Gibson's Paradox and the Gold Standard

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This paper contributes a new element to the explanation of the Gibson paradox, the puzzling correlation between interest rates and the price level seen during the gold standard period. A shock that raises the underlying real rate of return in the economy reduces the equilibrium relative price of gold and, with the nominal price of gold pegged by the authorities, must raise the price level. The mechanism involves the allocation of gold between monetary and nonmonetary uses. Our explanation helps to resolve some important anomalies in previous work and is supported by empirical evidence along a number of dimensions.

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 exhibited close comovement with the wholesale price index, alongside an essentially zero correlation with the inflation rate. Keynes referred to the strong positive correlation between nominal

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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, 2:198). Fisher wrote that "no problem in economics has been more hotly debated" (Fisher 1930, p. 399).

Fisher 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. His explanation has been widely challenged. Sargent (1973) noted that such a distributed lag appears incompatible with the stochastic process actually followed by inflation in the Gibson paradox period. Shiller and Siegel (1977) reported that movements in nominal rates during that period seem to be attributable to variation in real rates rather than the inflation premium.

Keynes (1930) and Wicksell (1936) argued that shifts in the profitability of capital would be accompanied by accommodative movements in the stock of inside and outside money through the behavior of private and central banks. The Keynes-Wicksell approach founders on the observation that "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" (Cagan 1965, p. 255). Instead, the dominant proximate determinant of the movement of prices and money during the period was variation in the stock of monetary gold. As Friedman and Schwartz (1976, p. 288) conclude, "the Gibsonian Paradox remains an empirical phenomenon without a theoretical explanation."

This paper contributes a new element to the explanation of the Gibson paradox. Noting the coincidence of the observation of the Gibson paradox and the gold standard period, we point out that the Gibson correlation may arise as a natural concomitant of a monetary standard based on a durable commodity.[1] 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. Determination of the general price level then amounts to the microeconomic problem of determining the relative price of gold. Since gold is a durable asset, its price is sensitive to the long-term interest rate.

Following the treatment of the gold standard by Friedman (1953),

[1] An independent and contemporaneous contribution that also stresses the mechanism of the gold standard is Lee and Petruzzi (1986). We point out the essential differences between that paper and the present one below.

we focus on the demand for gold in its real, as well as its monetary, uses. Using a model similar to that of Barro (1979), we show that if innovations in the productivity of capital are an important exogenous disturbance, as in Wicksell and Keynes, the negative equilibrium relationship between the relative price of gold and the real interest rate can give rise to Gibson's paradox. Our mechanism, which relies on the allocation of gold between monetary and nonmonetary uses, is (unlike the Keynes-Wicksell mechanism) consistent with the stylized fact that prices varied closely with the monetary gold stock during the gold standard period.

The paper is organized as follows. Section I refutes recent claims by Benjamin and Kochin (1984) that much of the Gibson correlation is spurious and demonstrates the temporal coincidence of the Gibson correlation and the gold standard. We also present evidence from equity yields indicating that the Gibson correlation held for real as well as nominal assets. Section II presents a theory of the price level under a gold standard and shows how the Gibson correlation arises naturally in such a setting. Section III shows that the inverse relationship between the relative price of gold and the real interest rate, which provides the basis for our resolution of Gibson's paradox, is a dominant feature of actual gold price fluctuations in the post-1970 period, when the nominal price of gold has floated freely. Section IV provides some limited evidence that two key ingredients of our theory, productivity shocks and substitution between monetary and nonmonetary gold, were in fact important features of the gold standard period. Section V contains a brief summary and conclusions.

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

This section examines world data on commodity prices, long-term interest rates, and stock yields in an effort to characterize Gibson's paradox. We address the arguments of Benjamin and Kochin (1984) concerning the spurious regression problem and go on to show that Gibson's paradox was primarily a gold standard phenomenon. 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 nominal assets.

We work with both British wholesale prices[2] and a world price index, which is a GNP-weighted average of the wholesale prices of

[2] The British price 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.

four countries.[3] In fact, the correlation of the British price series and our world price level is .96, and very similar results are obtained using either index. We take the yield on British consols to be the world long-term interest rate.[4]

Was There a Gibson Paradox?

Data on world prices and interest rates for the period 1821–1913 are plotted in figure 1. We use the consol yield because, as discussed below, our theoretical model points most clearly toward a relationship between long-term interest rates and gold prices. In table 2 below, we also present results using the short-term interest rate. Although a clear positive relationship is observable, Benjamin and Kochin (1984) note that the two series are very nearly random walks, and thus the risk of spurious correlation is high. Granger and Newbold (1974, 1977) show that an ordinary t-test is very likely to show a "significant" relationship between two random walks, even if they were generated independently. These authors also show that standard procedures for correcting serial correlation are inadequate when the error process involves a unit root.

