAB) was regressed on those variables required by the Fair technique, including the real growth rate variable lagged one period, and the exchange rate variable lagged one period.

(25) LDCFAB = 540.655 - 2.651RGOLDP + 0.157LDCFAB(-1)
(4.162) (-1.777) (0.894)

R^2 = .262 RHO = 0.713 Years: 1950 - 1987

The Developing Country gold fabrication results are very similar to the Developing Country results shown earlier. As expected the sign of RGOLDP is negative. At the point of means for the period, the short run price elasticity of demand is approximately -0.20. The long run elasticity of demand is approximately -0.24. The results suggest that Developed Country gold fabrication demand is highly price inelastic in both the long and short runs. The DEVFAB(-1) coefficient indicates that approximately eighty-four percent of the gap between actual and expected gold prices is adjusted for each year. This high adjustment speed in price expectations is reflected in the negligible difference between short and long

run demand elasticities.

ESTIMATION OF OFFICIAL RESERVE DEMAND

As detailed earlier, prior to 1971 when the price of gold was fixed, governments were required to purchase any gold remaining after non-monetary gold demand had been satisfied. It is expected therefore that during this period the price of gold and Official Reserve demand would be positively related as a real price increase would cause non-monetary gold demand to fall and therefore Official Reserve demand to rise. From 1971 onwards it was shown that official reserve demand is highly complex. Although gold no longer stands as an official currency valuation and is generally no longer related to money creation, official gold holdings continue to be very important in the international financial system. It was concluded that governments continue to demand and hold gold for reasons similar to that of an individual, for security, liquidity, insurance and speculative purposes. [76]

---

76. Several instrumental variables were tested, specifically the world conflict variable, the inflation rate variable and the real growth variable. The regression results were extremely poor.

In estimating the Official Reserve (OFFREV) demand curve no additional variables were used other than those required by the Fair method. The Official Reserve demand results are given in equation (26).

(26) $$\underset{(-2.022)}{\text{OFFREV} = -40.19} + \underset{(1.611)}{0.981\text{RGOLDP}} + \underset{(4.941)}{0.894\text{OFFREV}(-1)}$$

$R^2 = .690$ RHO = 0.986 Years: 1950 - 1987

As predicted the results indicate that real gold prices and official reserve demand are positively related. At the point of means for the period, the short run price elasticity of demand is approximately 0.44. The long run price elasticity is approximately 4.54. The OFFREV(-1) coefficient indicates that roughly only 10 percent of the gap between actual and expected gold prices is adjusted for each year. This low speed of adjustment is reflected in the large difference between short and long run demand elasticities.

ESTIMATION OF PRIVATE INVESTMENT DEMAND

The instrumental variables considered include many of those considered in the previous section on Developing Country Fabrication demand. Individuals hold gold for precautionary,

liquidity, and speculative motives. Therefore the same set of independent variables will be used.

YEARS: 1915 TO 1987

(27) PRIINV=-138.80-360.98EXCH-2.026INT+37.98CON+0.76RGNP+29.965CPIR
(-0.97) (-0.392) (-0.180) (3.992) (1.909) (1.737)

R^2 = .23 RHO = -0.168 D.W.= 1.93 SER =429.54

YEARS: 1968 TO 1987

(28) PRIINV=1245.14-1385.45EXCH+71.58INT-8.693CON-0.61RGNP+71.586CPIR
(1.696) (-0.894) (1.162) (-0.139) (-0.412) (1.488)

R^2 = .21 RHO = .662 D.W.= 1.62 SER =327.80

YEARS: 1915 TO 1967

(29) PRIINV=-212.26+248.75EXCH-1.125INT+21.69CON+0.56RGNP+30.988CPIR
(-0.87) (0.210) (-0.101) (0.966) (0.831) (1.693)

R^2 = .13 RHO = -.341 D.W.= 1.71 SER =477.56

The results for the 1915 to 1987 period suggests that the conflict variable (CON), real growth (RGNP), and the inflation rate (CPIR), are relatively important in explaining private investment demand. As expected the conflict variable is positive, implying that the greater the number of wars the greater is the tendency for the investor to demand gold. The investor may purchase gold under this scenario for two

reasons. Either he is demanding gold primarily for long term investment purposes, or he is purchasing gold for short term speculative purposes. That is, the greater the conflict, the greater may be the increase in the price of gold and therefore the greater the profit to be made. If the investor purchases gold for speculative reasons it would be anticipated that private investment gold demand and the real price of gold would be positively related.

Measured in metric tons, Private Investment demand (PRIINV) was regressed on those variables required by the Fair technique, including the real growth rate variable lagged one period, the exchange rate variable lagged one period and the world conflict lagged one period .

(25) $$\underset{\quad}{\text{PRIINV}} = \underset{(0.111)}{13.40} + \underset{(1.946)}{7.539}\text{RGOLDP} + \underset{(0.233)}{0.042}\text{PRIINV}(-1)$$

$R^2 = .110$ RHO = 0.303 Years: 1950 - 1987

The sign of the real gold price coefficient is positive suggesting that the investor purchases gold primarily for speculative reasons. Approximately all of the gap between actual and expected gold prices is adjusted for each year by the investor. The high speed of adjustment is reflected in

the negligible difference between short and long run price elasticities. Measured at the point of means for the period, the short run price elasticity of demand is approximately 0.60, whereas the long run price elasticity is approximately 0.63.

CONCLUSIONS

The results indicate that on the supply side of the gold market there is a tendency towards low adjustment speeds which are reflected in the long run supply elasticities being significantly greater than the short run elasticities. However, in the case of South Africa production and Net Communist sales the long run supply elasticities are still highly inelastic. Only in the case of Other Country production is the long run supply curve elastic. On the demand side, adjustment speeds are extremely high, meaning that there is very little difference between long run and short run elasticities. In general the demand elasticities were inelastic in both the long and short runs.

CHAPTER 6

GOLD PRICING MODELS AND FORECASTS

This chapter presents several reduced form gold pricing models, utilizing the detailed and theoretical gold market analysis developed in this disseration. In particular, supply variables are incorporated into several reduced form gold pricing models. Previous studies which have constructed reduced form gold pricing models have assumed that long term gold price movements rest primarily on price and income elasticities of demand and income growth in industrialized countries. The models developed in this Chapter address and test the importance of the supply side of the market in determining gold prices.

Once reduced form gold pricing models have been estimated and their tracking properties tested, they will be used to forecast gold prices to the year 1995 under a variety of different assumptions. Future supply and demand levels will then be determined by substituting gold price forecasts into the supply and demand equations estimated in the previous Chapter.

GOLD PRICE DETERMINANTS

The following chapter develops two reduced form gold pricing models. The first, models the log of the real U.S. dollar gold price (LRGOLDP). Real gold prices were calculated as the nominal U.S. dollar gold price divided by the U.S. wholesale price index (1930=100). The second, models the log of the nominal gold price in U.S. dollars (LNGOLDP).

Each model is tested separately against two sets of independent variables. The first set of independent variables includes only demand variables while the second set includes both demand and supply variables. Independent variables considered include many of those variables already tested in previous chapters. The following is a brief explanation of the supply and demand independent variables used in each reduced form gold pricing equation.

INDEPENDENT SUPPLY VARIABLES

LSACOST is the log of South African mining costs. As detailed earlier, empirical analysis on South African gold production indicated that costs are an important factor in

determining South African production. It is expected as the negative cost effect on tonnage milled is greater then the positive effect on the average grade of ore, that as costs rise, production will decline causing the price of gold to rise given constant gold demand.

LRGOLDP(-7) and LNGOLDP(-7) are respectively the log of the real and nominal U.S. price of gold lagged seven years. It has been shown that both of these variables are important in the determination of Other Country gold production. It is expected that as it takes approximately sevens years for a new mine to come on stream, higher prices in the past will mean increased supply, and assuming constant demand, lower current prices. Therefore gold prices lagged seven years should be negatively related to current gold prices.

It is anticipated that the above supply variables, will significantly improve the explanatory power of the conventional reduced-form gold pricing model.

INDEPENDENT DEMAND VARIABLES

LEXCH and LREXCH are respectively the log of the U.S. effective exchange rate and the log of the real U.S. effective

exchange rate, as given by the IMF in the International Financial Statistics. The weights are based on the Fund's Multilateral Exchange Rate Model. The rational for including the exchange rate is two-fold. It is expected that an increase in the value of the dollar will lead to a decline in the dollar gold price. Dollar denominated assets are a substitute investment for gold and therefore represent an opportunity cost of holding gold. The above factors influence gold prices in the same direction.

CON is a measure of world turmoil. The more unstable the world the greater will be the precautionary, insurance, liquidity and speculative motives for holding gold. As a result gold prices should be positively related to the conflict variable.

LDEVRGNP is the log of developing country real GNP. This series was taken from the IMF's International Statistics. While this variable is a measure of developing country growth it also reflects world growth. It has been shown that real growth is positively related to demand and therefore should be positively related to price.

REDUCED-FORM GOLD PRICING MODEL RESULTS

The following equations present reduced-form gold pricing results for LRGOLDP AND LNGOLDP using LEXCH, LREXCH, CON, and LDEVRGNP. In these two cases the supply variables will not be incorporated into the equations.

(1) LRGOLDP = -6.765 - 1.793LREXCH + 0.055CON + 0.558LDEVRGNP
(-5.921) (-4.703) (2.068) (1.798)

R^2 = .800 RHO = .652 D.W.= 1.63 SER = 0.353

YEARS: 1968 TO 1987

(2) LNGOLDP = -8.554 - 1.640LEXCH + 0.085CON + 2.238LDEVRGNP
(-5.795) (-5.517) (2.820) (6.316)

R^2 = .856 RHO = .450 D.W.= 1.37 SER = 0.137

YEARS: 1968 TO 1987

The results of the above equations are relatively strong. In all instances the independent variables are of the correct sign and are significant. More specifically the exchange rate variable is negative and significant. The results indicate that fluctuations in the trade weighted exchange rate strongly affect the dollar gold price. CON and LDEVRGNP are both significantly positive.

Supply independent variables were then incorporated into both of the reduced form gold pricing models. That is, each model was then regressed against the above set of demand independent variables in addition to the two supply variables, LSACOST and LRGOLDP(-7). The results are presented in equations 3 and 4.

(3) LRGOLDP = 6.180 - 2.277LREXCH + 0.054CON - 1.402LDEVRGNP +
(1.999) (-5.877) (1.999) (-1.690)

0.479LSACOST - 0.38LRGOLDP(-7)
(1.952) (-2.524)

R^2 = .902 RHO = .562 D.W.= 1.68 SER = 0.123

YEARS: 1968 TO 1987

(4) LNGOLDP = -4.351 - 1.876LEXCH + 0.071CON + 1.890LDEVRGNP +
(-2.211) (-6.930) (3.268) (1.950)

0.750LSACOST - 0.17LNGOLDP(-7)
(2.731) (-1.890)

R^2 = .973 RHO = .234 D.W.= 1.81 SER = 0.121

YEARS: 1968 TO 1987

The addition of South African cost of production and the lagged value of the gold price, variables which have been shown to be important in determining supply, significantly improved the explanatory power of equations 1 and 2. Including the supply variables, LSACOST and LRGOLDP(-7) into equation 1, increased the goodness of fit from 0.80 in equation 1 to 0.90 in equation 3. Similarly the R squared increased from 0.86 in equation 2 to 0.97 in equation 4 with the addition of LSACOST and LNGOLDP(-7). In both equations all explanatory supply variables were significant and had the expected signs.

The major difference between equations 3 and 4 is that the Durbin Watson statistic and the R squared values are higher in equation 4, the log of the nominal gold price model, than in equation 3, the log of the real gold price model. The next section will test the tracking and forecasting properties of equations 3 and 4.

