NBER WORKING PAPER SERIES

GIBSON'S PARADOX AND THE GOLD STANDARD

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Working Paper No. 1680

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 1985

We are grateful to Olivier Blanchard, Stanley Fischer, N. Gregory Mankiw, Franco Modigliani, Julio Rotemberg, and participants in seminars at Columbia, Harvard, Maryland, Michigan, MIT, UCLA, and the Federal Reserve for extremely helpful comments. The research reported here is part of the NBER's research programs in Economic Fluctuations and Financial Markets and Monetary Economics. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

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ABSTRACT

This paper provides a new explanation for Gibson's Paradox - the observation that the price level and the nominal interest rate were positively correlated over long periods of economic history. We explain this phenomenon in terms of the fundamental workings of a gold standard. Under a gold standard, the price level is the reciprocal of the real price of gold. Because gold is a durable asset, its relative price is systematically affected by fluctuations in the real productivity of capital, which also determine real interest rates.

Our resolution of the Gibson Paradox seems more satisfactory than previous hypotheses. It explains why the paradox applied to real as well as nominal rates of return, its coincidence with the gold standard period, and the co-movement of interest rates, prices, and the stock of monetary gold during the gold standard period. Empirical evidence using contemporary data on gold prices and real interest rates supports our theory.

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Monetary theory leads us to expect a correlation between nominal interest rates and the rate of change, rather than the level, of prices. Yet, as emphasized by Keynes (1930), two centuries of data do not confirm this expectation. Between 1730 and 1930, the British consol yield exhibits close co-movement with the wholesale price index, alongside an essentially zero correlation with the inflation rate. Keynes referred to the strong positive correlation between nominal interest rates and the price level, which he called "Gibson's Paradox, as "one of the most completely established empirical facts in the whole field of quantitative economics" (Keynes, 1930, vol. 2, p. 198). Fisher wrote that "no problem in economics has been more hotly debated" (Fisher, 1930, p. 399).

Fisher (1930) attempted to resolve the Gibson Paradox by combining his relation between nominal rates and expected inflation with the hypothesis that inflationary expectations were formed as a long distributed lag on past inflation, with slowly declining weights. Wicksell (1936) and Keynes (1930), treating the Gibson phenomenon as a correlation between the price index and the real rate of return, argued that exogenous shifts in the profitability of capital would be accompanied by accomodative movements in the stocks of inside and outside money through the behavior of private and central banks. However, monetary economists have found strong theoretical and empirical grounds for rejecting both the Fisherian and the Wicksell-Keynes explanations. Other resolutions of Gibson's Paradox have been proposed as well, but these have generally been viewed as too ad hoc to rationalize such a persistent phenomenon. As Friedman and Schwartz (1976, p. 288) conclude, "The Gibson Paradox remains an empirical phenomenon without a theoretical explanation".

This paper offers a new approach to the Gibson Paradox. Noting the coincidence of the Gibson Paradox observation and the gold standard period, we see the Gibson correlation as a natural concomitant of a monetary standard based on a durable commodity. Our theoretical explanation revolves around the essential nature of a metallic standard. Since the authorities peg the nominal price of gold at a constant, the general price level is the reciprocal of the price of gold in terms of goods. Thus, determination of the general price level amounts to the microeconomic problem of determining the relative price of gold. Following treatments of the gold standard by Friedman (1953), and Barro (1979), we focus on the demand for gold in its real, as well as its monetary, uses. Using a perfect foresight version of the model of Barro (1979), we are able to demonstrate that if (as in Wicksell and Keynes) innovations in the productivity of capital are an important exogenous disturbance, there will be a negative equilibrium relationship between the relative price of gold and the real interest rate, giving rise to Gibson's Paradox.

Our theory of the Gibson Paradox is supported by the historical coincidence of the Gibson Paradox period and the gold standard. It accounts for the anomalies which plague the Fisher and Keynes-Wicksell theories of the Gibson correlation. Further support comes from an analysis of contemporary data on gold pricing. In recent years, gold and other metals prices have moved as our theory would predict. A final source of supporting evidence is the available information on monetary and non-monetary gold stocks.

The paper is organized as follows. Section I documents that the Gibson correlation between interest rates and the price level is a major feature of data from the gold standard period. Recent claims by Benjamin and Kochin (1984) that much of the correlation is spurious and that it is in any event largely a wartime phenomenon are shown to be unwarranted. We also note two other facts that a satisfactory theory of the Gibson Paradox must contend with. The Gibson correlation evaporates in recent decades when a fiat money standard prevailed. Data on equity yields indicate that the Gibson correlation held for real as well as nominal assets.

Section II briefly reviews the major existing explanations of the Gibson Paradox. The Fisher explanation based on inflationary expectations has difficulty accounting for the correlation of real returns on equity and the price level. It is also inconsistent with the empirical observation that prices followed a process very close to a random walk during the Gibson Paradox period. The Keynes-Wicksell explanation based on the workings of the banking system founders on the observation that variation in the American money stock during the pre-1914 period reflected largely variation in the monetary gold stock rather than changes in the money multiplier or the ratio of outside money to the gold stock. Other explanations appear inadequate to the phenomenon.

Section III presents our theory of the Gibson Paradox. The Gibson correlation arises naturally in a model of the pricing of gold with a variable return to capital. We show that our model of gold pricing can rationalize the anomalies associated with the Fisher and Keynes-Wicksell explanations for Gibson's Paradox. In the face of real shocks, the price level should be correlated with real rates of return. Since gold is priced as an asset, the theory suggests that the price level will follow an approximate random walk. Finally, the process of substitution between monetary and non-monetary gold leads the model to predict the observed positive correlation of interest rates, the monetary gold stock and prices.

Section IV examines the correlation between real interest rates and the relative price of gold during the recent period when the price of gold has floated freely. The negative correlation between real interest rates and the real price of gold that forms the basis for our theory is a dominant feature of actual gold price fluctuations. Similar findings are obtained using an index of non-ferrous metal prices.

Section V returns to the gold standard period and examines the scanty available data on the stocks of monetary and non-monetary gold. Contemporaneous accounts suggest the importance of conversions of gold between monetary and non-monetary uses. Some very weak statistical evidence suggests that the share of gold held in monetary form was an increasing function of the interest rate, as predicted by our model.

Section VI presents some concluding remarks.

I. Gibson's Paradox in World Data, 1730 to 1938

This section examines world data on commodity prices, long-term interest rates, and stock yields in an effort to characterize Gibson's Paradox. We confirm that there is a Gibson Paradox to be explained; it is not merely a spurious correlation between two random walks. Then, using stock yield data, we argue that Gibson's Paradox involved the underlying real rate of return, and not merely the nominal yield on financial assets.

Data

The raw price data that we work with consist of wholesale price indices for four countries: Britain, France, Germany, and the United States. The U.S.

series is the all-items WPI from Warren and Pearson (1933). The British data are from Mitchell and Deane (1962), and were assembled by linking the Elizabeth Schumpeter Index with the annual average of the Gayer, Rostow, and Schwartz Monthly Index of British Commodity Prices, and then (beginning in 1846) the Sauerbeck-Statist Overall Price Index. The French and German indices are from Mitchell (1978). The series are based heavily on listed prices for institutional purchasers, and tend to emphasize internationally traded goods. Table 1 presents a correlation matrix for the four countries' prices for the years 1870 to 1913.

Table 1

	Britain	France	Germany	U.S.
Britain	1			
France	.94	1		
Germany	.65	.81	1	
U.S.	.85	.94	.81	1

For the years 1820 to 1870, British and French prices are almost as highly correlated as in the later period. Germany, however, is rather out of line with the other countries before 1870. The correlations of prices across countries do appear to be high enough to make the notion of a "world price level" a meaningful one.

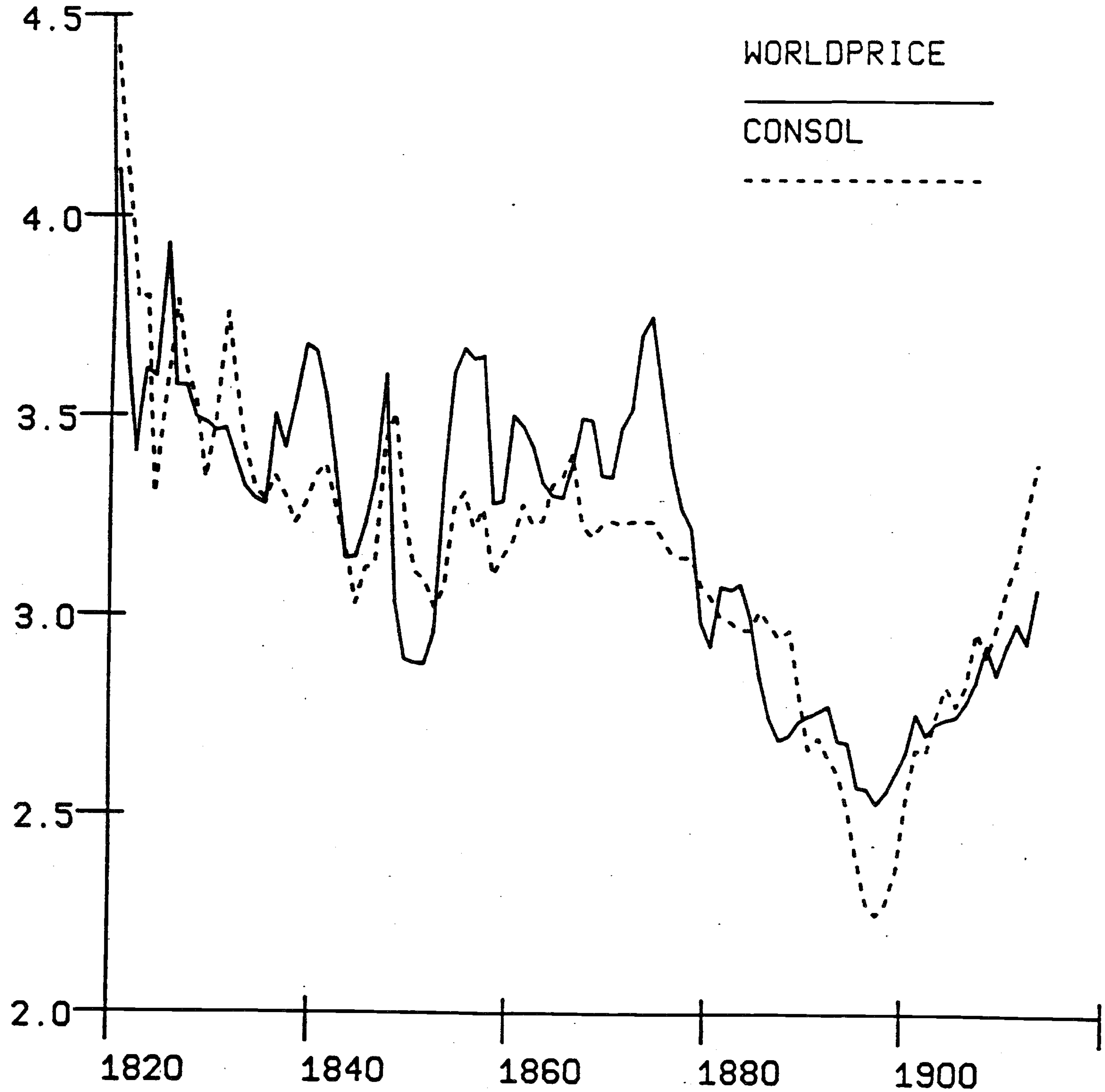
For our purposes, it is not necessary to pass judgment on whether the price levels of the various countries were held in line with one another only by laborious specie flows, as argued by Friedman and Schwartz (1963), or by "continuous arbitrage in goods" (McCloskey and Zecher, 1976). Most theories of the Gibson Paradox refer to the common movements in the various price series. We thus construct a "world price level" as a weighted average of the annual wholesale price series of the individual countries. The weights are from Bairoch (1982), which attempts to proxy total manufacturing output of a number of countries for the years 1860 and 1913. We exclude the U.S. data during the Civil War period. Although Bairoch's tables are an extremely rough guide to relative GNP's, none of our results are sensitive to the choice of weights. Probably because of the predominant role of traded goods in the wholesale price indices, the correlation of our world price series with the British series is an extraordinary .96. In all of the statistical manipulations reported below, very similar results are obtained using either the world or the British price level.