MODEL TESTS

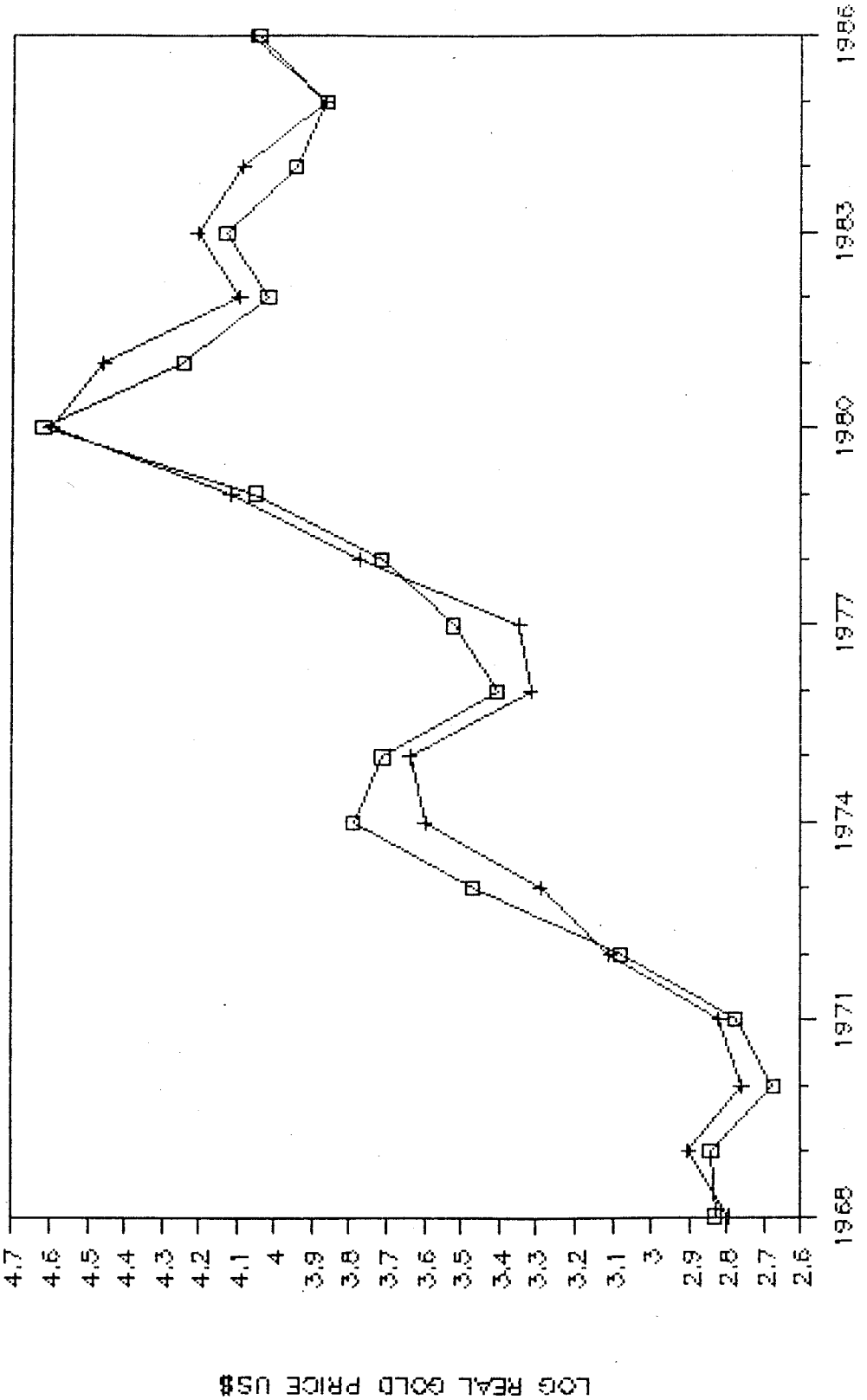
To test the tracking properties of equation 3 and 4, each model was simulated. The simulation process solves for the dependent variables using the values of the independent variables, coefficient values, and the values of lagged dependent or independent variables.

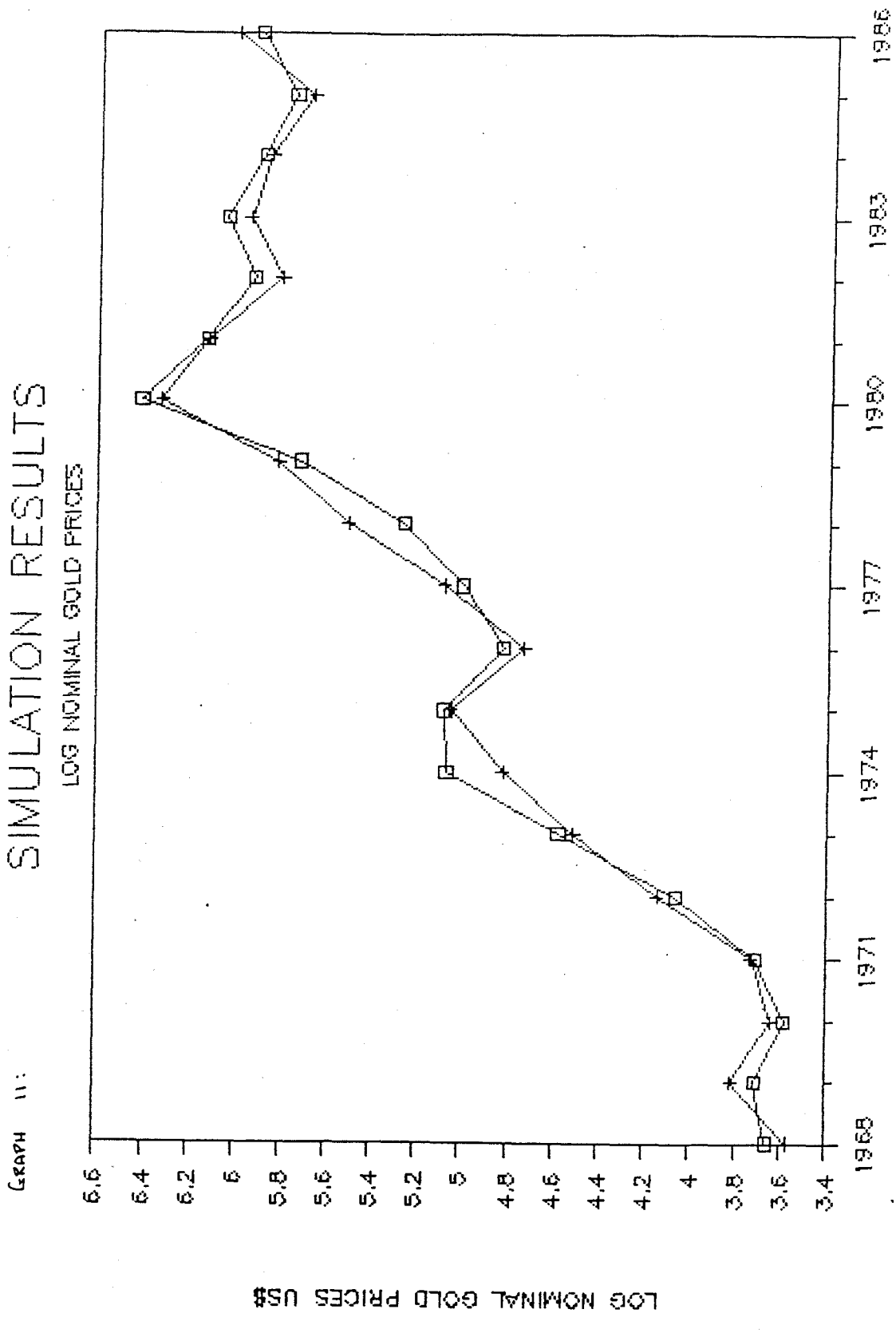
The results are illustrated in Graphs 10 and 11. In both simulations the root mean squared error statistic (RMS), which is the square root of the average of the forecast errors squared and is an indicator of forecast accuracy, was between 2.5% and 3.0%. Graph 10 illustrates the simulation results for equation 3. In graph 10 the simulated results are indicated by the crosses where the actual results are indicated by the boxes. The results of the simulated reduced-form log real gold pricing model (equation 3) are impressive. Since 1970, the real gold price model is able to predict all the major turning points in real gold prices.

GRAPH: 10

SIMULATION RESULTS

LOG REAL GOLD PRICES



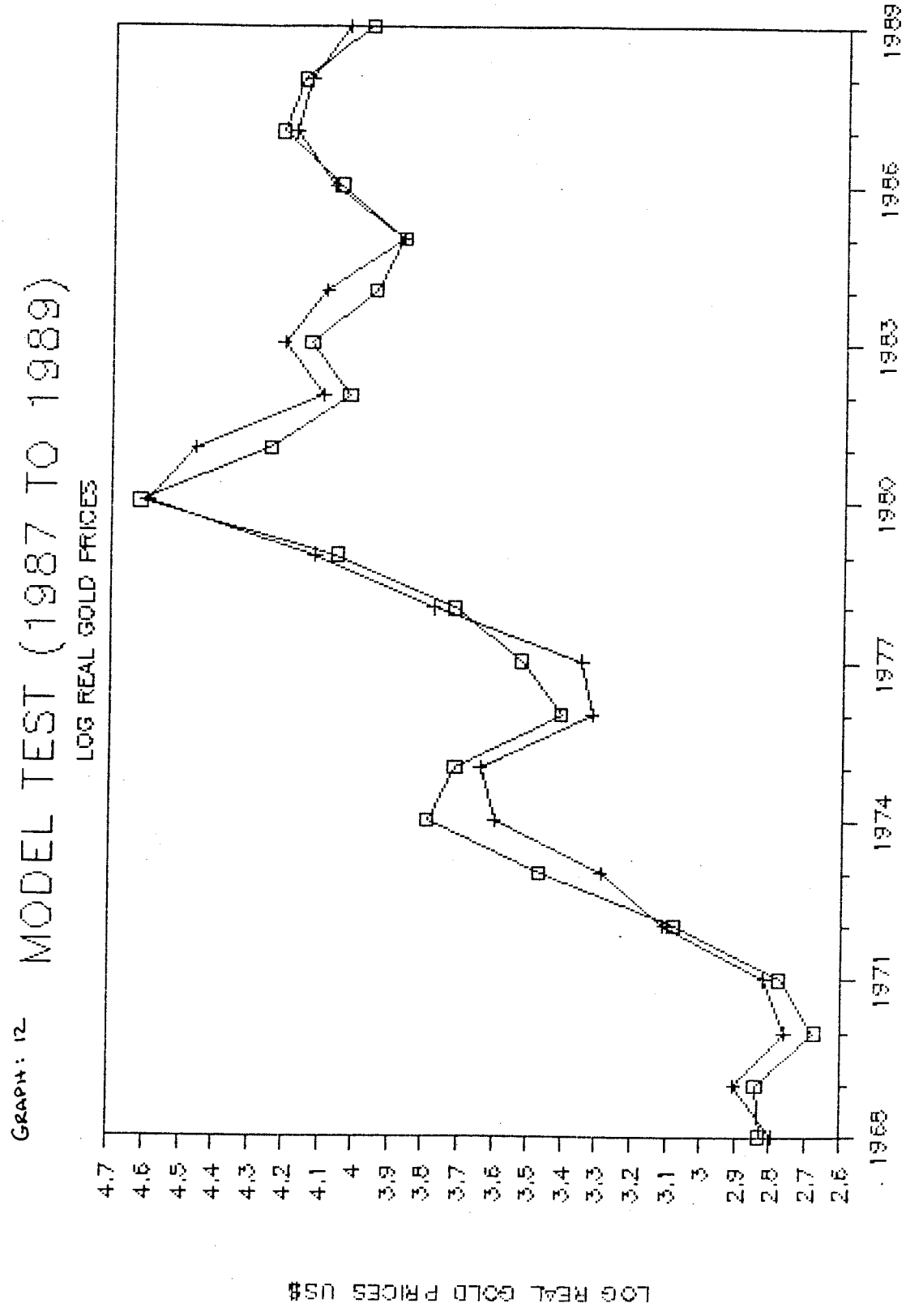

GRAPH 11:
SIMULATION RESULTS
LOG NOMINAL GOLD PRICES
LOG NOMINAL GOLD PRICES US$
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
1968
1971
1974
1977
1980
1983
1986
YEARS
□ ACTUALS
+ SIMULATED

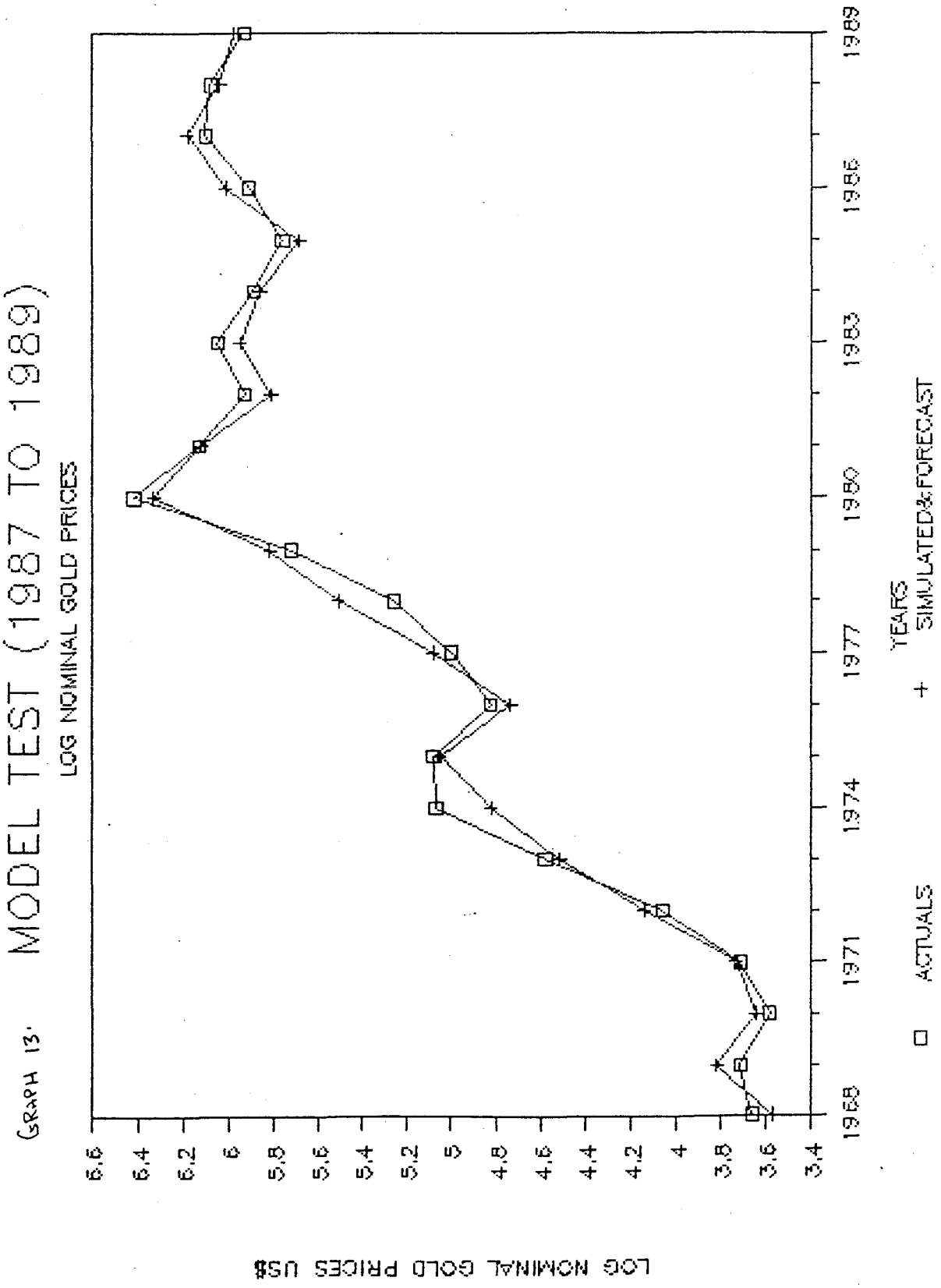
Graphs 11 illustrates the simulation results for equation 4. It is evident from the graph that the set of independent variables tracks movements in the log of the nominal price of gold accurately. All in all the simulation results of equations 3 and 4 are extremely good.

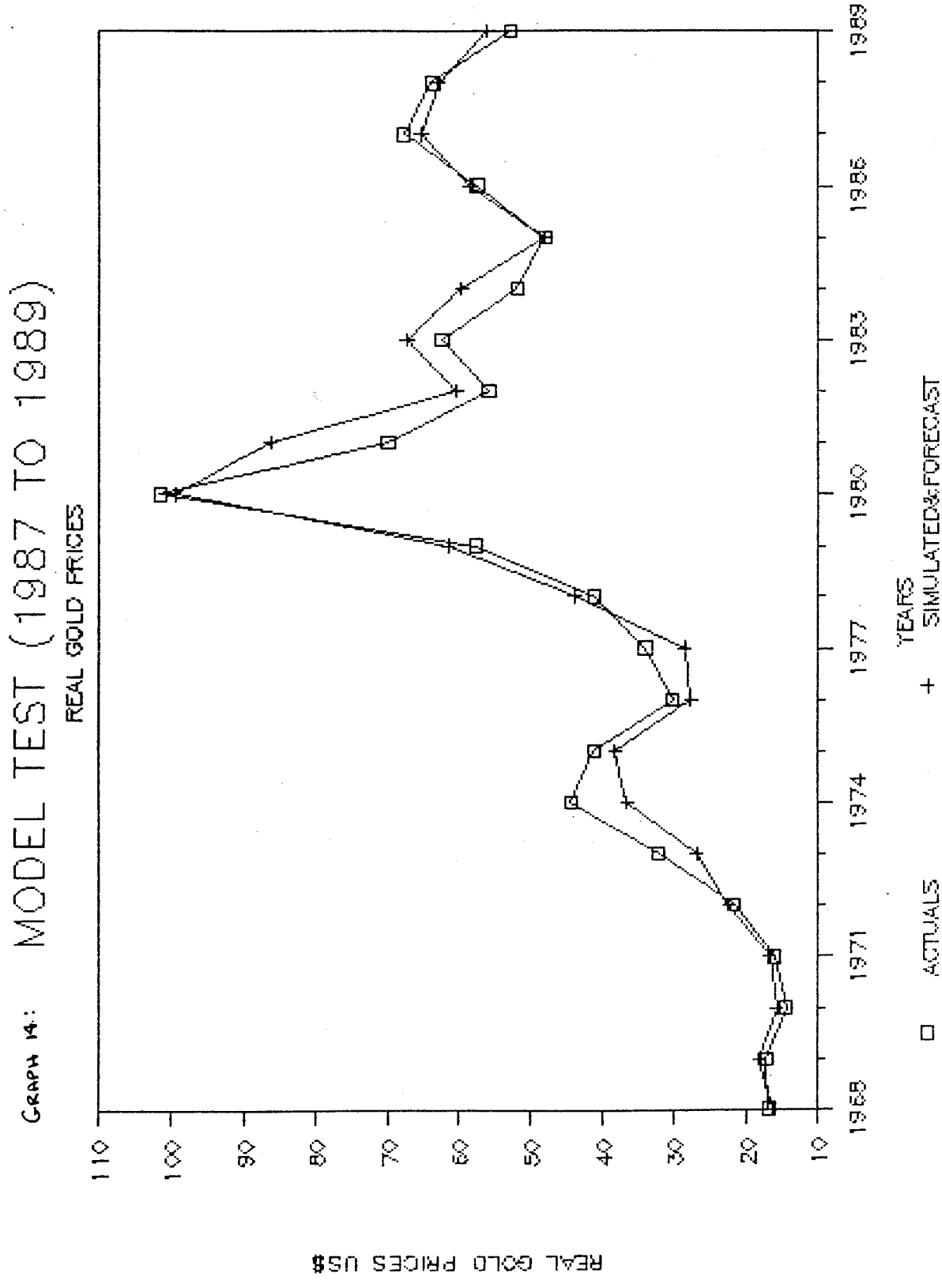
To further test the predictive powers of equations 3 and 4, both reduced-form models were estimated over the period 1967 to 1986. The regression results were then used to forecast the log of the nominal and real gold price for the years 1987, 1988, 1989. As the values for the independent variables are actuals it is expected that each model should accurately forecast the gold price.

The actual and forecast values for the log of the real gold price,(equation 3) are shown in Graph 12. Once again the simulated and forecast values ar e indicated by crosses and the actuals by boxes. The model correctly forecasts, first the increase in the log of the nominal price of gold in 1987 and then the steady decline through 1989. Logged nominal gold price results as shown in Graph 13 are much the same as the logged real gold model results. However, for 1988, the forecast and the actual values are identical.

GRAPH: 12


MODEL TEST (1987 TO 1989)
LOG REAL GOLD PRICES
LOG REAL GOLD PRICES US$
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
1968
1971
1974
1977
1980
1983
1986
1989
YEARS
□ ACTUALS
+ SIMULATED&FORECAST

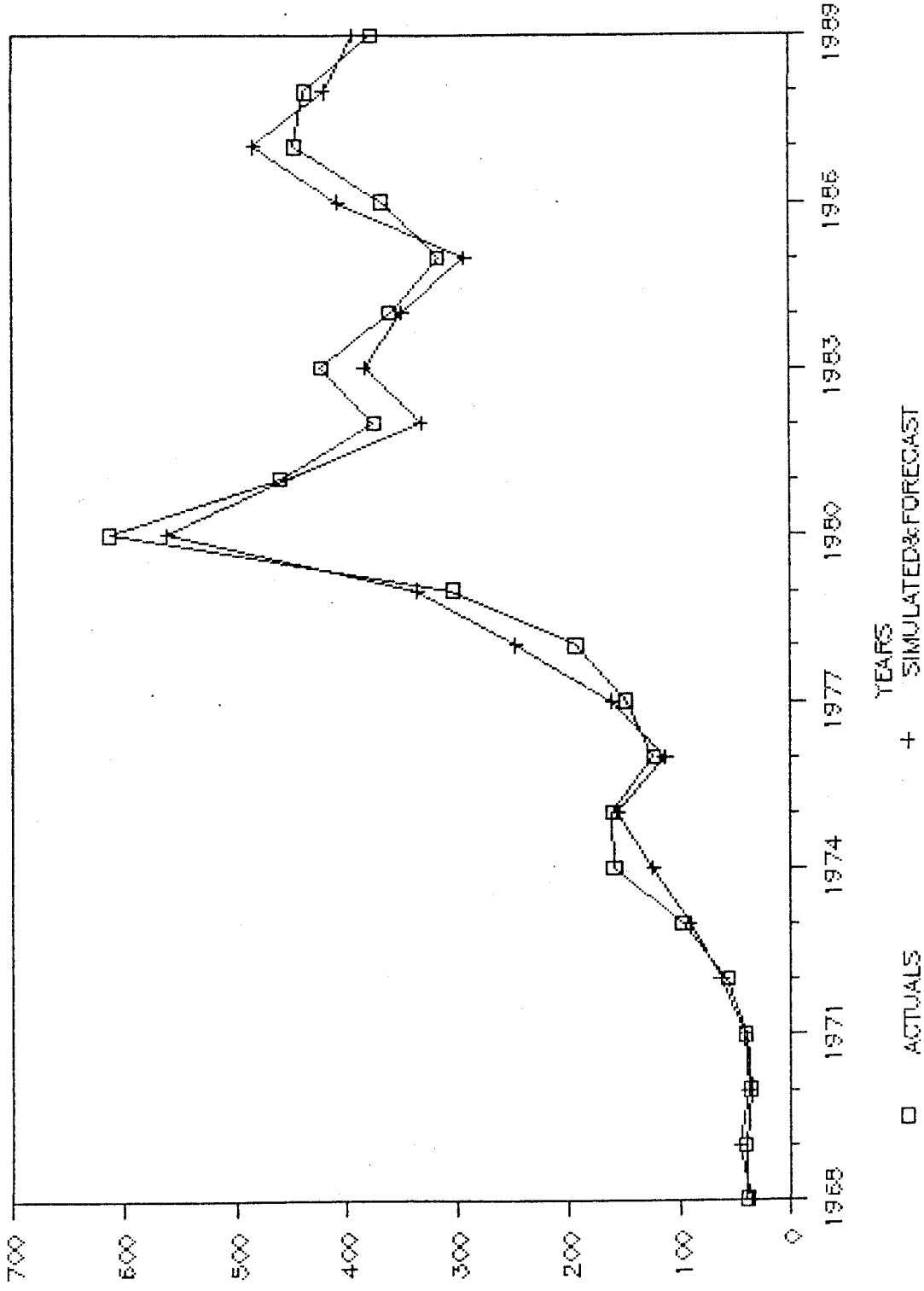

GRAPH 13' MODEL TEST (1987 TO 1989)
LOG NOMINAL GOLD PRICES
LOG NOMINAL GOLD PRICES US$
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
1968
1971
1974
1977
1980
1983
1986
1989
YEARS
□ ACTUALS
+ SIMULATED&FORECAST


GRAPH 14: MODEL TEST (1987 TO 1989)
REAL GOLD PRICES
REAL GOLD PRICES US$
110
100
90
80
70
60
50
40
30
20
10
1968
1971
1974
1977
1980
1983
1986
1989
YEARS
□ ACTUALS
+ SIMULATED&FORECAST

GRAPH: 15

MODEL TEST (1987 TO 1989)

NOMINAL GOLD PRICES



Graphs 14 and 15 give the simulation results in terms of real and nominal gold prices for the period 1968 to 1989. The above results indicate that both of the above reduced-form gold models work extremely well in tracking real and nominal gold price movements over the last 20 years. These results are clearly an improvement on those models that have only considered the demand side of the market.[77]

GOLD MODEL FORECASTS

In this section the supply side reduced-form gold pricing models, as outlined above in equations 3 and 4, were used to project real and nominal gold prices out to 1995. At the outset it should be mentioned that reliable gold price projections are due to good forecasts being made on the exogenous variables. In the Base Case forecast or "Most Likely Forecast" the following assumptions were made with respect to each of the exogenous variables.