The degree of capital mobility between countries continues to be a controversial issue, with regard to both historical and current data. Because taking a weighted average of interest rates across countries would be an exercise with no clear interpretation, we treat the British consol rate (from Homer, 1977) as a measure of the world long-term interest rate.[1] London was the undisputed center of the world capital market during the gold standard, and capital flows to and from London were prodigious (see the papers in Bordo and Schwartz, 1984).

<u>Was There A Gibson's Paradox</u>?

Data on world prices and interest rates are plotted in Figure 1. To the naked eye a clear positive relationship between interest rates and prices appears observable. Nonetheless, Benjamin and Kochin (1984) raise two questions about

Figure 1
The World Price Level and the Consol Yield



the existence and scope of Gibson's Paradox. First, they note that both prices and interest rates were close to random walks, and thus the risk of spurious correlation is high. Second, they allege that to the extent Gibson's Paradox is present at all, it is primarily a wartime phenomenon. We consider these issues in turn.

The spurious regression argument, as developed by Granger and Newbold (1974) and Plosser and Schwert (1978), has two parts. Under certain circumstances, when two random walks are regressed, the regularity conditions for least squares may be violated. In this case, estimated coefficients and confidence intervals will be meaningless. Moreover, even when the coefficient estimates are meaningful, the associated standard errors are likely to be underestimated by a factor of five or more. These authors also demonstrate that standard serial correlation corrections are inadequate when error processes involve unit roots.

A standard diagnostic procedure recommended explicitly by Granger and Newbold (1977) is estimation in first differences. Gibson regressions estimated in this way are presented below. Estimation in first differences, however, presents its own statistical problems. Measurement error in the regressors is likely to lead to far more serious errors in differenced regressions than in level regressions. Anderson (1971) demonstrates that differencing accentuates high frequency variation in data at the expense of low frequency variation. Given the inevitable uncertainties surrounding the exact timing of the relationship, estimation techniques which focus on low frequency variations are to be preferred.

For these reasons, we also perform regressions relating the levels of prices and interest rates. The simulation studies of Granger and Newbold (1974,

1977) provide some rough guidance as to the correct critical levels for rejection of the null hypothesis that two random walks are independent. They suggest that, with fifty observations, an ordinary "t-statistic" greater than 10 or so (corresponding to an R^2 of about .7) would properly lead to a rejection at the 90 to 95 percent level. This suggests that the estimated standard errors should be inflated by fivefold or a little more.

Table 2 reports Gibson regressions for various subperiods of 1720 to 1938. Because of the difficulties inherent in finding consistent price series before and after WWI for several countries, the world price series was constructed only for the years 1821 to 1913. Regressions using British data are reported for periods outside of this band. The regressions in both levels and differences are shown.

The first period, 1729 to 1819, provides ambiguous evidence as to whether or not Gibson's Paradox holds in these years. In differences, the estimate is slightly negative. In levels, the regression is nearly significant at the five percent level. The closeness of the estimated coefficient to that for 1821 to 1913 may give one further pause in concluding that the regression is spurious.

The period 1821 to 1913, on the other hand, as well as its various subperiods, exhibits the Gibson correlation both in levels and in first difference form. This period is described by Bordo (1981) as the "classical gold standard". The beginning of the period marks the resumption of specie payments by Britain after the Napoleanic Wars, and the beginning of nearly a century of an essentially uninterrupted gold standard. The end of the period is, of course, the last year before World War I, which was accompanied by indefinite suspension of specie payments by most countries. In the regression

Table 2: Regression of Logarithm of Price Level on Consol Rate (Levels and First Differences)

Sample Period	Price Series	Levels or First Differences	Coefficient of Consol Yield	D-W Stat.	$\bar{R}^2$
1730-1819	British	Levels	.36 (.04)	0.36	.49
		1st Differences	-.03 (.02)	1.77	.02
1821-1913	World	Levels	.40 (.03)	0.47	.71
		1st Differences	.15 (.04)	1.73	.11
	British	Levels	.38 (.03)	0.44	.65
		1st Differences	.16 (.05)	1.71	.10
1821-1871	World	Levels	.17 (.05)	0.61	.18
		1st Differences	.14 (.06)	1.72	.10
	British	Levels	.16 (.06)	0.52	.11
		1st Differences	.14 (.06)	1.77	.08
1872-1913	World	Levels	.43 (.04)	0.32	.71
		1st Differences	.21 (.08)	1.79	.11
	British	Levels	.41 (.05)	0.28	.67
		1st Differences	.24 (.09)	1.50	.14
1872-1938*	British	Levels	.36 (.02)	.40	.78
		1st Differences	.24 (.05)	1.57	.24
1914-1919*	British	Levels	.74 (.10	1.60	.91
		1st Differences	.34 (.17)	1.77	.37
1920-1938*	British	Levels	.31 (.06)	0.62	.58
		1st Differences	.16 (.09)	1.97	.09

*The world price series covers only 1821 to 1913. See p.8 in text.

in levels, the ordinary t-statistic is in excess of 10 with an R^2 of .71, thus exceeding the five percent critical level implied by the Granger and Newbold (1974, 1977) simulation studies. In differenced form, the t-statistic of 3.5 is significant at the one percent level. Thus Gibson's Paradox characterizes the classical gold standard. Note, in particular, the stability of the regression in differences over the various subsamples.

On any criterion, there is a marked positive correlation between prices and the interest rate during World War I. This is exactly what one would expect from a dramatic increase in government purchases accompanied by a large expansion of the (fiat) money stock. What is striking is not the rather easily explicable wartime correlation but the highly persistent, stable, and far more puzzling relationship during the peacetime gold standard years. It was clearly the latter that captured the attention of Keynes (1930), who emphasized the long period over which Gibson's Paradox apparently held. Friedman and Schwartz (1982), too, regard Gibson's Paradox as almost entirely a gold standard phenomenon:

> For the period our data cover [1880 to 1976], it [Gibson's Paradox] holds clearly and unambiguously for the United States and the United Kingdom only for the period from 1880 to 1914, and less clearly for the interwar period [p. 586].

The final entry in Table 2 covers the interwar period 1920 to 1938. Most of this period was characterized by a return to gold, and these regressions are consistent with those from the prewar gold standard period.

Is There Still a Gibson Paradox?

An important question, and a frequent source of confusion, is whether or not Gibson's Paradox persists into the post-World War II period. Some authors have concluded that it does, on the basis of raw correlations alone. This is inappropriate for a period during which the price level rose in every year. To establish an economically meaningful Gibson Paradox, one would need to show that when the rate of inflation slowed (remaining positive, however), the interest rate continued to rise with the price level. That this was not the case is clearly seen in Figure 2.[2] As becomes especially clear after 1965, the interest rate follows the rate of inflation rather than the price level.

<u>Gibson's Paradox and Real Rates</u>

In explaining Gibson's paradox it is critical to determine whether it applies to nominal or to real rates of return. Below we present indirect evidence that the paradox applies to real rates of return by arguing that nominal interest rates during the gold standard period did not incorporate inflation premia. Here we present more direct evidence by looking at equity yields. We examine both earnings/price and dividend/price ratios. The former reflect total returns to shareholders. The latter have the virtue that they are less likely to be distorted by transitory developments.

We rely on the composite dividend and earnings yields given in Cowles (1939). These data are available only after 1871. Table 3 reports regressions involving the yields, in level and first differences, comparable to the regressions in Table 2. The coefficients of the regressions in levels are always positive, with conventional "t-statistics" typically between 5 and 15. The dividend yield regressions for 1872 to 1913, in particular, yield large conventional t-statistics. The estimated coefficients do tend to be smaller than those from regressions using the bond yield. The first difference regression