- For South African production costs (LSACOST) it was assumed that costs increase 10% per year over the period.

---

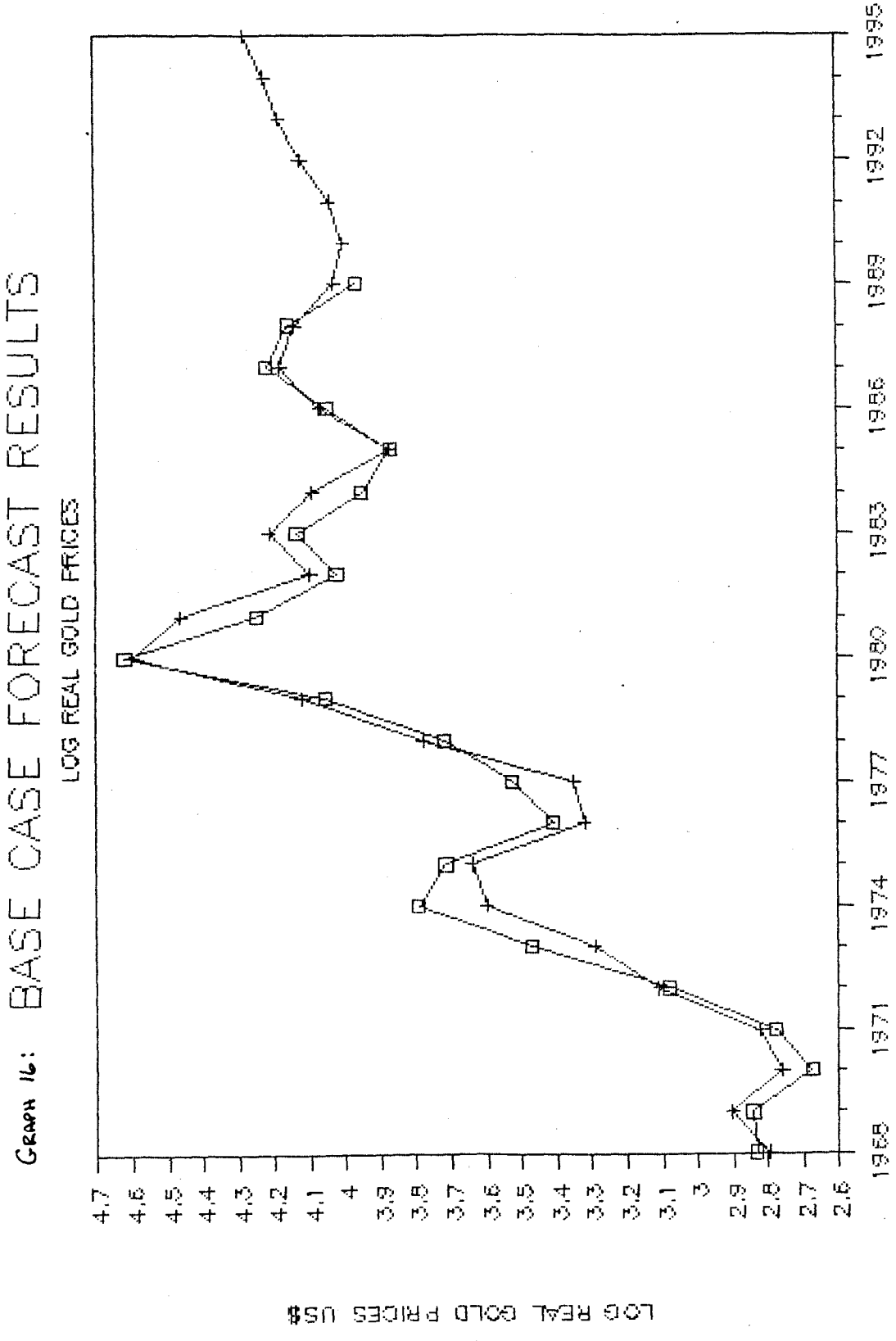
77. See Chapter 2, particularly the results of Baker and Van Tassel (1982) and Sherman (1986).

- The trade weighted U.S. dollar exchange rate (LEXCH and LREXCH) remains relatively strong over the period. An average of the exchanges rate over the past five years was used.

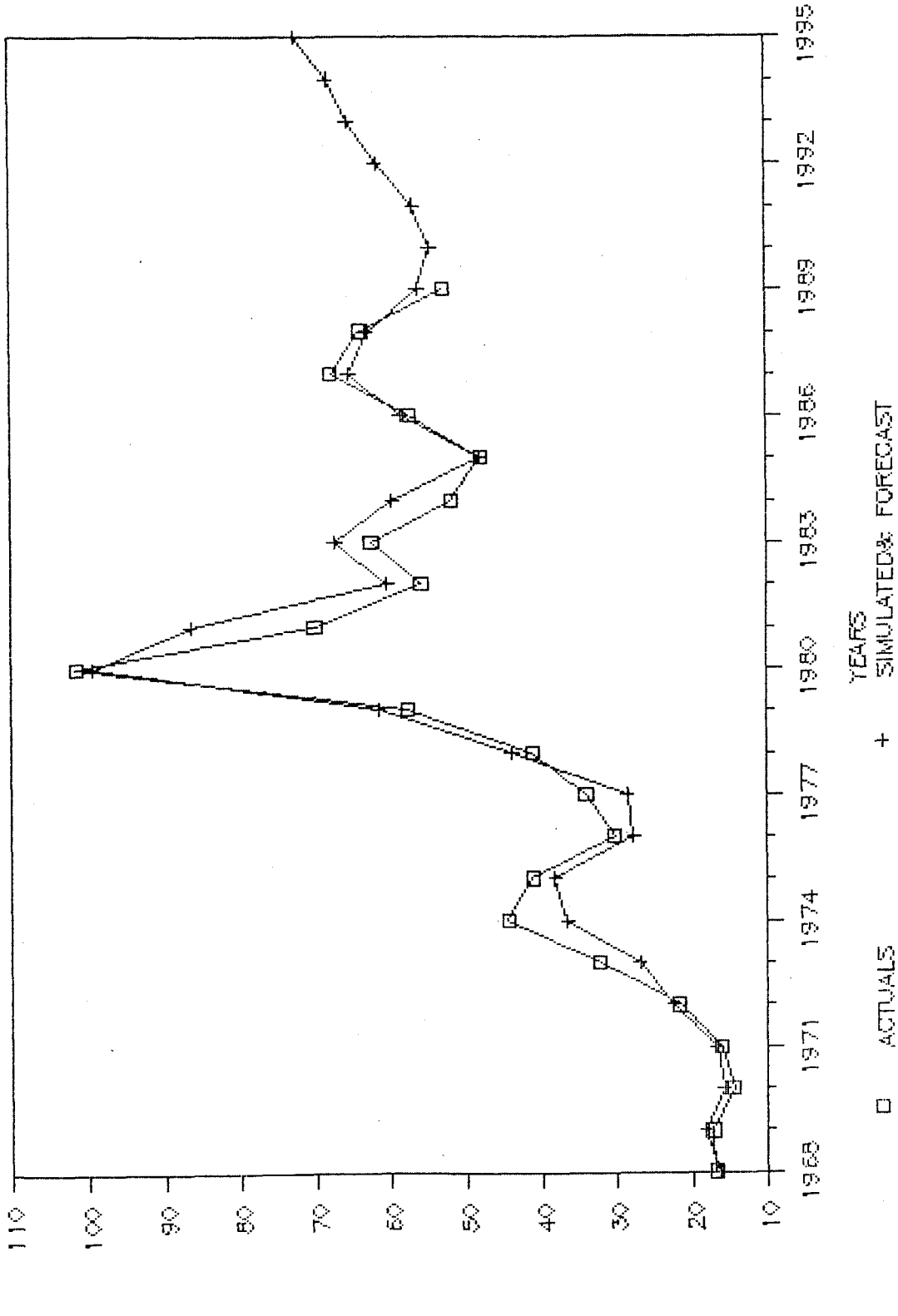
- The average annual number of conflicts (CON) over the last 35 years was used. It is assumed no major wars occur during the period.

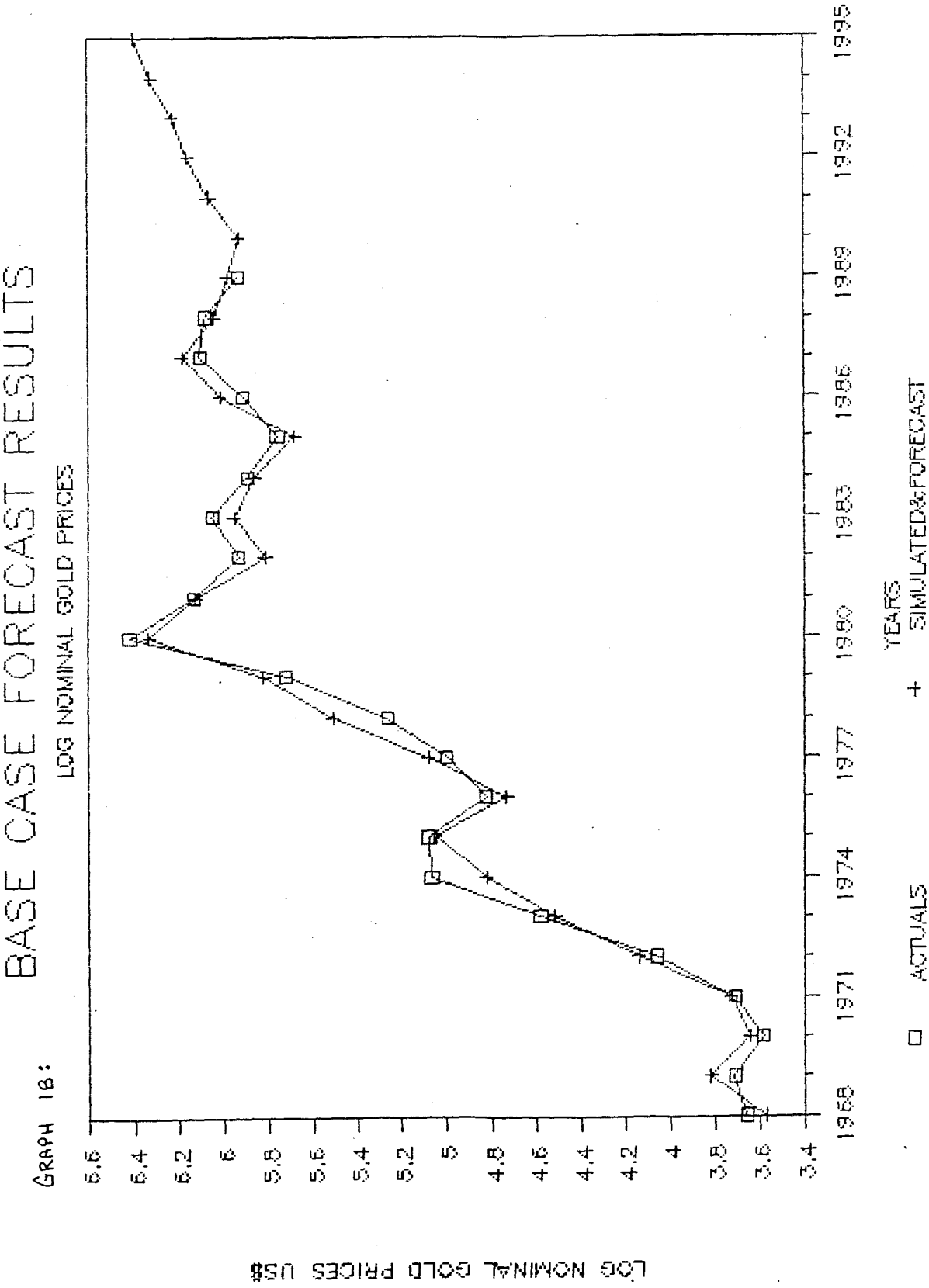
- Economic growth in Developing Countries (LDEVRGNP) is assumed to be stable over the period with real growth averaging 2.5% per year. It is assumed a world economic growth downturn does not occur during the period.

Graphs 16 and 17 give the forecast results for the log of real gold prices and real gold prices respectively. The results indicate that in 1990 real gold prices will remain virtually unchanged from the 1989 average. In 1991 the forecast shows that there will be an improvement in the real price of gold and this trend will continue through to 1995. It is estimated that by 1995, gold prices in real terms (Graph 17) will have only reached 1987 real gold price levels. The results indicate that the real gold price will average approximately $65.00 U.S. over the forecast horizon.


GRAPH 16: BASE CASE FORECAST RESULTS
LOG REAL GOLD PRICES
LOG REAL GOLD PRICES US$
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
YEARS
□ ACTUALS
+ SIMULATED&FORECAST

GRAPH 17: BASE CASE FORECAST RESULTS

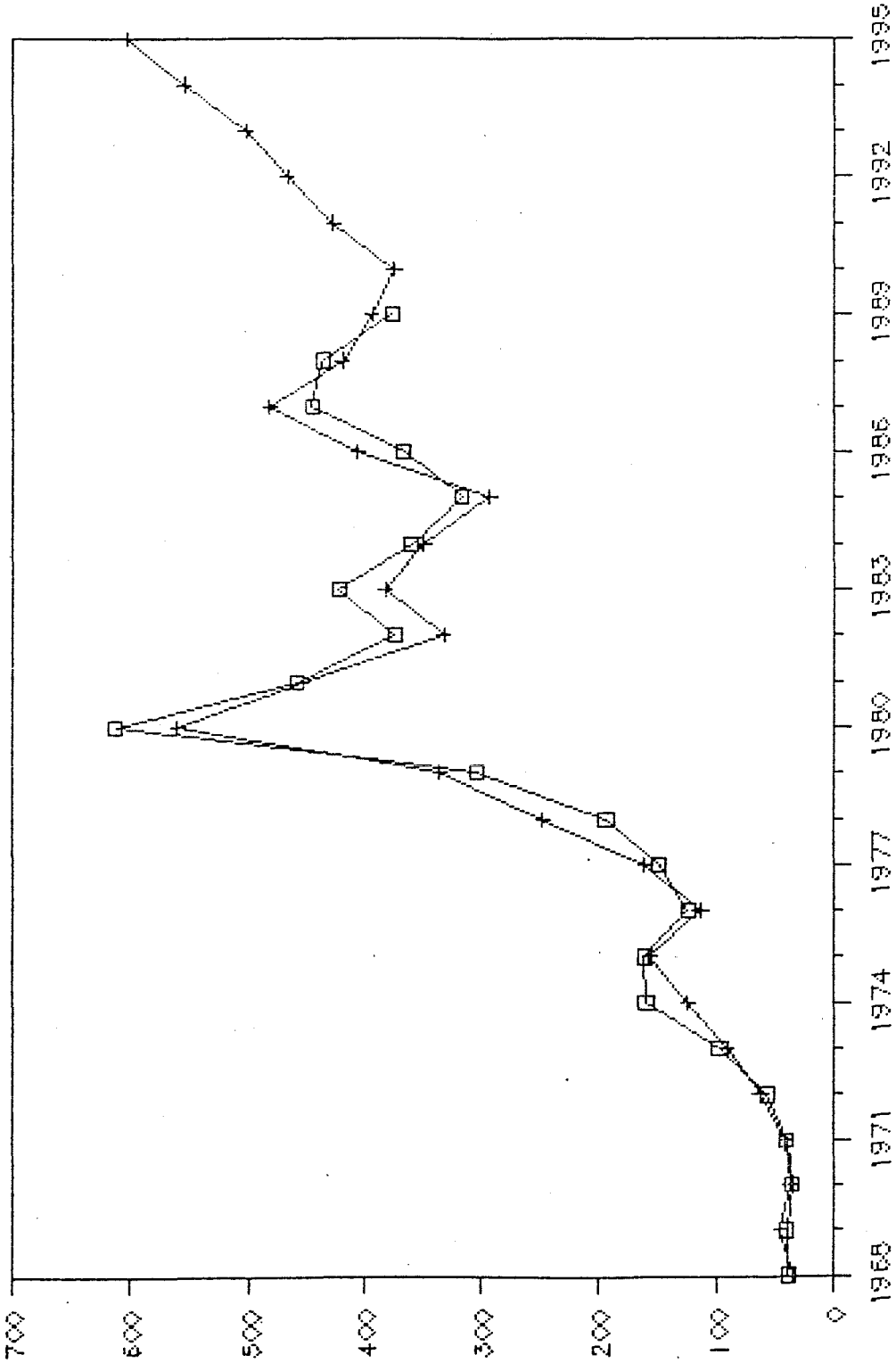



GRAPH 18:
BASE CASE FORECAST RESULTS
LOG NOMINAL GOLD PRICES
LOG NOMINAL GOLD PRICES US$
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
YEARS
□ ACTUALS
+ SIMULATED&FORECAST

GRAPH 19:

BASE CASE GOLD PRICE FORECAST

NOMINAL GOLD PRICES



Graphs 18 and 19 present the log of the nominal gold price and nominal gold price forecast results. The nominal gold pricing model (equation 4) indicates, under the assumptions given above, that nominal gold prices will average $385.00 U.S. in 1990. (See Graph 19). In 1991 nominal gold prices strengthen to $420.00 U.S. and it is estimated by 1995 that nominal gold prices will approach $600.00 U.S. The major reasons for the steady increase in nominal gold prices is due to the relatively strong world growth assumption and the assumption that South African production costs will continue to increase over the period.

The nominal gold pricing model was then used to predict gold prices under a number of different world scenarios. Table 21 gives nominal gold price forecasts results. The assumptions made in each forecast are given below.

- the Weak U.S. Dollar scenario assumes that the trade weighted U.S. dollar exchange rate weakens significantly in 1991 and the weakness continues through 1995. All other exogenous variables remain unchanged from the Base Case.

- The Recession scenario assumes that economic growth in

Developing Countries weakens in 1990 and 1991 and returns to the Base Case levels in 1993. All other variables are unchanged from the Base Case.

- The world conflict scenario assumes that beginning in 1990 and lasting throughout the forecast period there is a 50% increase from the Base Case assumption in the number of conflicts in the world. All other variables are unchanged from the Base Case.

- The 20% costs scenario assumes South African Production costs increase by 20% per year instead of the Base Case assumption of 10%. All other variables are unchanged from the Base Case.

- The peace scenario assumes a 10% per year reduction in the number of conflicts in the world. All other variables are unchanged from the Base Case.

TABLE 21: FORECAST RESULTS

(Nominal U.S.$ Gold Prices)

	SCENARIOS					
YEAR	BASE CASE	WEAK DOLLAR	RECESSION	WORLD CONFLICT	20% COSTS	PEACE
1990	$385	$400	$370	$700	$415	$350
1991	$420	$530	$410	$795	$520	$380
1992	$467	$690	$450	$875	$625	$400
1993	$500	$721	$485	$1000	$740	$410
1994	$551	$755	$528	$1125	$880	$440
1995	$595	$799	$575	$1275	$990	$475

The above results indicate that should the U.S. dollar weaken significantly; should there be an increase in the number of wars and conflicts in the world; and should production costs be greater than anticipated, the nominal gold price will increase significantly from the Base Case scenario. Assuming a recession in Developing Countries appears to have little effect on the nominal gold prices from Base Case projections. Under the peace scenario gold prices will remain around the $400.00 U.S. level over the period.

FORECAST SUPPLY AND DEMAND LEVELS (BASE CASE SCENARIO)

In this section, the Base Case real gold price forecast values are entered in the supply and demand curve equations estimated in the previous chapter.[78] Table 22 gives the supply simulation results for the 1990-1995 period while Table 22 gives the demand simulation results.

---

78. Equations used in this following tables are the estimated distributed lag supply and demand equations. Results for the long run supply and demand equations are similar and are given in Appendix C.

TABLE 22:

BASE CASE SIMULATION RESULTS BY SUPPLY COMPONENT

METRIC TONS

YEAR	SOUTH AFRICAN PRODUCTION	OTHER COUNTRY PRODUCTION	NET COMMUNIST SALES	TOTAL
1990	612	994	299	1905
1991	606	991	297	1893
1992	597	993	294	1884
1993	586	996	292	1874
1994	574	1001	289	1864
1995	560	1010	286	1856

The Base Case supply simulation results indicate that total supply will decrease over the period despite real gold prices increasing. This decrease will be due primarily to production declines in South Africa. It is expected that by 1995 South African production will be 560 tons. Other Country production remains relatively constant over the period averaging roughly 1000 tons.

TABLE 23:

BASE CASE SIMULATION RESULTS BY DEMAND COMPONENT

METRIC TONS

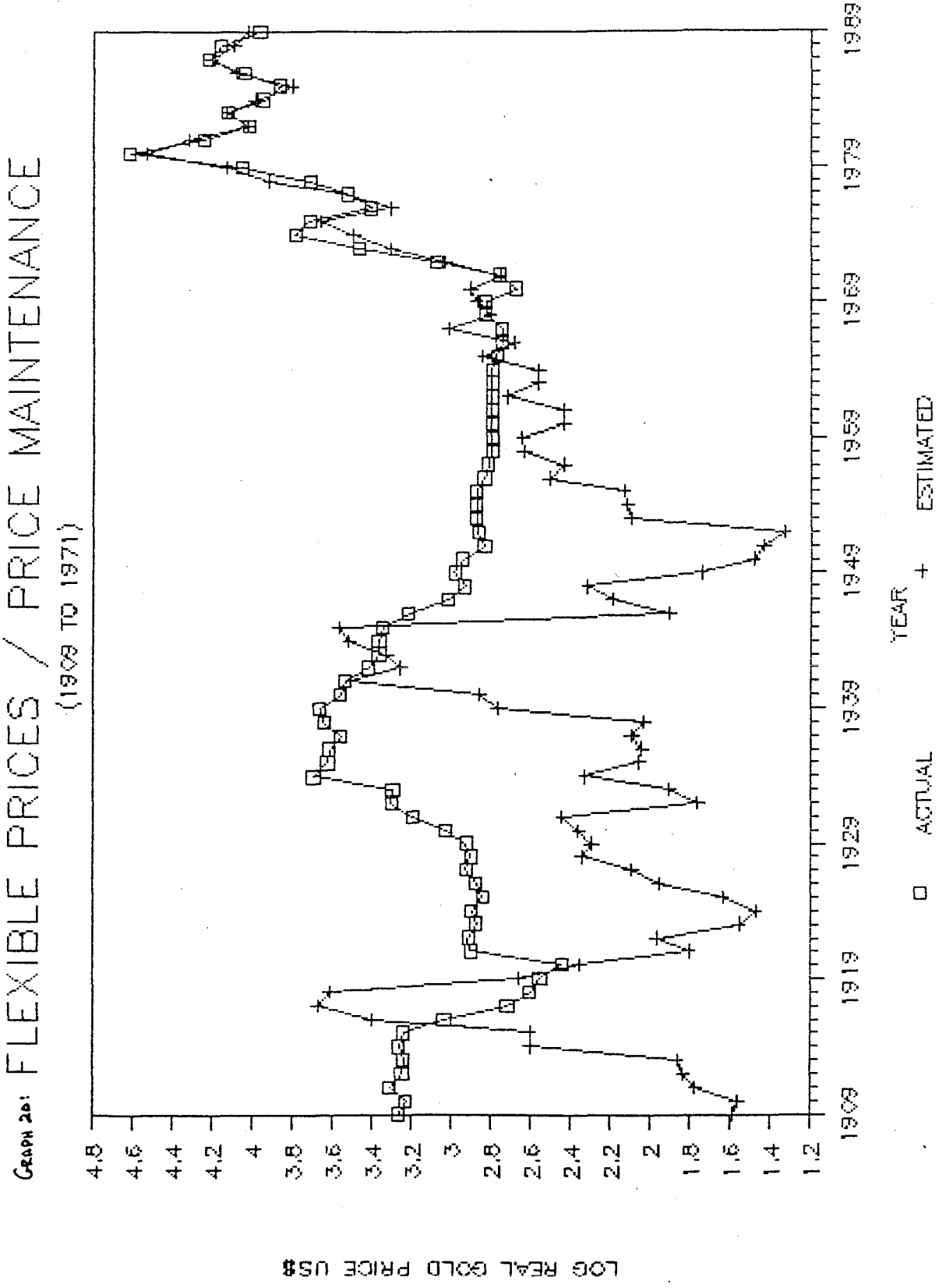
YEAR	DEVELOPED COUNTRY FABRICATION	DEVELOPING COUNTRY FABRICATION	OFFICIAL RESERVE DEMAND	PRIVATE INVESTMENT DEMAND	TOTAL DEMAND
1990	850	474	121	430	1875
1991	843	467	123	457	1890
1992	832	456	128	486	1902
1993	824	449	134	502	1909
1994	815	442	143	522	1921
1995	805	433	153	544	1935