Figure 2

Gibson's Paradox vs. the Fisher Effect: 1953 to 1984

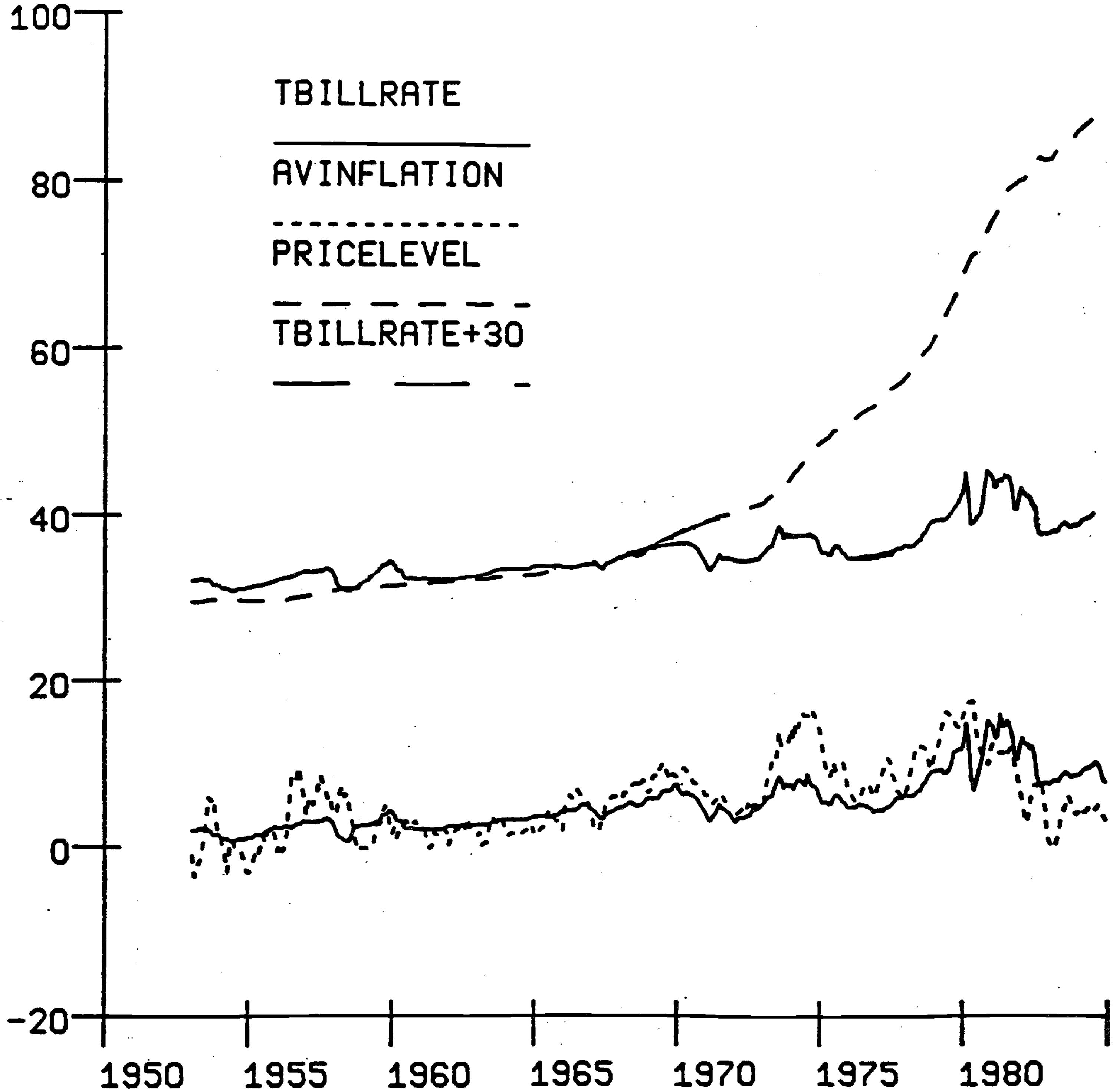


Table 3: Regression of Logarithm of Price Level on Cowles Commision Stock Yields

Sample Period	Price Series	Yield	Levels/First Difference	Coefficient of Stock Yield	D-W Stat.	$\bar{R}^2$
1872-1913	World	DPR	Levels	.14 (.01)	1.17	.74
			1st Differences	.03 (.01)	1.84	.12
	British		Levels	.13 (.02)	0.70	.61
			1st Differences	.03 (.01)	1.43	.11
	U.S.		Levels	.12 (.02)	0.82	.44
			1st Differences	-.02 (.02)	1.61	.01
	World	EPR	Levels	.07 (.01)	0.61	.38
			1st Differences	-.01 (.01)	1.26	.01
	British		Levels	.08 (.01)	0.59	.52
			1st Differences	.02 (.01)	1.34	.09
	U.S.		Levels	.08 (.01)	0.79	.45
			1st Differences	.00 (.01)	2.14	-.02
1872-1938*	British	DPR	Levels	.19 (.03)	0.44	.38
			1st Differences	.03 (.02)	1.38	.02
	U.S.		Levels	.15 (.04)	0.17	.15
			1st Differences	-.01 (.01)	1.31	-.01
	British	EPR	Levels	.06 (.01)	0.20	.28
			1st Differences	.02 (.01)	1.24	.16
	U.S.		Levels	.04 (.02)	0.05	.05
			1st Differences	.01 (.01)	1.40	.08

Table 3. Continued

1921-1938*	British	DPR	Levels	.11 (.05)	0.44	.15
			1st Differences	-.01 (.03)	0.75	.00
	U.S.		Levels	.03 (.03)	0.27	-.00
			1st Differences	-.03 (.01)	0.94	.17
	British	EPR	Levels	.05 (.01)	0.73	.44
			1st Differences	.02 (.01)	0.85	.16
	U.S.		Levels	.03 (.01)	0.58	.47
			1st Differences	.01 (.00)	0.87	.42

*The world price series covers only 1821 to 1913. See p.8 in text.

coefficients are significantly positive in half of the cases, insignificant in the remainder. Overall, the regressions support the view that Gibson's Paradox involved the real rate.

An alternative to using dividend or earnings yields as a measure of the required real return on equity is to construct an "internal rate of return" variable using forecasts of future dividends. To implement this approach, we first estimated rolling bivariate autoregressions for real dividends and real stock prices (using the composite data from Cowles, 1939), and used these to generate k-step-ahead forecasts of aggregate real dividend payments. For each year, we then solved iteratively for the value R^* that would discount the predicted future dividends to the current stock price. The resulting discount rate series can be interpreted as a dividend/price ratio adjusted for cyclical fluctuations and trend growth in dividends. Regressions of the commodity price indices on this variable yielded almost identical results to those using the dividend/price ratio.

We conclude this section with a summary of the empirical findings about Gibson's Paradox that theory should seek to explain.

1. There is a Gibson's Paradox which is more than spurious correlation between two random walks.

2. Far from being primarily a wartime phenomenon, Gibson's Paradox characterizes the gold standard years 1821 to 1913, which were free from major conflicts, and is quite stable during this period. The gold standard represents the only long period over which the Gibson correlation holds continuously.

3. Gibson's Paradox had clearly vanished by the 1970's. It apparently held more weakly before the advent of the classical gold standard in 1821 than after it.

4. The paradox appears to involve the real rate. As we argue in Section II below, most of the variation in nominal yields should probably be attributed to real rate variation. Regressions using the Cowles stock yield data suggest that the price level was correlated with the expected return on capital.

II. Existing Resolutions of the Gibson Paradox

As noted by Keynes (1930), the simplest explanation of the Gibson correlation, while logically consistent, can be rather easily disposed of empirically. Consider the full employment IS-LM model (see, e.g. Mundell, 1971). If a shifting IS locus is coupled with a relatively stable LM curve, a positive correlation between prices and interest rates will be observed. The problem with this solution to the Gibson riddle is that it implies that important long-run price changes were due to interest-induced movements in velocity. Keynes (1930) found variation in velocity insufficient to account for more than a fraction of the low-frequency price changes that are the subject of Gibson's Paradox. More detailed quantitative analysis (see, e.g. Cagan, 1965; Schwartz, 1973; Siegel and Shiller, 1977) supports this view, finding instead that long-run price variation was closely associated with changes in the money stock, and hence LM shifts.

The Fisher Explanation

The best-known explanation of Gibson's Paradox is that of Fisher (1930). Suppose that expected inflation is formed as a long distributed lag on past inflation. If the weights decline sufficiently slowly, expected inflation will resemble the price level more closely than it resembles the contemporaneous rate of inflation. Thus a positive correlation between nominal interest rates and the price level could arise from the theoretical Fisher relation in combination with a particular process for inflationary expectations. Movements in the real rate of interest play no role in Fisher's resolution.

Sargent (1973) challenged the Fisher explanation on the grounds that it appears inconsistent with rationality, given the process actually followed by inflation. If Fisher is correct (under the assumption that the real rate was nearly constant), the regression of the nominal interest rate on past inflation ought to resemble the regression of inflation on its own past. However, inflation was largely serially uncorrelated during the Gibson Paradox period, leading Sargent to reject this cross-equation restriction. During the gold standard years, a forecast of zero inflation each year would have been superior to Fisher's scheme in terms of ex post rationality (Siegel and Shiller, 1977; see also Barsky, 1984).

Table 4 presents estimates of the autocorrelations of inflation for various periods. While there is some weak evidence of negative serial correlation, the inflation rate appears to be close to white noise, implying that the price level was close to a random walk. Note that in the presence of negative serial correlation in inflation one would expect, if anything, a negative correlation between prices and interest rates on the basis of Fisher's logic. Given the unpredictability of inflation, it seems unlikely that fluctuations in interest rates reflected variation in inflationary expectations to an appreciable extent.[3] Shiller and Siegel (1977) appear to be correct in claiming

Table 4: Estimated Autocorrelation Function of First-Differenced Log Price Level (annual data)

Sample Period	Price Series	Asymptotic Std. Error	Lags	Sample Autocorrelations					
1821-1913	World	.10	1-6	.17	-.01	-.16	-.27	-.17	.05
			7-12	.23	.10	.03	.03	-.02	-.23
	British		1-6	.15	-.12	-.12	-.21	-.18	.07
			7-12	.22	.09	.09	.03	-.02	-.18
1821-1869	World	.14	1-6	.14	-.08	-.23	-.29	-.20	.10
			7-12	.21	.09	-.05	-.07	-.05	-.26
	British		1-6	.10	-.14	-.13	-.25	-.24	.10
			7-12	.19	.07	.02	-.02	-.07	-.28
1870-1913	World	.15	1-6	.24	.18	.03	-.23	-.12	-.16
			7-12	.24	.16	.27	.28	.01	-.08
	British		1-6	.26	-.08	-.08	-.10	-.05	-.01
			7-12	.31	.13	.20	.18	.10	-.05
	U.S.		1-6	-.07	.01	.11	-.11	-.03	-.06
			7-12	.21	.10	.09	.15	.10	-.13

that variation in nominal rates during this period should be regarded as variation in real rates. This judgment is further supported by Barsky's (forthcoming) finding that dividend yields and earnings yields moved essentially one for one with Macaulay's adjusted nominal yield on U.S. long term bonds during the pre-1930 period.

A second implication of Fisher's resolution is that the Gibson correlation ought only to characterize nominal interest rates, not the real return to capital or the yields on common stocks. This proposition was tested and rejected in the previous section, where we found that proxies for the real return to capital displayed a relationship to prices similar to the relationship between prices and nominal yields. This corroborates the findings of Sargent (1973), who applied a somewhat different test to these data and reached a parallel conclusion.

The Keynes-Wicksell Explanation

The major class of alternatives to Fisher's explanation is associated with the names of Wicksell (1936) and Keynes (1930). Both saw exogenous innovations in the productivity of capital as the underlying forcing variable. Wicksell (1936) argued that an increase in the "natural rate" of interest would be accompanied both by an increase in bank lending and a gradual rise in the nominal yield on financial instruments. As the stock of (inside) money expanded, prices would rise, and this would probably occur while the "market" interest rate was still rising to the equilibrium "natural rate". The Wicksellian theory is rather flatly refuted by the evidence in Cagan (1965) that changes in high-powered money, not bank loans, were responsible for the long-run price movements that are relevant in discussions of the Gibson phenomenon (see also Shiller and Siegel, 1977).

Keynes (1930) argued that central banks acted to finance expansions in real activity and that this could explain the movements in high-powered money not accounted for in the theory of Wicksell. Building on the Keynesian analysis, Shiller and Siegel (1977) argue that wars, in particular, were financed by a combination of high-powered money and interest-bearing debt, raising both the price level and interest rates.[4] Although possibly an accurate picture of World War I experience, this argument has less appeal for the years of the classical gold standard (1821 to 1913, say, for the U.K., 1879 to 1913 for the U.S.), the key Gibson Paradox period. Cagan (1965), addressing the arguments of both Keynes (1930) and Wicksell (1936) in an exhaustive study of the determinants of the U.S. money stock, reports:

> Neither changes in banks' reserve ratios nor in the ratio of the domestic gold stock to high-powered money account for any sizable part of the long-run movements in the U.S. money stock before 1914 [p. 254].
>
> Neither (Wicksell nor Keynes) realized how fully the cumulative effect of changes in the U.S. gold stock[5] accounted for the variations in growth of the money stock of the United States (and probably of all gold-standard countries) up to World War I...[p. 255].

Cagan's results imply that any theory of the relationship between prices and interest under the gold standard ought to work through the monetary gold stock. Below we present a model which follows Keynes and Wicksell in regarding shocks to the productivity of capital as the driving force behind Gibson's Paradox, but which allows them to work through the monetary gold stock.