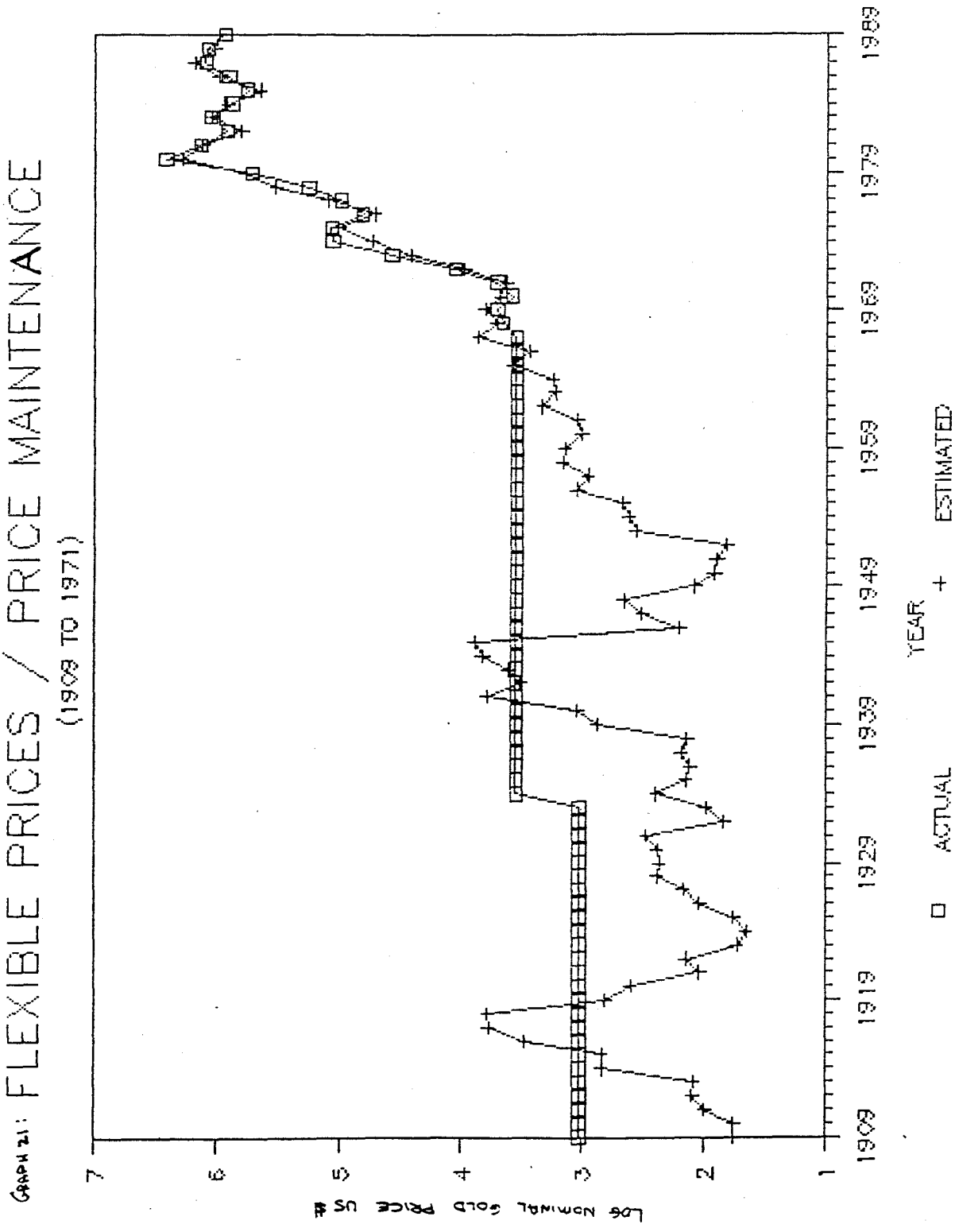
The demand simulation results indicate that total demand will increase over the 1990 to 1995 period. As was the case in the 1980's, official reserve demand and private investment demand will continue to strengthen over the period.

IMPLEMENTATION OF A NEW GOLD STANDARD: AT WHAT PRICE SHOULD GOLD BE PEGGED?

One of the basic questions concerning those advocating the renewal of a form of gold standard is, what price should gold be fixed? It has been shown that for the Gold Standard to work, the real price of gold has to be high enough to generate enough production to accommodate non-monetary and monetary gold demand. It is therefore anticipated that during the fixed gold price era, the fixed price of gold would have had to be considerably higher than the "market price" to ensure an adequate supply of monetary gold.

To test this hypothesis the previous reduced form gold pricing models were regressed over the 1967 to 1987 period. The regression results were then used to estimate how prices would have varied had the gold price been allowed to float over the 1909 to 1971 period. Graphs 20 and 21 illustrate the flexible price estimations for the log of the real and nominal gold prices. As expected, with the exception of the two World


GRAPH 2a: FLEXIBLE PRICES / PRICE MAINTENANCE
(1909 TO 1971)
LOG REAL GOLD PRICE US$
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1909
1919
1929
1939
1949
1959
1969
1979
1989
YEAR
□ ACTUAL + ESTIMATED


GRAPH 21: FLEXIBLE PRICES / PRICE MAINTENANCE
(1968 TO 1971)
Log NOMINAL GOLD PRICE US $
7
6
5
4
3
2
1
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
YEAR
□ ACTUAL
+ ESTIMATED

War periods and up to approximately 1960, the estimated flexible real and nominal price of gold was well below the floor price.

Both graphs indicate that beginning in the late 1950's, despite increasing supply, the "market price" steadily increased to where by 1966 both the estimated flexible price and the floor price were the same. As noted earlier in this dissertation, and as shown in Table 12, Column F, 1966 was the first year since the 1930's that non-monetary gold demand exceeded new mine production.

The information contained in Graphs 20 and 21 allow for the relationship between the the fixed price and the estimated "market price" of gold to be quantified. For example, over the 1909 to 1967 period, fixed nominal gold prices were on average 100% higher than the estimated nominal "market price". Similarly for real gold prices, the average difference between real fixed prices and estimated real "market prices" over the same period was 110%.

Estimations using the above reduced form gold pricing models therefore indicate that if the U.S were to peg the price of gold, the fixed price would have to be approximately

100% higher than the current market price for the new regime to work.

CONCLUSIONS

This chapter has developed, tested and forecast several reduced-form gold pricing models. These models differ from conventional reduced form gold pricing models in that they include supply variables. The models developed in this dissertation track historical gold price movements exceptionally well. Forecasting the models indicates that nominal gold prices will begin to strengthen in 1990 increasing to around $600.00 U.S. by 1995. Under the same forecast assumptions real gold prices are expected to increase between 3% and 6% per year over the 1990 to 1995 period.

CHAPTER 7

CONCLUSIONS

Currently the world is in the midst of its fourth gold rush. New finds in North America, Australia, and Latin America have significantly changed the structure of the mining industry and therefore the structure of the gold market. South Africa, with the world's richest known gold reserves has seen its share of world gold production fall from 78.5% in 1970 to roughly 44% in 1988. Although the world has faced a gold rush when the price of gold was fixed and gold was primarily a monetary metal it has not faced a gold rush under a flexible gold price environment.

One of the major purposes of this dissertation has been to study in detail the supply side of the gold market. In particular, a theoretical model of South African production is developed and supply variables are introduced into several reduced form gold pricing models. In addition, this dissertation has theoretically and empirically identified the major factors influencing gold supply and demand and has estimated long and short run supply and demand equations for various gold components. The thesis also presents a variety of gold price forecasts using the reduced form gold pricing

models developed.

What distinguishes this study from other gold studies is its scope of analysis and its attention to the supply side of the gold market. One of the largest and most extensive historical databases on gold demand and supply has been compiled. This has allowed for a depth of market analysis unparalleled by other studies.

This dissertation has presented an exhaustive theoretical and empirical analysis on the following major supply and demand gold categories.

SUPPLY
1. South African Gold Production.
2. Other Country Gold Production.
3. Net Communist Sales.

DEMAND
4. Developed Country Gold Fabrication Demand.
5. Developing Country Gold Fabrication Demand.
6. Official Reserve Demand.
7. Private Investment Demand.

Supply and demand curves for each of the above components were estimated using a method similar to the Fair Method. The Fair Method is a two stage least squares technique with an adjustment for autocorrelation.

It was found that on the supply side of the gold market there is a tendency towards low adjustment speeds which are reflected in the long run supply elasticities being greater than the short run elasticities. In the case of South Africa production, as expected, real gold prices and production were found to be inversely related. In addition, it was shown that the short and long run supply curves are highly inelastic. Other Country production results indicate that the long run supply curve is elastic with real gold prices and production being positively related.

The results suggest that when South Africa was the dominant gold supplier producing 70% of total world annual production, the total long run supply curve was highly inelastic. With the importance of South Africa production declining and Other Country production increasing significantly, this has resulted in the long run total supply becoming more and more elastic. As a consequence, demand shifts on an ever increasing elastic supply curve have increasingly impacted the physical quantity of gold rather than the dollar gold price.

This is exactly the situation that has been evident in the gold market over the last 10 years. Severe gold price

changes have not occurred, as gold production in general has become more price sensitive due to the increase in Other Country production. Should the importance of South African production increase or the importance of Other Country production decline in the future, it can be expected that gold price fluctuations would once again increase significantly. The gold market would then return to a demand driven market where demand changes impact the price rather than the physical quantity.

On the demand side, adjustment speeds were found to be extremely high, meaning that there is very little difference between long and short run elasticities. In general, demand elasticities were found to be low in both the long and short runs. More specifically , for Developed Country gold fabrication demand, price and demand were found to be negatively related and highly inelastic. Similar results were found for Developing Country gold fabrication demand. Real gold prices and Official Reserve demand were found to be positively related and the long run demand curve relatively elastic.

Private Investment demand, which has become an extremely volatile demand component since 1971, was found to be

positively related to real gold prices. Rising prices cause investors to purchase more gold in anticipation of higher future prices. The short and long run Private Investment demand curves were found to be identical and highly inelastic.

From the above theoretical and empirical analysis several reduced form gold pricing models were developed and tested. It was found that the addition of supply variables greatly improved the predictive powers of the standard all demand variable reduced form gold pricing models. In all cases the supply variables had the expected signs and were significant. The gold pricing models developed in this paper explained approximately 95% of the annual variation in the real and nominal price of gold. Simulations and test results indicated that the model's tracking and predictive properties were excellent.

The reduced form models were then used to forecast the future price of gold. Forecasts indicate that real gold prices are expected to increase between 3% and 6% per year over the 1990 to 1995 period. Nominal gold prices will begin to strengthen in 1990 increasing to approximately $600.00 U.S. by 1995. This forecast was based on the following

assumptions:

- an 10% annual increase in South African Production cost,
- a relatively strong trade weighted U.S. dollar,
- no major world conflicts or wars.
- Real growth in developing countries averaging 2.5% per year.

The reduced form gold pricing models were also used to estimate at what price gold should be fixed if the U.S. were to return to a gold standard. Model results indicate that the fixed price should be 100% higher than the current market price.

To conclude, the purpose of this dissertation has been to analyse in detail the physical gold market, paying particular attention to the supply side of the market. While the dissertation has been extensive in its analysis of the non-communist market, future work is required to include communist production and demand. More specifically, the Soviet Union and China are currently, or have the potential to be, among the largest gold producers in the world. It may be the case that to finance any transition from communism to capitalism, both countries may have to sell enormous

quantities of gold. As this dissertation has indicated, supply shifts impact the price rather than the physical quantity of gold, large scale sales by either country could significantly erode world gold prices.

In addition, with a softening in East-West political tensions, the precautionary reasons for holding gold have begun to change significantly. It will be interesting to see how the gold market reacts over the coming months to the democratization of many of the worlds major communist countries. This fundamental change in East-West tensions may result in a fundamental shift away from gold, causing gold prices to soften further.

Finally, greater research is needed on the Official Sector. As has been shown, the gold reserves held by governments are extremely large and poise a serious concern to long term gold prices.

APPENDIX A: NON-COMMUNIST WORLD SUPPLY AND DEMAND FOR GOLD, 1968-1987

YEAR	NON-COMMUNIST WORLD MINE PRODUCTION	NET-COMMUNIST SALES OR PURCHASES	SUPPLY	NET OFFICIAL SALES OR PURCHASES	DEVELOPED COUNTRY JEWELLERY FABRICATION	DEVELOPING COUNTRY JEWELLERY FABRICATION	INDUSTRIAL USE	COINS AND MEDAL FABRICATION	PRIVATE INVESTMENT RESIDUAL	GOLD PRICE US$/oz
1968	1245	-29	1216	-620	483.1	428.9	200.2	107.8	616	39
1969	1252	-15	1237	90	509.3	395.1	223.4	69.5	-50.3	41
1970	1273	-3	1270	236	507.8	554.4	210.1	100.2	-338.5	36
1971	1233	54	1287	-96	563.4	496.1	217.3	106.1	0.1	41
1972	1177	213	1390	151	713.8	281.8	241.7	103.3	-101.6	58
1973	1111	275	1386	-6	440.3	71.9	266.2	75.4	538.2	97
1974	996	220	1216	-20	280.2	-65.7	219.1	294.5	507.9	159
1975	946	149	1095	-9	313.1	202.5	189.2	264.6	134.6	161
1976	964	412	1376	-58	474.9	461.3	218.2	233.1	46.5	124
1977	962	401	1363	-269	546.3	458.1	225.9	194.1	207.6	148
1978	972	410	1382	-362	592.6	411.3	256.1	337.1	146.9	193
1979	959	199	1158	-544	544.6	183.3	268.1	324.1	381.9	305
1980	959	90	1049	230	276.1	-148	213.1	199.1	278.7	612
1981	981	280	1261	276	355.5	257.5	216.1	218.1	-62.2	460
1982	1028	203	1231	85	405.7	326.6	204.1	153.1	56.5	375
1983	1114	93	1207	-142	369.7	260.5	205.1	196.1	317.6	424
1984	1162	205	1367	-85	429.1	424.9	232.1	174.1	191.8	361
1985	1233	210	1443	132	488.7	402.3	225.1	120.1	74.8	317
1986	1291	402	1693	143	511.1	318.9	221.8	338.1	160.1	368
1987	1373	303	1676	70	501.6	370.1	219.8	222.3	292.2	447

SOURCE: VARIOUS ISSUES OF CONSOLIDATED GOLD FIELDS "GOLD"

APPENDIX B

APPENDIX B: CONVERSION TABLE

MASS	METRIC TON	LONG TON	SHORT TON	POUND	KILOGRAMS	OUNZE TROY
METRIC TON		0.984	1.102	2204.5	1000	
LONG TON	1.016		1.120	2240.0	1016	
SHORT TON	0.907	0.893		2000.0	907	
POUND	0.0004	0.0004	0.0005		0.4536	14.583
KILOGRAM	0.001			2.2045		32.150
OUNZE TROY						

APPENDIX C

LONG RUN

BASE CASE SIMULATION RESULTS BY SUPPLY COMPONENT

METRIC TONS

YEAR	SOUTH AFRICAN PRODUCTION	OTHER COUNTRY PRODUCTION	NET COMMUNIST SALES	TOTAL
1990	616	951	298	1865
1991	592	1006	292	1890
1992	569	1057	287	1913
1993	557	1084	284	1925
1994	541	1120	281	1942
1995	524	1160	277	1961

APPENDIX C CONT'D

LONG RUN

BASE CASE SIMULATION RESULTS BY DEMAND COMPONENT

METRIC TONS

YEAR	DEVELOPED COUNTRY FABRICATION	DEVELOPING COUNTRY FABRICATION	OFFICIAL RESERVE DEMAND	PRIVATE INVESTMENT DEMAND	TOTAL DEMAND
1990	854	478	100	427	1859
1991	840	465	136	458	1899
1992	827	454	170	487	1938
1993	820	448	187	503	1958
1994	811	440	211	523	1985
1995	801	431	237	545	2014

APPENDIX D

REAL GOLD PRICES
(1930 U.S. WPI= 100)

Year	U.S.$/ Ounze	Year	U.S.$/ Ounze	Year	U.S.$/ Ounze
1890	31.8	1930	20.7	1970	14.5
1991	32.0	1931	24.5	1971	16.1
1892	34.3	1932	27.4	1972	21.7
1893	33.4	1933	27.1	1973	32.1
1894	37.3	1934	40.6	1974	44.3
1895	36.6	1935	37.8	1975	41.1
1896	38.4	1936	37.4	1976	30.2
1897	38.4	1937	35.1	1977	34.0
1898	36.8	1938	38.5	1978	41.1
1899	34.3	1939	39.2	1979	57.8
1900	31.9	1940	38.5	1980	101.6
1901	32.3	1941	34.6	1981	70.0
1902	30.3	1942	30.7	1982	55.9
1903	29.9	1943	29.1	1983	62.4
1904	29.9	1944	29.1	1984	51.9
1905	29.7	1945	28.6	1985	48.0
1906	28.9	1946	25.1	1986	57.4
1907	27.5	1947	20.4	1987	67.9
1908	28.4	1948	18.8	1988	64.0
1909	26.4	1949	19.8	1989	52.9
1910	25.4	1950	19.1		
1911	27.5	1951	17.1		
1912	25.8	1952	17.6		
1913	25.6	1953	17.9		
1914	26.3	1954	17.8		
1915	25.7	1955	17.8		
1916	20.9	1956	17.2		
1917	15.2	1957	16.7		
1918	13.6	1958	16.5		
1919	12.9	1959	16.5		
1920	11.6	1960	16.5		
1921	18.3	1961	16.5		
1922	18.5	1962	16.5		
1923	17.6	1963	16.5		
1924	18.2	1964	16.5		
1925	17.3	1965	16.2		
1926	17.9	1966	15.6		
1927	18.7	1967	15.6		
1928	18.4	1968	17.0		
1929	18.8	1969	17.2		

BIBLIOGRAPHY

ADLER, M. and B. DUMAS. 1975. "Optimal International Acquisitions". Journal of Finance. p. 1-19.

AGGARWAL, R. and LUC SOENEN. 1985. "The Nature and Efficiency of the Gold Market". Journal of Portfolio Management. p.8-12.

ALIBER, R.Z. 1982. "Inflationary Expectations and the Price of Gold". Ch. 15 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

ANDERS, G. 1986. Gold Price Forecasting: Commodity and Monetary Perspectives. A discussion paper.

ANIKIA, A. 1983. Gold: The Yellow Devil. International Publishers.

BACHE, J.J. 1987. World Gold Deposits: Geological Classification. Elsevier. New York, New York.

BAHMANI-OSKOOEE, M. 1986. "Gold Price as Another Determinant of Demand for International Reserves". Journal of Economic Studies. p.23-32.

BAKER, S.A. and ROGER VAN TASSEL. July, 1985. "Forcasting the Price of Gold: A Fundamentalist Approach". Atlantic Economic Journal. p. 43-51.

BANK OF CANADA. Various Issues. Bank of Canada Review.

BARRO, R.J. March, 1979. "Money and the Price Level Under the Gold Standard". Economic Journal. p. 13-33.

BLOOMFIELD, P. October 11,1989. "All Eyes Fixed on Gold as Analysts Await Turnaround". The Financial Post.

BORDO, M.D. May, 1981. "The Classical Gold Standard: Some Lessons for Today". Federal Reserve Bank of St. Louis. p. 2-17.

BORDO, M.D. 1982. "The Gold Standard: The Traditional Approach". Ch. 1 in Bordo and Schwartz, ed. A Retrospective on the Classical Gold Standard, 1821 to 1931. University of Chicago Press, Chicago, Illinois.

BORDO, M.D. and RICHARD ELLSON. A Model of the Classical Gold

Standard with Depletion. (working paper). University of South Carolina. South Carolina.

BOYLE, R.W. 1987. Gold: History and Genesis of Deposists. Van Nostramd Reinhold Co. New York, New York.

BROWN, B. 1982. A Theory of Hedge Investments. Macmillan Press. London, England.

BUSSCHAU, W.J. 1949. Measure of Gold. Central News Agency Ltd. South Africa.

BUSSCHAU, W.J. 1936. THE THEORY OF GOLD SUPPLY. Oxford University Press, Oxford.

BUSSCHAU, W.J., DONALD MCLAUGHLIN, and MICHAEL SPIELER. 1967. "The Price of Gold and the Level of World Gold Reserves". Ch. 9 in Randal Hinshaw, ed. The Price of Gold. Johns Hopkins Press. Baltimore, Maryland.

CAMPBELL, C.D. and WILLIAM DOUGAN, ed. 1986. Alternative Monetary Regimes. Johns Hopkins University Press. Baltimore, Maryland.

CAMPBELL, G.A. 1985. "The Theory of Mineral Demand". Part 2.5 in William Vogely ed. Economics of the Mineral Industries: Fourth Edition. American Institute of Mining, Metalurgical,and Petroleum Engineers Inc. New York, New York.

COLLERY, ARNOLD. 1971. "International Adjustment, Open Economies, and the Quantity Theory of Money". Princeton Studies in International Finance. No. 28. Princeton University.

CONSOLIDATED GOLD FIELDS LIMITED. Various Years. Gold. Consolidated Gold Fields PLC. London, England.

COOPER, R.N., PETER B. KENEN, JORGE B. DE MACEDO, and JACQUES VAN YPERSELE. 1982. The International Monetary System Under Flexible Exchange Rates: Global, Regional and National. Ballinger Publishing Co. Cambridge, Massachusetts.

COUSINEAU, E. and P.R. RICHARDSON. 1979. Gold: The World Industry and Canadian Corporate Strategy. Queens University. Kingston, Ontario.

COYNE, H.J. 1982. "World Monetary Demand for Gold: Key tothe Gold Price Outlook". Ch. 11 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press.

Oxford, England.

DAM, K.W. 1984. "The Future of Gold". Occasional Papers. The University of Chicago Law School.

DAM, K.W. 1982. The Rules of the Game: Reform and Evolution in the International Monetary System. University of Chicago Press. Chicago, Illinois.

DESAI, M. 1966. " An Econometric Model Of the World Tin Economy". Econometrica p.105-135.

DE CECCO, M. 1984. The International Gold Standard. Frances Pinter. London, England.

DICK, T.J.O. and J. FLOYD. 1987. Balance of Payment Adjustment Under the International Gold Standard: Canada, 1871-1913. Draft Manuscript.

DICK, T.J.O. and J. FLOYD. 1987. Canada and the Gold Standard: 1871-1913. Draft Manuscript.

DHRYMES, P. 1971. Distributed lags: Problems of Estimation and Formulation Holden-Day. San Francisco.

DU BOULAY, L. and PETER D. FELLS. 1982. "The Medium and Long Term Structural Aspects for Gold". Ch. 9 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

EASTON, S.T. 1982. "Real Output and the Gold Standard Years, 1830-1913". Ch. 11 in Bordo and Schwartz, ed. A Retrospective on the Classical Gold Standard, 1821 to 1931. University of Chicago Press, Chicago, Illinois.

EATON, C.B. and D. EATON. 1988. Microeconomics. W.H. Freeman and Co. New York, New York.

EICHENGREEN, B. ed. 1985. The Gold Standard in Theory and History. Methuen Inc. New York, New York.

EINSIG, P. 1972. The Destiny of Gold. MacMillan Press. New York, New York.

FAIR, R.C. 1970. " The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First Order Serially Correlated Errors". Econometrica. p. 507-516.

FISHER,F.M., P.H. COOTNER and M. BAILEY. 1972, "An Econometric

Model of the World Copper Industry". Bell Journal of Economics and Management Science. p.568-609.

FISHER, I. 1963. The Purchasing Power of Money. New York, New York.

FLEMING, D.R. 1967. " An Investigation of Possible Methods of Preventing Loss of Gold Ore Caused By Escalation of the Pay Limit". Journal of the South African Institute of Mining and Metallurgy. p.235-243.