Other Explanations

The remaining explanations of Gibson's Paradox involve the redistributional effects of major, unanticipated price changes (Macaulay, 1938; Siegel, 1975; Shiller and Siegel, 1977). The best-developed argument based on distribution effects (Siegel, 1975; Shiller and Siegel, 1977) distinguishes between agents desiring net short positions in nominal debt and those choosing net long positions. An unanticipated rise in the price level redistributes wealth toward borrowers, raising the desired supply of debt, while reducing the willingness of the creditor group to hold debt. The resulting excess supply of nominal bonds means that the interest rate must rise to restore capital market equilibrium.

There are a number of problems with the Shiller-Siegel approach. First, as noted by Shiller and Siegel (1977) and Friedman and Schwartz (1982, p. 567-8), the ability of this reasoning to account for the correlations in the data is highly sensitive to assumptions about the timing of the effects. This is especially serious given the low frequency nature of the Gibson phenomenon. Second, Shiller and Siegel do not suggest that the wealth effects of unanticipated price changes can account for increases in equity yields. Third, no direct or indirect empirical support has been adduced for this explanation. Contemporary evidence certainly does not support Shiller and Siegel's prediction that unanticipated inflation should raise real interest rates.

Our survey of alternative explanations for Gibson's Paradox finds none of them entirely satisfactory. In addition to the limitations noted already, none can explain why only the gold standard years show clear evidence of the Gibson correlation. We address this question in the next section. Our proposed resolution of the Gibson Paradox relies on the workings of the gold standard.

It also permits us to resolve the anomalies raised by the Fisher and Keynes-Wicksell explanations.

III. A Theory of the Real Price of Gold and the World Price Level

This section develops a simple perfect foresight model of the determination of the real price of gold, and hence the general price level, under a gold standard. We then discuss the time series properties of the model under various disturbances to the real rate of return. Formally, the model describes a closed, full employment economy, which is best thought of as the world economy under fixed exchange rates and fully flexible prices. The model is very close to that of Barro (1979), except that it replaces the partial adjustment, static expectations formulation of that paper with a perfect foresight, equilibrium treatment.

For our purposes, a gold standard is defined as the maintenance of full convertibility between gold and dollars at a fixed ratio. The gold backing of the money stock need not be one-for-one. Money consists of bank deposits and, for simplicity, there are no gold coins. The fixed nominal price of gold implies that determining the general price level is equivalent to determining the equilibrium relative price of gold. We set the nominal price of gold equal to unity for convenience. The real price of gold is then $P_g = 1/P$, where P is the general price level.

Gold is a highly durable asset, and thus, as stressed by Levhari and Pindyck (1981), the demand for the existing stock (as opposed to the new flow) must be modelled. The willingness to hold the stock of gold depends on the rate of return available on alternative assets. We assume that the alternative assets are physical capital with (instantaneous) real rate of return r, and nominal bonds with (instantaneous) nominal return $i = r + \dot{P}/P = r - \dot{P}_g/P_g$. The real rate of return is exogenous to the model, but subject to shocks. These shocks reflect changes in the actual or perceived productivity of capital as envisioned by Keynes and Wicksell.

The Model

The gold stock G is held in two forms: as bank reserves (denoted G_m), and as nonmonetary gold (denoted G_n). Nonmonetary gold (best thought of as jewelry, objects of art, etc.) is held partly for its service flow or "dividend", which is denoted $D(G_n)$, with $D' < 0$. Consumers equate the service flow $D(G_n)$ to the user cost $rP_g - \dot{P}_g$ (we assume no depreciation), so that at all times the real gold price must satisfy:

$$(1)\ \dot{P}_g = rP_g - D(G_n).$$

Because $\dot{P}_g = -(\dot{P}/P)P_g$, (1) can also be written as:

$$(1')\ D(G_n)/P_g = i,$$

where i is the nominal interest rate. Equation (1') makes clear that agents rent the services of nonmonetary gold at the nominal interest rate. However, since r is the exogenous forcing variable in this model, (1) is, for most purposes, the more useful formulation.

The monetary side consists of a conventional demand for real balances

$$(2)\ M/P = L(i) = L(r-\dot{P}_g/P_g),\quad L' < 0,$$

and a relation between monetary gold reseves and the money stock:

(3) $M = \mu G_m$.

where μ is a fixed parameter. Equating (2) and (3), and using $P = 1/P_g$ yields

(4) $G_m = L(r-\dot{P}_g/P_g)/\mu P_g$

Substituting (4) into (1) yields a locus in P_g,G space along which the real price of gold is constant:

(5) $\dot{P}_g = rP_g - D(G - L(r-\dot{P}_g/P_g)/\mu P_g) = 0.$

It is trivial to verify that the $\dot{P}_g = 0$ locus is downward-sloping.

To close the model, it is necessary to specify the evolution of the total gold stock. We assume that the rate at which gold is mined is an increasing function of its real price and a decreasing function of the quantity of gold that has already been mined, reflecting the depletion of easily mined ores. That is:

(6) $\dot{G} = \gamma(P_g,G),\ \gamma_1 > 0,\ \gamma_2 < 0$

Equation (6) implies that the $\dot{G} = 0$ locus is upward sloping in P_g,G space.

Figure 3 shows the steady state where $\dot{P}_g = \dot{G} = 0$, and the dynamic behavior of the model out of steady state. The system is saddle-point stable.

The Effects of an Increase in the Real Interest Rate

Now consider the response to an exogenous increase in the real rate of return r. The general effect is, of course, a reduced willingness to hold both monetary and non-monetary gold, which appears as a downward shift of the $\dot{P}g = 0$ locus. Figure 4 analyzes the case where the rise in r is unanticipated, but understood to be permanent once it occurs.[6] There is an immediate drop in the