FLOOD, R.P. and PETER GARBER. September 1980. Gold Monetization and Gold Discipline. NBER working paper series. Cambridge, Massachusetts.

FRANKEL, S.H. 1967. Investment and the Return to Equity Capital in the South African Gold Mining Industry: 1887-1965. Harvard University Press. Cambridge, Massachusetts.

FREMLING, G.M. 1986. "A Specie-Flow Model of the Gold Standard". Journal of International Money and Finance. p. 37-55.

FRIEDMAN, M. 1953. Essays in Positive Economics. University of Chicago Press. Chicago, Illinois.

FRIEDMAN, M. and ANNA SCHWARTZ. 1963. A Monetary History of the United States: 1867 - 1960. Princeton University Press. Princeton.

GAZMARARIAN, D. 1982. "Markets and Intermediaries in the Far East". Ch. 6 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

GOLD COMMISSION REPORT. March, 1982. The Report to the Congress of the Commission of the Role of Gold in the Domestic and International Monetary Systems.

GORDON, R.L. 1985. "The Production of Mineral Commodities". Part 2.4 in William Vogely ed. Economics of the Mineral Industries: Fourth Edition. American Institute of Mining, Metalurgical,and Petroleum Engineers Inc. New York, New York.

GREEN, T. 1988. The Prospect for Gold: The View to the Year 2000". Walker and Co. New York, New York.

GREEN, T. 1968. The World of Gold. Walker and Co. New York, New York.

GRILICHES, Z. 1967. " Distributed Lags: A Survey". Econometrica. p.16-49.

GRUBEL, H.G. 1982. "Gold and the Dollar Crisis: Twenty Years Later". The International Monetary System Under Flexible Exchange Rates. Cooper, Kenen, deMacedo, van Ypersele, ed. Ballinger Publishing Co. Cambridge, Massachusetts.

GRUBEL, H.G. 1981. International Economics. Richard D. Irwin. Homewood, Illinois.

GRUBEL, H.G. December, 1968. "Internationally Diversified Portfolios: Welfare Gains and Capital Flows". American Economic Review. p. 1229-1314.

GRUBEL, H.G. and K. FADNER. 1971. "The Interdependance of International Equity Markets". Journal of Finance. p. 89-94.

HANSELMANN, G.R. 1982. "The International Gold Markets: The View of a Swiss Bank". Ch. 1 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

HEFFERLIN, J. 1981. Making Inflation Pay. Harbor Publishing. San Francisco, California.

HERBST, A.F. 1983. "Gold Versus U.S. Common Market Stocks: Some Evidence on Inflation Hedge Performance and Cyclical Behaviour". Financial Analysts Journal. p.66-74.

HINSHAW, R. ed. 1967. The Monetary Reform and the Price of Gold: Alternative Approaches. Johns Hopkins Press. Balitmore, Maryland.

HIRSHLEIFER, J. 1984. The Price Theory and Applications: Third Edition. Prentice Hall. Englewood Cliffs, New Jersey.

HOTELLING, H. April, 1931. "The Economics of Exhaustible Resources". Journal of Political Economy. p. 137-175.

IBBOTSON, R.G. , L.B. SIEGEL, and K.S. LOVE. 1985. "World Wealth: Market Values and Returns". The Journal of Portfolio Management. p. 4-22.

INTERNATIONAL MONETARY FUND. Various Issues. International Financial Statistics.

IRWIN, H.S. and D. LANDA. 1987. "Real Estate, Futures, and Gold as Portfolio Assets". The Journal of Portfolio

Management. p. 29-34.

J. ARON and CO. Various Issues. Gold Statistics and Analysis.

JACKSON, R.S. 1988. North American Gold Stocks. Probus Publishing. Chicago, Illinois.

JANISCH, P.R. 1986. "Gold and South Africa". The Journal of the South African Institute of Mining and Metallurgy. p. 273-316.

JASTRAM, R.W. 1982. "The Golden Constant, or the Gold Standard and the Behaviour of Commodity Price Levels". Ch. 14 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

JASTRAM, R.W. 1977. The Golden Constant: The English and American Experience. John Wiley and Sons. New York, New York.

JASTRAM, R.W. 1981. Silver: The Restless Metal . John Wiley and Sons. New York, New York.

KATZEN, L. 1964. Gold and the South African Economy. A.A. Balkema. Cape Town, South Africa.

KEMMERER, E.W. 1944. Gold and the Gold Standard. McGraw/Hill. New York, New York.

KENNEDY, P. 1985. A Guide to Econometrics: Second Edition. MIT Press. Cambridge, Massachusetts.

KETTELL, B. 1982. Gold. Graham & Trotman Ltd. London, England.

KEYNES, J.M. September, 1986. "The Supply of Gold". Economic Journal. p. 412-418.

KOYCK, L.M. 1954. Distributed Lags and Investment Analysis. North-Holland. Amsterdam.

LABYS, W.C., FRANK FIELD and JOEL CLARK. 1985. "Mineral Models". Part 3.9 in William Vogely ed. Economics of the Mineral Industries: Fourth Edition. American Institute of Mining, Metalurgical,and Petroleum Engineers Inc. New York, New York.

LEAGUE OF NATIONS. 1978. The Interim Report of the Gold Delegation and Report of the Gold Delegation. Arno Press. New York, New York.

LESSARD, D.R. February. 1976. "World, Country and Industry Relationships in Equity Returns: Implications for Risk Reduction Through International Diversification". Financial Analyst Journal. p. 32-38.

LESSARD, D.R. May, 1974. "World, National and Industry Factors in Equity Returns". Journal of Finance. p. 379-391.

LEVHARI, D. and R. PINDYCK. August, 1981. "The Economics of Exhaustible Resources". Quarterly Journal of Economics. p. 365-377.

LEVINE, E. ed. Various Issues. The Gold Report. The South African Gold Exchange.

LEVY, H. and M. SARNAT. September, 1970. "International Diversification of Investment Portfolios". American Economic Review. p. 668-675.

LINDERT, P.H. 1969. Key Currencies and Gold. 1900-1913. Princeton University, Princeton, New Jersy.

LONDON AND CAMBRIDGE ECONOMIC SERVICE. The British Economy: Key Statistics 1900-1970. Times Newspapers Ltd. London, England.

MACHLUP, F. 1968. "The Price of Gold". Reprints in International Finance. Princeton University.

MACHLUP, F. 1969. "Speculation on Gold Speculation". Reprints in International Finance. Princeton University. 332-343.

MAIN, T.R.N. 1982. "Factors Affecting Production and Costs in the Medium to Long Term in the Gold Mining Industry". Ch. 10 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

MARKOWITZ, H. March, 1952. "Portfolio Selection". Journal of Finance. p. 71-91.

MARSH, B.J. Jan-Mar, 1983. "Keynes on the Supply of Gold: A Statistical Test". Eastern Economic Journal. p. 7-12.

MASERA, R.S. and GIANANDREA FALCHI. 1982. "The Role of Gold in Central Banks' Reserve Composition". Ch. 22 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

MORGAN, V. and A. MORGAN. 1976. Gold or Paper? The Institute

of Economic Affairs. London, England.

NERLOVE, M. 1972. " Lags in Economic Behavior". Econometrica. p.221-251.

NESSIM, R. 1982. "Physical and Futures Markets with Reference to the US". Ch. 3 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

NIEHANS, J. 1982. "Gold Operations as an Instrument of Monetary Policy". Ch. 24 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

NIEHANS, J. 1978. The Theory of Money. Johns Hopkins University Press. Baltimore, Maryland.

OPPENHEIMER, P.M. 1982. "Possible and Desirable Roles for Gold in the International Monetary System: Reconsideration and Proposals". Ch. 18 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD). Various Issues. OECD Economic Outlook.

PAISH, F.W. November 1938. "Causes of Changes in Gold Supply". Economica. p.379-409.

PALYI, M. 1972. The Twilight of Gold. Henry Regnery Co. Chicago, Illinois.

PAUL, R. and LEWIS LEHRMAN. 1982. The Case for Gold: A Minority Report of the US Gold Commission. CATO Institute, Washington, D.C.

PINDYCK, R.S. October, 1978. "The Optimal Exploration and Production of Non-Renewable Resources". Journal of Political Economy. p 841-861.

PINDYCK, R.S. and D.L. RUBINFELD. 1976. Econometric Models and Economic Forecasts. McGraw-Hill. New York, New York.

RADETZKI,M. 1989. " Precious Metals: The Fundamental Determinants of Their Price Behaviour". Resources Policy. p.194-208.

RICARDO, D. 1963. The Principles of Economy and Taxation.

Richard D. Irwin. Homewood, Illinois.

RICARDO, D. 1809. Three Letters on the Price of Gold. Johns Hopkins Press. Baltimore, Maryland.

ROBBINS, P. and DOUGLASS LEE. 1979. Guide to Precious Metals and their Markets. Nichols Publishing Co. New York, New York.

ROCKOFF, H. 1982. "Some Evidence on the Real Price of Gold, It's Cost of Production, and Commodity Prices". Ch. 14 in Bordo and Schwartz, ed. A Retrospective on the Classical Gold Standard, 1821 to 1931. University of Chicago Press, Chicago, Illinois.

ROCKWELL, L.H. JR. 1985. The Gold Standard: An Austrian Perspective. Lexington Books. Toronto, Ontario.

ROYAL INSTITUTE OF INTERNATIONAL AFFAIRS. 1931. The International Gold Problem: Collected Papers. Oxford University Press. London, England.

SALANT, S.W. and D.W. HENDERSON. August, 1978. "Market Anticipations of Government Policies and the Price of Gold". Journal of Political Economy. p.227-649.

SAMUEL MONTAGU and CO. Various Issues. Annual Bullion Review. London, England.

SARNOFF, P. 1980. Trading in Gold. Woodhead-Faulkner. Cambridge, England.

SCHWARTZ, A. 1982. "The Past, Current and Prospective Role of Gold in the US Monetary System". Ch. 21 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

SHANNON, I. 1964. International Liquidity: A Study in the Economic Functions of Gold. Henry Regnery and Co. Chicago, Illinois.

SHERMAN, E.J. 1986. Gold Investment: Theory and Application. New York Institute of Finance. New York, New York.

SIVARD, R.L. 1987. World Military and Social Expenditures: 1987. World Priorities. Washington, D.C.

SKOUSEN, M. 1977. The 100% Gold Standard: Economics of a Pure Money Commodity. University Press of America. Washington, D.C.

SOLT, M.E. and P.J. SWANSON. 1981. "On the Efficiency of the Markets for Gold and Silver". The Journal of Business. p.453-479.

SOUTH AFRICAN RESERVE BANK. Various Issues. Quarterly Bulletin.

SPRINKEL, B.W. 1964. Money in Stock Prices. Richard D. Irwin. Homewood, Illinois.

STELLA, L. and FABIO V. TORBOLI. 1982. "Aspects of the Industrial Demand as to Jewellery: Case Study of a Typical Country". Ch. 13 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

SUTTON, A.C. 1977. War on Gold. 76 Press. Seal Beach, California.

SYLOS-LABINI, P. 1982. "On the Instability of Raw Materials Prices and the Problem of Gold". Ch. 16 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

TAN, R.H.L. 1981. The Gold Market. Singapore University Press. Singapore.

TOBIN, J. 1958. "Liquidty Preference as Behaviour Towards Risk". Review of Economic Studies. p.65-86.

TRIFFEN, R. 1964. Gold and the Dollar Crisis. Yale University Press. New Haven, Connecticut.

TRIFFEN, R. 1978. Gold and the Dollar Crisis: Yesterday and Tomorrow. Princeton University. Princeton, New Jersey.

TSCHOEGL, A. 1980. "Efficiency in the Gold Market". Journal of Banking and Finance. p.371-379.

UNITED NATIONS. 1985. 1985 Report on the World Social Situation . New York, New York.

VAN TASSEL, R.C. 1982. "Gold: Fundamental Influences Upon the Investment Climate". Ch. 12 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.

VOGELY, W.A. ed. 1985. Economics of the Mineral Industries. American Institute of Mining, Metallurical and Petroleum

Engineers Inc. Hoboken, New York.

WISE, E.M. ed. 1964. Gold: Recovery, Properties and Applications. D. Van Nostramd Co. Inc. Princeton, New Jersey.

WITTICH, G. 1982. "The Role of Gold in the International Monetary Fund Today". Ch. 20 in Alberto Quadrio-Curzio ed. The Gold Problem: Economic Perspectives. Oxford University Press. Oxford, England.