Figure 3
Steady State and Dynamics of the Gold Model

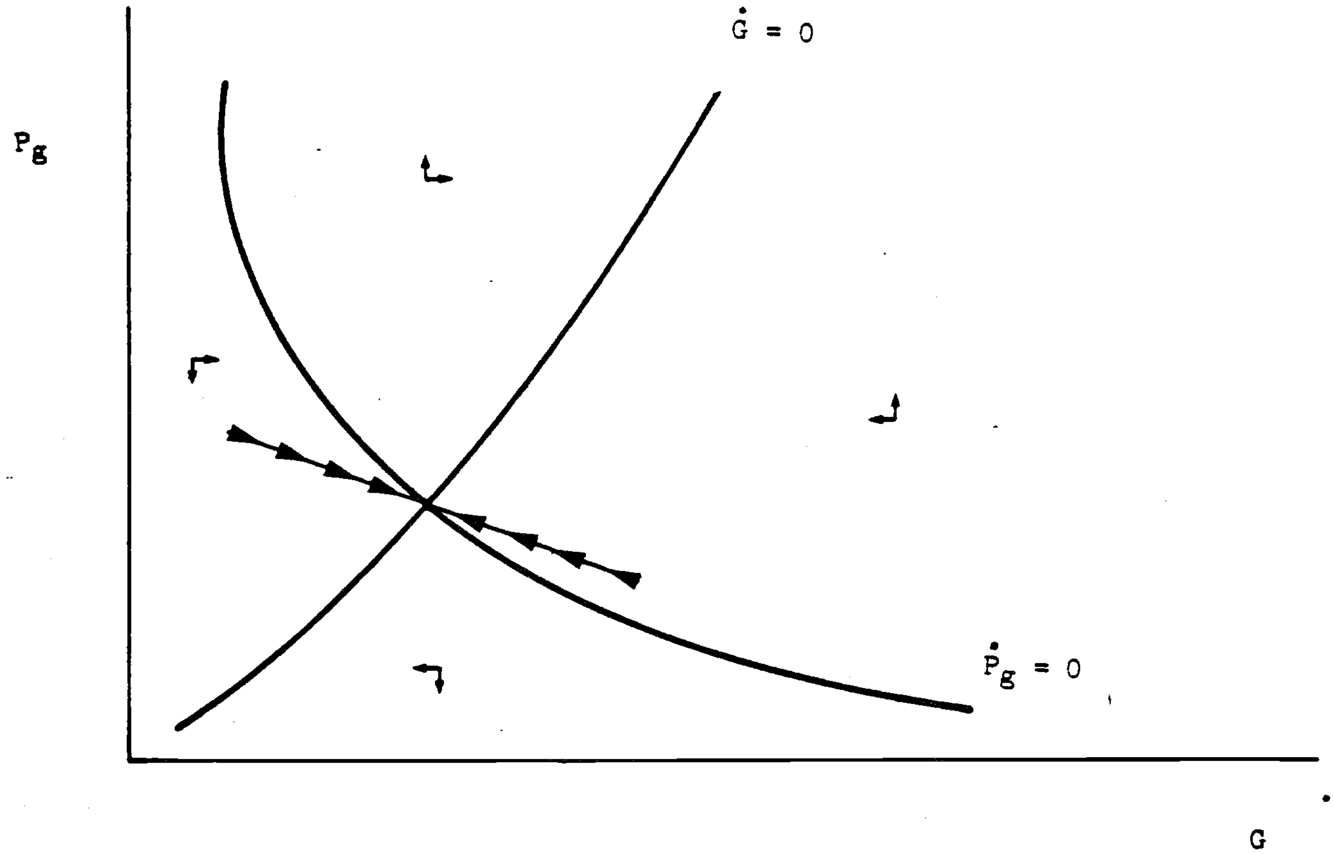


Figure 4
Unanticipated, Permanent Increase in the Real Rate

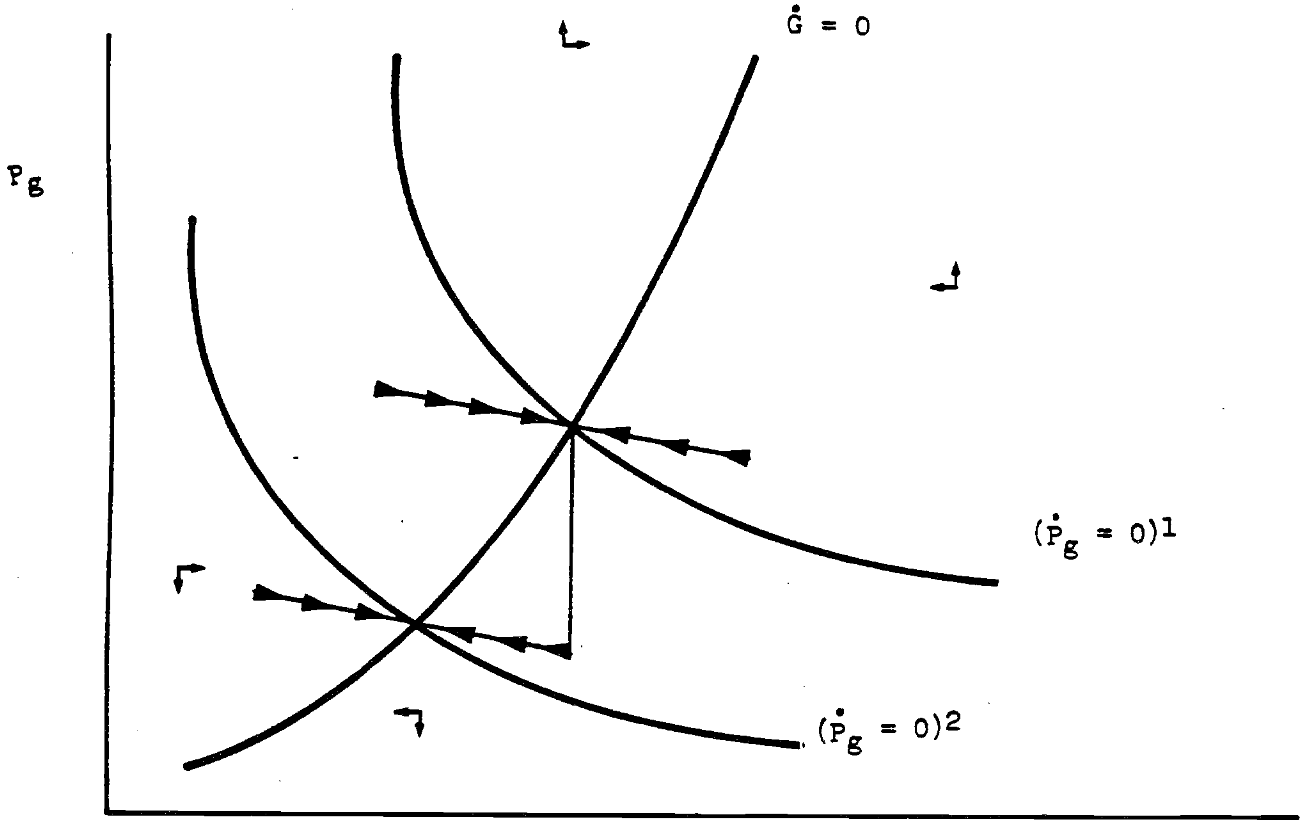
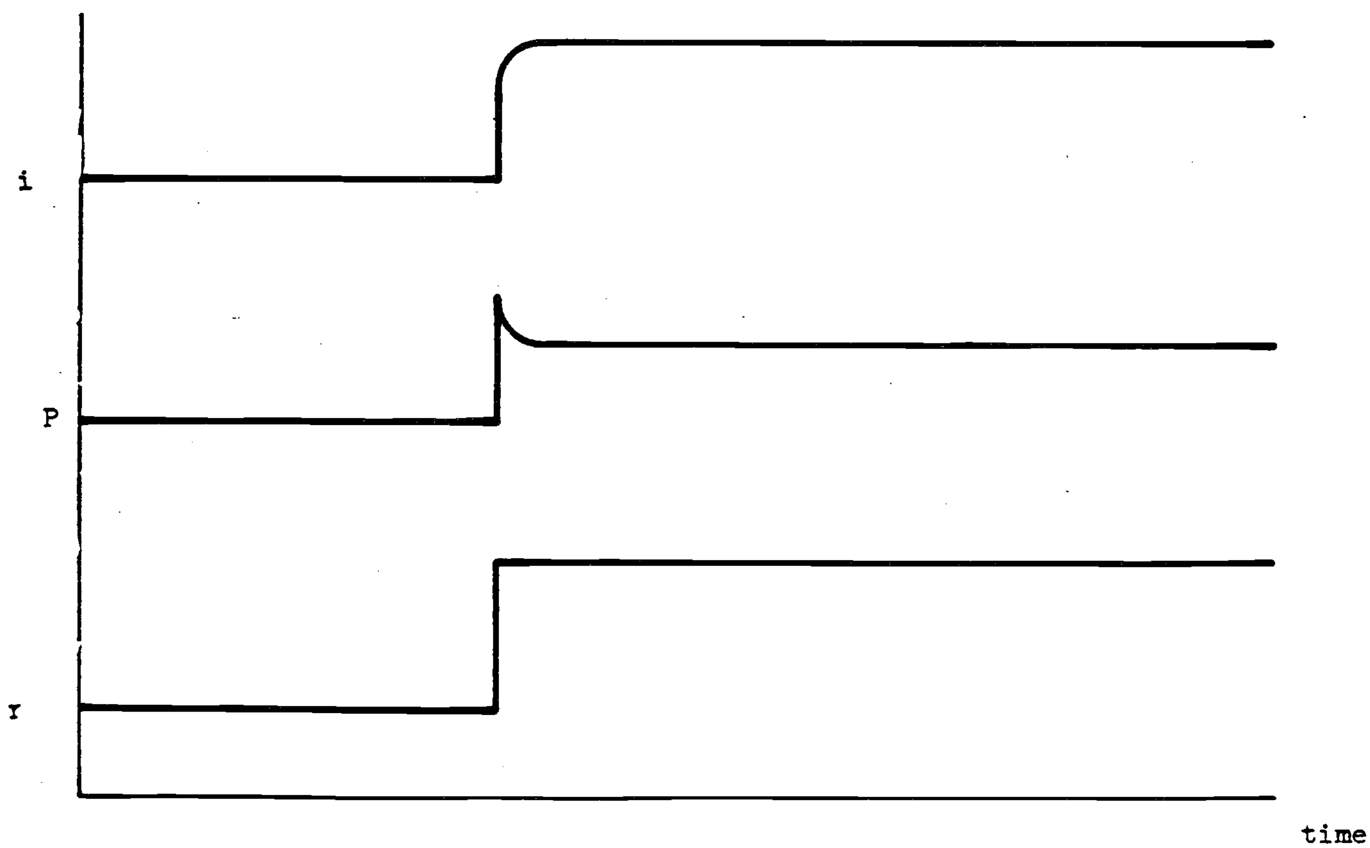


Figure 4-b
Time Paths of the Variables



real price of gold (i.e. a rise in the price level), due both to an increase in monetary velocity and to the monetization of some non-monetary gold holdings. Since the new steady state will have a lower total gold stock, the initial jump in the price level actually overshoots the steady state. The real price of gold exhibits serially correlated increases as the gold stock gradually falls to its new equilibrium level. Of course, the price level returns only part way back to its level before the shock. If the $\dot{G} = 0$ locus is nearly vertical,[7] the partial retreat of the price level will be strongly overshadowed by its initial jump.

Figure 4-b depicts the time paths of the general price level ($P = 1/P_g$), the (exogenous) real interest rate, and the (endogenous) nominal interest rate. Although the positive jump in r is accompanied by the onset of expected deflation, analysis of equation (1') in conjunction with (4) shows that there must be a positive jump in i as well. For suppose the nominal rate did not rise. Since Pg has fallen, $D(G_n)$ must fall (by at least as much, proportionately). With G fixed at a point in time, a fall in $D(G_n)$ requires a reduction in G_m. But with lower i and higher P, monetary equilibrium requires an increase in G_m. Thus the nominal interest rate and the price level jump together. Clearly they are positively correlated across steady states. During the transition, however, while the system is moving along the new saddle path, the two variables do not move together.

Now consider a transitory shock to the real rate, an unanticipated rise in r which is to persist for some known duration and to be followed by a return to the previously prevailing rate (see Figure 5). The initial price jump is followed by a movement alongside the stable arm associated with the higher r.

Figure 5

Unanticipated, Transitory Increase in the Real Rate

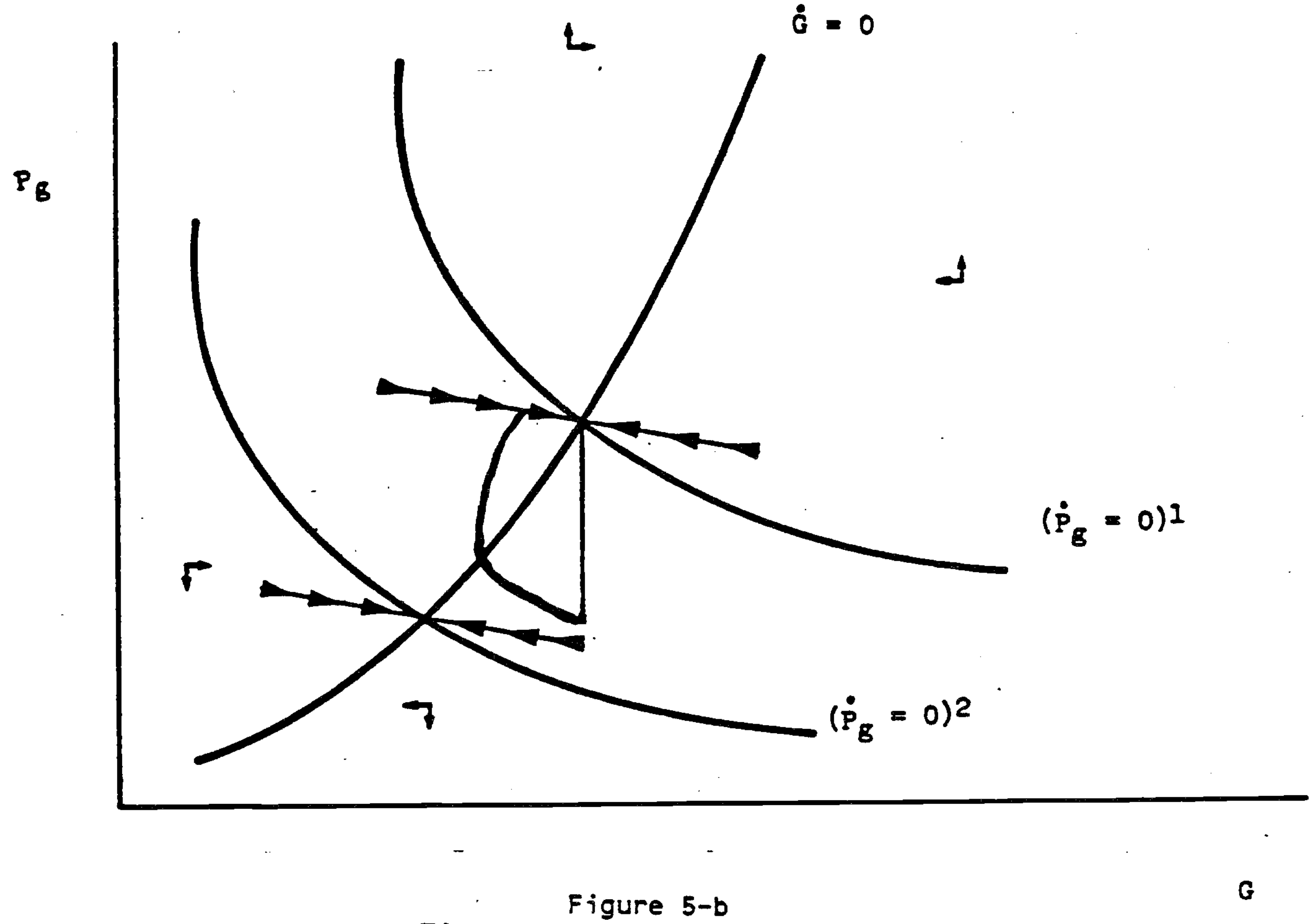
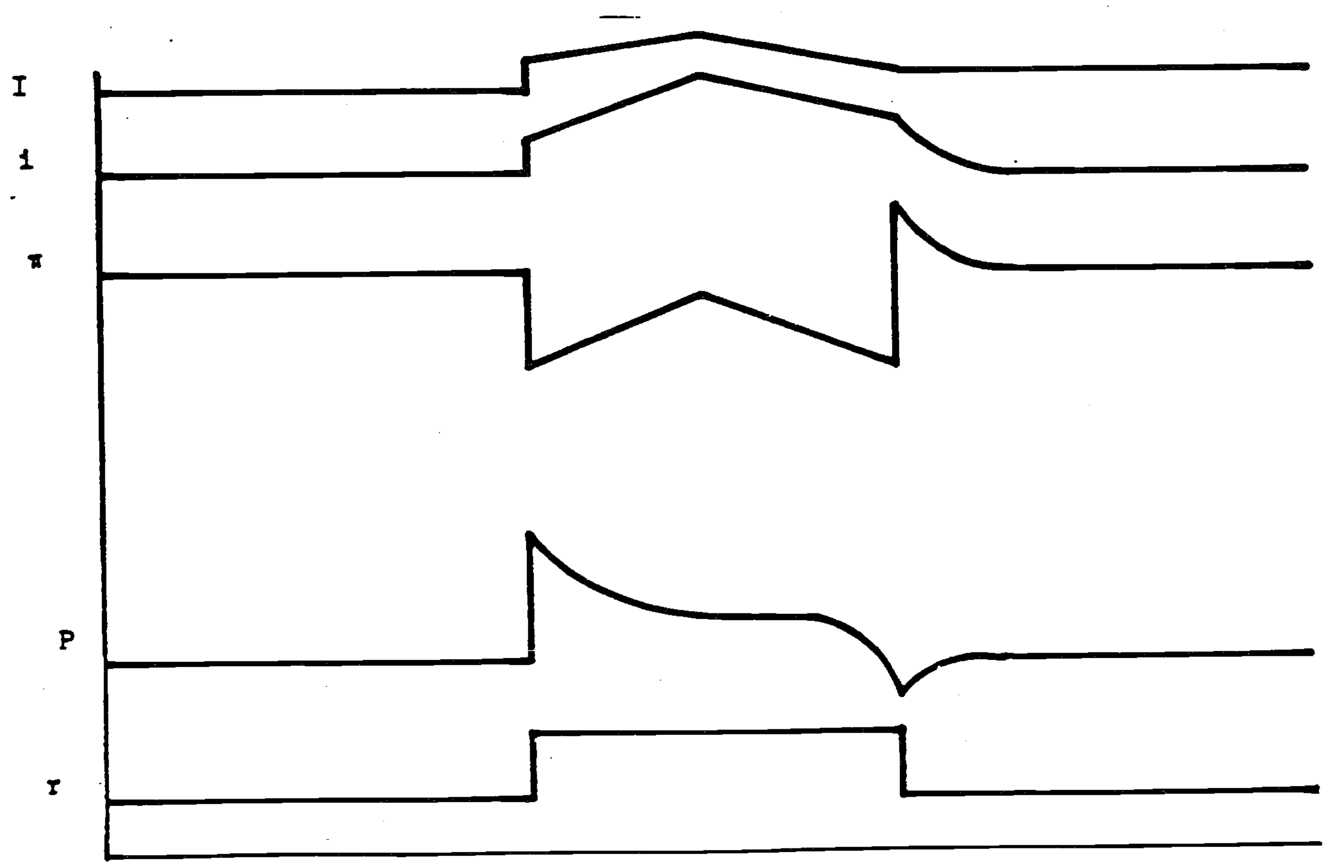


Figure 5-b

Time paths of the Variables



This is a period of declining gold stocks and resultant deflation. While the real rate is still transitorily high, the system enters an explosive phase with further deflation (increases in the real gold price), but now a rising stock of gold. This replenishing of the gold supply is in preparation for the return to a lower real interest rate. When the lower rate is restored, the system arrives on the stable arm associated with the original $\dot{P}_g = 0$ locus. Because the gold stock is still below its steady state, the "dividend yield" exceeds r along the saddle path. The inflation that takes place along this path provides the necessary real capital loss on gold to bring its user cost up to its marginal service yield.

Figure 5-b shows the time paths of the variables, as for the previous case, but with the addition of the long-term rate I. The nominal rate and the price level do jump together (for the same reason given above), but otherwise this case does not yield a Gibson Paradox. Two of the three segments of the adjustment paths involve a negative correlation between i and P, a characteristic (as we have seen) of the saddle paths. The long-term rate actually does not display much variation at all, because of the transitory nature of the short rate movements.

The analysis of this section suggest that, under a gold standard also characterized by shocks to the real interest rate, the interest rate and the price level should exhibit strong positive correlation across steady states. It also suggests that, outside of the steady state, the two variables will move together often, but by no means always. Thus Gibson's Paradox should be more striking as a long-run phenomenon than as one apparent at the high frequencies.

Note that there is little tendency for a Fisher effect to appear in the model when the underlying shocks are disturbances to the real rate. While i sometimes moves in the same direction as expected inflation, most of the movements in the nominal rate are indicative of real rate variation. Because the price level does display some serially correlated movements during adjustment processes, expected inflation is not always zero, and the price level is not literally a random walk. However, the price level will be close to a random walk if most shocks to the required rate of return are unanticipated and permanent, and if the $\dot{G} = 0$ locus is nearly vertical.

Of course, by no means all conceivable shocks involve the real interest rate, and we do not argue that other disturbances were not also important determinants of the price level during the gold standard period. A "gold discovery" appears in the model as an outward shift of the $\gamma(P_g, G)$ function. This shifts the $\dot{G} = 0$ locus to the right, raising the steady state price level and gold stock, and leaving the interest rate in long-run equilibrium unchanged. During the transition period, the model exhibits a Fisher effect. Since an initial jump in the price level (the "announcement" effect of a gold discovery) is followed by further, anticipated inflation, a positive correlation between the nominal interest rate and prices does result. The correlation works entirely through the Fisher relation, and thus cannot be the principal explanation of Gibson's Paradox. This mechanism does, however, reinforce the tendency towards positive correlation between prices and interest rates.

Note that there is, by definition, no such thing as steady state inflation in this model of a gold standard. Unlike fiat money, which can be printed without limit by the authorities, the monetary gold stock tends toward constancy over time, and this alone makes inflations self-limiting. Since we rule out the possibility that the system remains forever on an explosive path, the real price of gold tends toward its equilibrium value based on fundamentals. The absence of ongoing, steady state inflation should, however, in no way be confused with price stability. The long asset duration of gold, which makes its equilibrium value sensitive to the real interest rate, combined with unanticipated gold discoveries, may make the price level particulary volatile under this regime.

Our model provides an explanation for the Gibson's Paradox observation and for its coincidence with the gold standard period. It also accounts for the anomalies that have been raised in discussions of alternative resolutions of Gibson's Paradox. Our model relies on real shocks as a driving force and thus unlike the Fisher explanation, it is consistent with the finding that Gibson's correlation is observed using proxies for real rates of return. Our resolution also addresses the principal weakness of the Keynes-Wicksell explanations of the Gibson Paradox -- the apparent close linkage between the price level and the stock of monetary gold. In our formulation, the productivity of capital, through its effect on the cost of holding non-monetary gold, is a key determinant of the monetary gold stock.

In the next section we use recent data to document that the real interest rate is in fact a dominant determinant of the real price of gold. Then we turn to a direct examination of substitution between monetary and non-monetary uses of gold.

IV. Real Interest Rates and the Relative Price of Gold, 1973 to 1984

The theory of the price level under a gold standard in Section III is essentially a general theory of the relative price of gold. Omitting the monetary demand for gold, we see that the theory continues to go through in the same fashion. Thus an important test of the model is to see how well it accounts for movements in the relative price of gold (and other metals) outside the context of a gold standard. The properties of the inverse relative prices of metals today ought to be similar to the properties of the general price level during the gold standard years.

We focus on the period from 1973 to the present, after the gold market was sufficiently free from government pegging operations and from limitations on private trading for there to be a genuine "market" price of gold. Note first that the real gold price from this period is very nearly a random walk.[8] In this section we show that the real gold price, as well as the relative price of an index of nonferrous metals, displays marked negative correlation with the real interest rate. The results for nonferrous metals insure that our findings do not reflect the "safe haven" quality often attributed to gold.

In order to study long-term real rates in recent years, we require forecasts of inflation over a horizon appropriate to a long-term bond. Fortunately, Box-Jenkins analysis suggests that the inflation rate in the 1970's is well modelled as an IMA(1,1) process. This stochastic process, resulting from a mixture of permanent and transitory shocks (Muth, 1960), yields the same k-step ahead forecast for all horizons $k \geq 1$ (see Sargent, 1979, p. 265). Thus the one-step-ahead forecast of inflation from an IMA(1,1) model has an interpretation as "permanent expected inflation". The forecasts are based on a "rolling ARIMA" procedure, so that only information available as of the forecast date is used. For each forecast date, the information set is taken to be inflation for the past ten years, so that 40 quarterly observations are used in each estimation. To form an expected real interest rate variable, the inflation forecast is subtracted from the nominal yield on government securities at constant maturity of 20 years.

Figure 6 displays the (log) inverse real gold price and our estimate of the expected pre-tax real interest rate. The strong co-movement over the longer cycles is reminiscent of Gibson's Paradox. Variation in the real interest rate appears to be responsible for much of the year-to-year movement in the relative price of gold. After 1980, inflation exhibits increased volatility, and the ARIMA forecast is less satisfactory. Some of the variation in our proxy for the expected real yield on bonds ought to be regarded as spurious. Also, it is clear that from 1980 onward, the relative price of gold is higher for any given real interest rate than it was during the 1970's. This is as it should be. Real interest rates are not the only determinant of the relative price of gold. Yet the impression that real rates have been high since 1981, and that these high rates have been associated with a low relative price of gold vis a vis the 1980 level is unmistakable.[9]

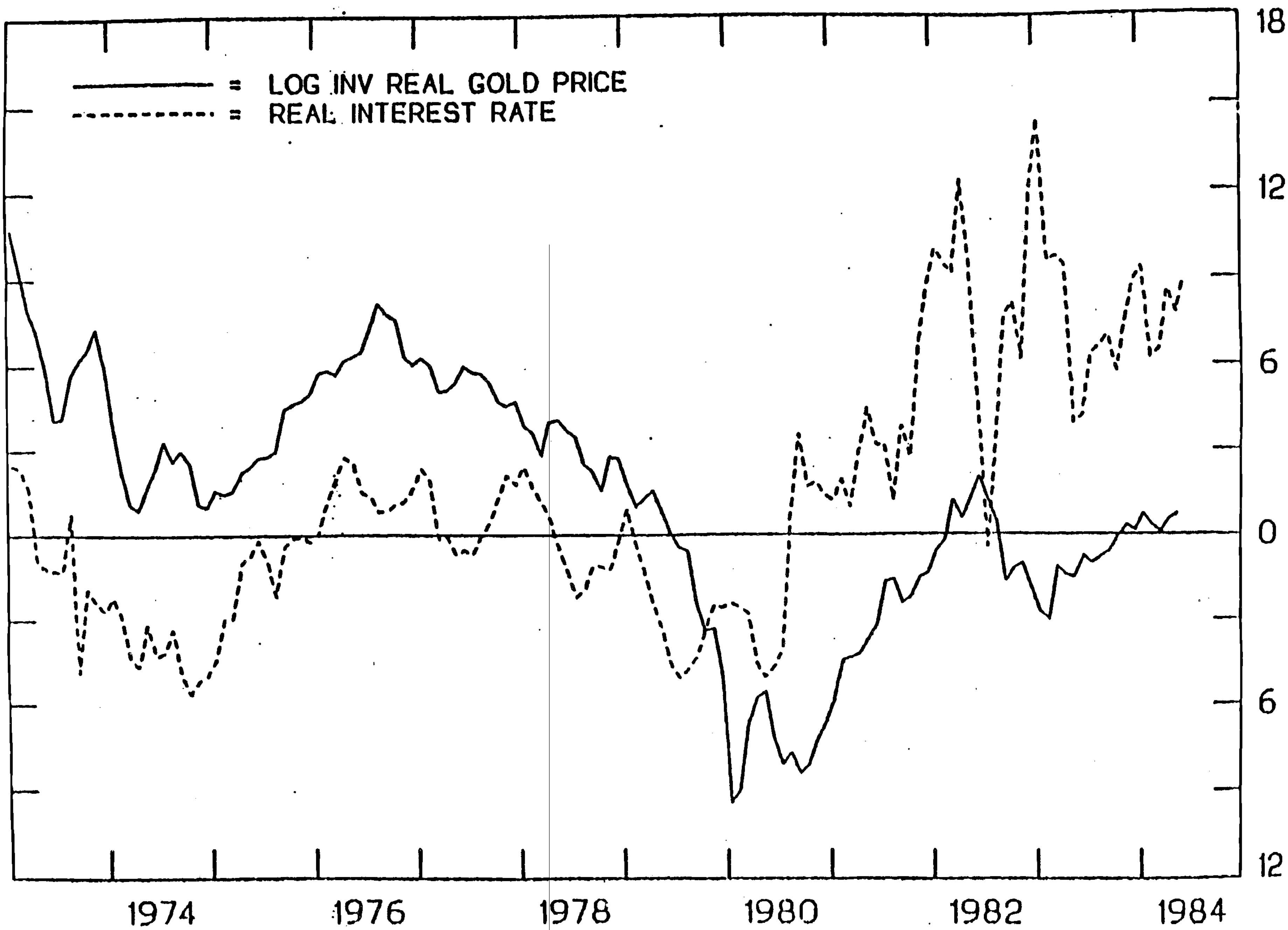
A regression of the log real gold price on our long-term real interest rate, allowing a separate constant term for the post-1980 period, yields:

$$\log(\text{GoldPrice}/\text{CPI}) = \underset{(.03)}{4.54} + \underset{(.06)}{.84}\ \text{Post1980} - \underset{(.01)}{.06}\ \text{RealR}, \qquad R^2 = .81 \quad \text{D.W.} = 1.13.$$

The data strongly reject constancy of the intercept term before and after 1980. The slope estimate, however, is quite stable across subperiods. Using an after-tax real interest rate strengthens our results, for the reasons discussed by Feldstein (1980).

To ensure that we are capturing the general tendency of increases in real

Figure 6
The (Pre-tax) Real Interest Rate and the Inverse Relative Price of Gold



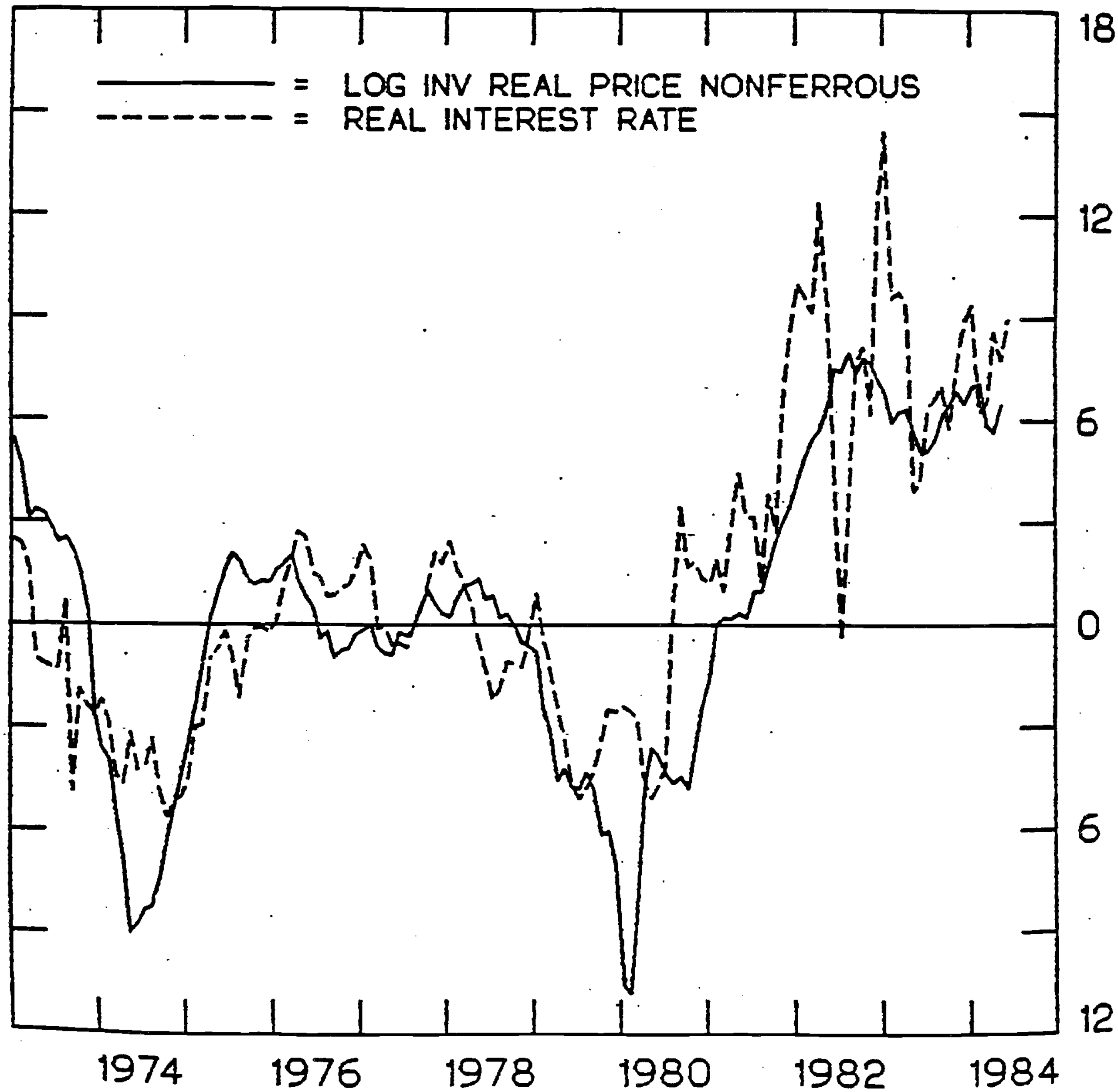
interest rates to depress the prices of durable assets, and not some peculiarity of the gold market, we also examine the behavior of other metals prices. Figure 7 shows our long-term real interest rate variable with the level of the PPI index of nonferrous metals prices relative to the CPI. The results are, if anything, even more striking than those for gold, providing further support for the asset pricing approach to metals prices.

V. Monetary and Nonmonetary Gold Stocks

The essence of the model in Section III is a negative equilibrium relationship between the real price of gold (inverse general price level) and the real interest rate when the underlying forcing variable is the real rate. How is this relationship consistent with the quantity theory, which ascribes price movements to changes in the quantity of money, and which we take to be the proper description of longer-run price changes? The answer must be that interest-induced variation in the demand for gold as a durable good (i.e. nonmonetary gold) is an important source of variation in the monetary gold stock. Coin can be melted for conversion into art objects, and non-monetary stocks can be coined or brought to the bank in exchange for deposits. Over time, there is choice as to the allocation of newly mined gold between monetary and non-monetary use.

The canonical model of the world price level under a gold standard, as developed by Friedman (1951) and Barro (1979), and reflected in Section IV of this paper, involves substitution between monetary and nonmonetary gold as a prominent feature. Much informal discussion of the gold standard, however,

Figure 7
The (Pre-tax) Real Interest Rate and the Inverse Relative Price of Nonferrous Metals



appears to embody the presumption that the production of new gold was a sufficient statistic for changes in the monetary gold stock. The goal of this section is to highlight the role of nonmonetary gold in the workings of the gold standard.

Contemporary observers of the gold standard regarded changes in nonmonetary demand as something to be ignored only at ones's peril in attempts to relate movement in gold stocks to commodity prices. Probably the best known student of world gold stocks, Joseph Kitchin (see Kitchin, 1930a and 1930b), writes:

> For the purpose of the work of this group, the annual addition to gold money is of more importance than the annual addition to the gold output and it is therefore necessary to go into the matter of consumption, especially so far as that consumption is the result of demand and is not automatic. When new gold is produced and comes into the market, the industrial arts, together with India and to some extent China, lay claim to a large proportion of it, and the balance, from the nature of things, goes automatically to swell the amount of gold money. That is, in practice the manufacturers of money have no say as to what those additions to their stock should be, and no matter whether the balance after the satisfying of demand is large or small, the manufactures of money have to accept it, whether they will or no [1930b, p.61].
>
> I think one can test the correspondence between money and prices much better by comparing prices, not with the total stock of gold, but with the stock of gold money [1930b, p.66].

Writing fifty years earlier, Del Mar (1880) strikes much the same note:

> Upon a general review of the subject it would appear that now, at least, not coin, but the arts, are the first and principal attraction that determines the distribution of the precious metals, and that it is only after the demand for the arts has been satisfied that the supplies of specie are permitted to accumulate as coin [p. 188].

Even dramatic gold inflations were not always due to new discoveries or production (as opposed to monetization of existing gold stocks), as illustrated in the following remark by Stamp (1932):

> Then there is also a great deal of gold not now in monetary use which perhaps could be made available. There is an immense stock of precious metals in India, which has been buried out of sight, but I do not know what its extent is or what the possibilities are of bringing it back. The greatest change in price levels, that which followed the discovery of the Americas, was not due to the flow of gold into Europe from mines, but to the accumulated stocks which were looted from the temples and sent home to Spain and Italy and so into the main trade channels of Europe. The price levels went up first in the near countries and then in the remote, so that to read of it is like watching a coloured liquid flowing into a bowl of clear liquid and gradually colouring the whole of it [p. 3].

The only available estimates of world stocks of monetary and nonmonetary gold are those of Kitchin (1930a,b) who attempted to adjust his estimates of the monetary gold stock for the flow of gold into nonmonetary uses. Kitchin computed his estimates of the change in the monetary stock by subtracting from world gold production an estimate of the net demand (expressed as a flow) by India and the industrial arts in each year. Kitchin did not attempt to deal with "re-used" gold at all, and his numbers on new gold bought for fabrication appear artificially smooth, as noted by Rockoff (1984). Because he assumed that nonmonetary demand did not vary a great deal, Kitchin essentially constrained the change in the monetary gold stock to reflect mainly new gold production. Hawtrey (1932), in reviewing Kitchin's work, concluded:

> It is probable that there has been a fairly steady leakage from the monetary to the non-monetary side which is not disclosed in the statistics of industrial consumption...[p. 71]

Kitchin's estimates were challenged by Edie (1929), who attempted a direct count of the gold in world central banks in two benchmark years. In Edie's words:

> During the past fifteen years, the average annual gross product of the gold mines has been $392,000,000. This figure is derived from reasonably accurate reports to the

> Director of the Mint of the United States. Of this sum, $270,000,000 has annually been drawn off into hoarding or the industrial arts, leaving only $122,000,000 for monetary use. In other words, only 30 per cent has become available as money; the remaining 70 per cent has been drawn off into other uses.
>
> According to this calculation, Mr. Kitchin has credited monetary stocks with nearly double the amount of new gold which actually has been added to them [Edie, 1929, pp. 34-35].

While these data seem unlikely to reveal any movements in the share of monetary gold in total gold, it is nonetheless tempting to test our theory of the Gibson correlation by examining the relationship between the share of gold held in monetary form and the interest rate. Our theory would predict a positive relationship, since increases in the interest rate make holding nonmonetary gold more costly. A regression of the ratio of monetary gold to the total gold stock on the consol rate and a time trend for the period 1850 to 1910 yields:

$$\text{Mongold/Goldstock} = \underset{(.04)}{.23} + \underset{(.000)}{.002}\ \text{time} + \underset{(.013)}{.060}\ \text{Consol Yield}, \qquad \begin{matrix} R^2 = .52 \\ DW = .12 \end{matrix}$$

While confirming our theory, this result should not be taken too seriously because of the problems in data construction and the high degree of autocorrelation exhibited by the residuals. Given the weakness of the data, more elaborate statistical technique seems inappropriate. In particular, differencing to take account of autocorrelation would produce largely noise. An attempt to construct better series on monetary and nonmonetary stocks from primary sources might conceivably be a direction for further research. Otherwise future research will have to focus on less direct implications of our theory of the Gibson Paradox.

VI. Summary and Conclusion

The famous positive correlation between prices and interest rates seen in two centuries of data appears far less mysterious when thought of as a negative equilibrium relationship between the real price of gold and the real interest rate. In this paper we have presented evidence along several dimensions for the view that this may be a fruitful approach to understanding the Gibson correlation. Strong co-movement between the inverse relative price of gold (and other metals) on the one hand, and the real interest rate on the other, characterizes non-gold standard years as well. The price level during the Gibson Paradox period nearly followed a random walk, as do real metals prices today. The limited evidence on monetary and nonmonetary stocks of gold is consistent with the notion that changes in nonmonetary demand were an important determinant of the supply of metal to the monetary sector during the classical gold standard years. Finally, as also noted by Friedman and Schwartz (1982), the only extended period clearly characterized by the Gibson correlation is precisely the era of the gold standard.

Although there is little evidence of any trends in pre-1930 prices, the price level during the gold standard years was anything but stable. Jumps in the price level, in either direction, were the rule rather than the exception. In addition to rationalizing Gibson's Paradox, the asset price approach to the gold standard of this paper accounts for the very substantial volatility of the price level in this period.

The production of new gold undoubtedly played a major role in the history of prices. Yet the amount of new gold extracted in a year never exceeded two or three percent of the total stock. Thus factors impinging on agents' willingness to hold the existing stock must not be neglected. It has long been clear that the effect of changes in the rate of interest on ordinary monetary velocity is insufficient to account for the Gibson Paradox. The broader view of gold as a durable real asset in this paper may well provide the necessary missing link.

Notes

1. Following the suggestion of Homer (1977) and Shiller and Siegel (1977), we use the yields on 2½ percent government annuities for the years 1881 to 1888, instead of consol yields. During this period, yields had fallen below the 3 percent rate at which consols were issued, and the possibility of government redemption (which occurred in the "refunding of 1888") kept the yields on consols from falling much further.

2. Figure 2, which shows the 3-month treasury bill rate alongside the level of the CPI and a six-month moving average of inflation, extends a similar chart presented in Friedman and Schwartz (1976).

3. Barsky (1984) considers the possibility that inflation was significantly more forecastable with a larger information set. While it is impossible to give a fully satisfactory treatment of this issue with the limited data available, it remains true that there is little evidence of a rational Fisherian premium in nominal interest rates prior to 1914.

4. Benjamin and Kochin, working in the framework of Barro, argue that transitorily high government purchases per se raise interest rates, whether financed by debt or by current taxes.

5. From the context, it is clear that Cagan means the monetary gold stock.

6. An anticipated rise in r is easily worked out. The initial jump in P and i (at the announcement of higher real rates in the future) and the correlation across steady states, are identical to the unanticipated case.

7. A nearly vertical $\dot{G} = 0$ locus means that the responsiveness of supply to price has only a small effect on the steady state gold stock.

8. In quarterly data from 1973:1 to 1984:2 , the first 5 autocorrelations of the change in the log real gold price are .10, -.06, .33, .08, and -.19, with an asymptotic standard error of .15.

9. The reader might wonder whether this conclusion would be overturned by considering a "world" real gold price. We constructed one, using the trade-weighted real exchange value of the dollar series supplied by the Federal Reserve. Through 1982, the results were almost identical. In the last three years, the large real appreciation of the dollar caused the dollar real price of gold to be considerably lower than the world real price. Note, however, that real interest rates have been considerably higher in the U.S. than in the rest of the world by almost any measure.

References

Anderson, T. W. 1971. The Statistical Analysis of Time Series, New York, Wiley.

Bairoch, Paul. 1982. International Industrialization Levels from 1750 to 1980. Journal of European Economic History, 11(2) (Spring), p. 269-333.

Barro, Robert J. 1979. Money and the Price Level Under the Gold Standard. Economic Journal 89 (March): 13-33.

Barsky, Robert B. 1984. Tests of the Fisher Hypothesis and the Forecastability of Inflation Under Alternative Monetary Regimes. Unpublished manuscript, M.I.T.

__________________ forthcoming. Long-Run Variation in Stock Yields and Real Bond Yields.

Benjamin, Daniel K. and Kochin, Levis K. 1984. War, Prices, and Interest Rates: A Martial Solution to Gibson's Paradox. In A Retrospective on the Classical Gold Standard, ed. Michael D. Bordo and Anna J. Schwartz. Chicago: University of Chicago Press.

Bordo, Michael D. 1981. The Classical Gold Standard: Some Lessons for Today. Federal Reserve Bank of St. Louis Review 63: 2-17.

________________ and Schwartz, Anna J. ed. 1984. A Retrospective on the Classical Gold Standard. Chicago: University of Chicago Press.

Cagan, Phillip. 1965. Determinants and Effects of Changes in the Stock of Money, 1875-1960. New York: Columbia University Press for N.B.E.R.

Cowles, Alfred. 1939. Common Stock Indexes. Bloomington.

Del Mar, Alexander. 1880. A History of the Precious Metals, from the Earliest Times to the Present. London.

Edie, Lionel D. 1929. Capital, the Money Market, and Gold. Chicago: University of Chicago Press.

Feldstein, Martin. 1980. Inflation, Taxes, and the Prices of Land and Gold. Journal of Public Economics.

Fisher, Irving. 1930. The Theory of Interest. New York: Macmillan.

Franklin, E. L. 1932. Discussion of "Gold Production" by Kitchin, Joseph. In The International Gold Problem. Royal Institute of International Affairs. London: Oxford University Press.

Friedman, Milton. 1953. Commodity-Reserve Currency. In Essays in Positive Economics. Chicago: University of Chicago Press. (First published in Journal of Political Economy 59: 203-32 (1951).

____________and Schwartz, Anna J. 1963. A Monetary History of the United States. Princeton: Princeton University Press.

____________ 1976. From Gibson to Fisher. Explorations in Economic Research (Occasional Papers of the N.B.E.R.) vol. 3, 2 (Spring): p. 288-9.

____________ 1982. Monetary Trends in the United States and the United Kingdom: Their Relation to Income, Prices, and Interest Rates. 1867-1975. Chicago: University of Chicago Press.

Granger, C.W.J. and Newbold, Paul. 1974. Spurious Regressions in Econometrics. Journal of Econometrics 2: 111-120.

____________. 1977. Forecasting Economic Time Series. New York: Academic Press.

Hawtrey, R.G. 1932. Discussion of Kitchin, Joseph. Gold Production. In The International Gold Problem. Royal Institute of Economic Affairs. London: Oxford University Press.

Homer, Sidney. 1977. A History of Interest Rates. New Brunswick, N.J.: Rutgers University Press.

Keynes, John M. 1930. A Treatise on Money. New York: Macmillan.

Kitchin, Joseph. 1926. Statement of Evidence. In Great Britain: Report of the Royal Commission on Indian Currency and Finance, vol. iii (appendices).

____________1930a. Memorandum on Gold Production. In The International Gold Problem. Royal Institute of Economic Affairs. London: Oxford University Press.

____________1930b. Gold Production. In The International Gold Problem.

Levhari, David and Pindyck, Robert. 1981. The Pricing of Durable Exhaustable Resources. Quarterly Journal of Economics 96: 365-77.

Macaulay, Frederick. 1938. Some Theoretical Problems Suggested by the Movements of Interest Rates, Bond Yields, and Stock Prices in the United States Since 1856. New York: National Bureau of Economic Research.

McCloskey, Donald N. and Zecher, J. Richard. 1976. How the Gold Standard Worked, 1880-1913. In The Monetary Approach to the Balance of Payments, ed. J.A. Frenkel and H.G. Johnson. Toronto: University of Toronto Press.

Mitchell, B.R. 1978. European Historical Statistics, 1750-1970. New York: Columbia University Press.

____________. and Deane, P. 1962. Abstract of British Historical Statistics. Cambridge: Cambridge University Press.

Mundell, Robert. 1971. Monetary Theory. Pacific Palisades, Calif: Goodyear.

Muth, John F. 1960. Optimal Properties of Exponentially Weighted Forecasts. Journal of the American Statistical Association, 55, 290.

Plosser, Charles and Schwert, G. William. 1978. Money, Income, and Sunspots: Measuring Economic Relationships and the Effects of Differencing. Journal of Monetary Economics

Rockoff, Hugh. 1984. Some Evidence on the Real Price of Gold, Its Cost of Production, and Commodity Prices. In A Retrospective on the Classical Gold Standard, 1821-1931. ed. Bordo and Schwartz (see above).

Sargent, Thomas. J. 1973. Interest Rates and Prices in the Long Run: A Study of the Gibson Paradox. J. Money, Credit and Banking 4 (February): 385-449.

________________ 1979. Macroeconomic Theory. New York: Academic Press.

Schwartz, Anna J. 1973. Secular Price Change in Historical Perspective. J. Money, Credit, and Banking.

Shiller, Robert J. and Siegel, Jeremy J. 1977. The Gibson Paradox and Historical Movements in Real Interest Rates. Journal of Political Economy 85.

Siegel, Jeremy J. 1975. The Correlation Between Interest and Prices: Explanations of the Gibson Paradox. Unpublished Manuscript, Univ. of Pennsylvania.

Stamp, Josiah. 1932. The International Functions of Gold: An Introductory Survey. In The International Gold Problem. Royal Institute of Economic Affairs. London: Oxford University Press.

Warren, G. and Pearson, F. 1933. Prices. New York: John Wiley and Sons.

Wicksell, Knut. 1936. Interest and Prices. Translated from the German. London: Macmillan. (First published in 1898 as Geldzins und Guterpreise).