We deal with the spurious regression problems in two ways. First, we run the regression in first differences, a standard diagnostic procedure recommended by Granger and Newbold (1977) and Plosser and Schwert (1978). Because first-differencing accentuates the high frequency variation in the data at the expense of the low frequencies (Anderson 1971) and because it may exacerbate the problem of errors-in-variables (Plosser and Schwert 1978), we also report regressions in 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 an ordinary t-statistic greater than 10 or so (corresponding, with 50 observations, to

[3] We construct the world price index because our model, like that of Barro (1979), concerns the world price level under a gold standard. The four countries are Britain, France, Germany, and the United States, although we exclude the U.S. data during the Civil War period. The weights are from Bairoch (1982), who attempts to proxy manufacturing output of a number of countries in the years 1860 and 1913. The prices for France and Germany are from Mitchell (1975), while those for the United States are from Warren and Pearson (1933).

[4] Following the suggestion of Homer (1977) and Shiller and Siegel (1977), we use the yields on 2.5 percent government annuities for the years 1881–88 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 actually occurred in the "refunding of 1888") kept the yields on consols from falling much further.

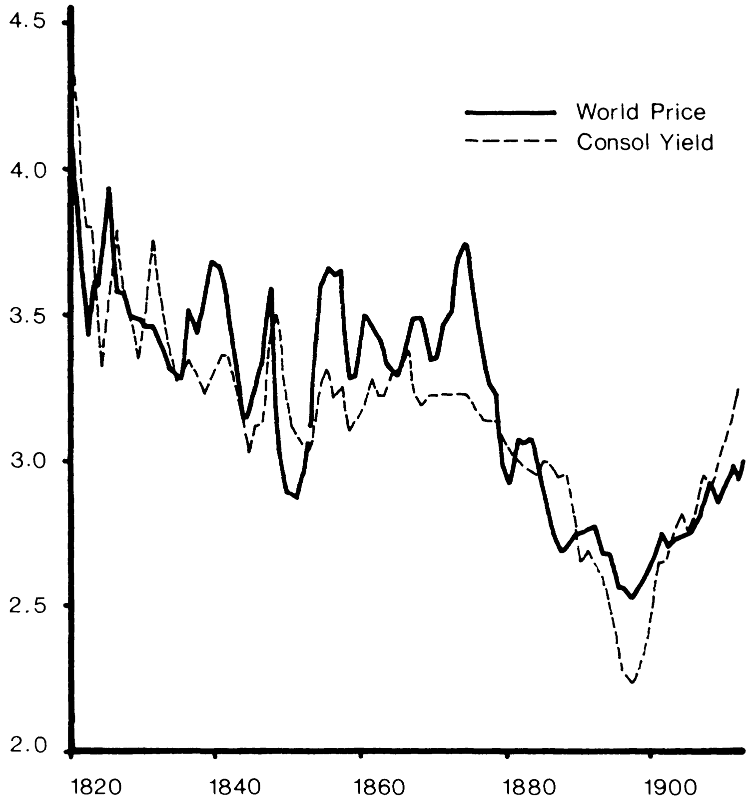

FIG. 1.—The world price level and the consol yield

an R^2 of about .7) would properly lead to rejection at the 5–10 percent level. We take this as our criterion for significance of the regressions in levels.

Table 1 presents Gibson regressions, in both levels and first differences, for various subperiods of 1730–1938 (table 2 reports analogous regressions using the British open market rate of discount, a short-term rate given by Homer [1977]). The results justify several important conclusions. First, Gibson's paradox is not an example of the spurious regression phenomenon, at least not during the classical gold standard years 1821–1913. The regressions in table 1 using the consol yield in differences are significant at the 1 percent level for the period as a whole and at least at the 5 percent level for both of the subperiods 1821–71 and 1872–1913. The regressions in levels for the whole period have t-statistics in excess of 10. The results in table 2 using the short rate are somewhat weaker but consistent.

Second, Gibson's paradox is by no means a wartime phenomenon.

TABLE 1

REGRESSION OF LOGARITHM OF PRICE LEVEL ON CONSOL RATE
(Levels and First Differences)

Sample Period	Price Series	Levels/First Differences	Coefficients of Consol Yield	Durbin-Watson Statistic	$\bar{R}^2$
1730–96	British	Levels	.15 (.02)	.44	.43
		First differences	−.02 (.02)	1.88	.01
1797–1820	British	Levels	−.08 (.05)	.72	.11
		First differences	−.05 (.04)	1.68	.06
1821–1913	World	Levels	.40 (.03)	.47	.71
		First differences	.15 (.04)	1.73	.11
	British	Levels	.38 (.03)	.44	.65
		First differences	.16 (.05)	1.71	.10
1821–71	World	Levels	.17 (.05)	.61	.18
		First differences	.14 (.06)	1.72	.10
	British	Levels	.16 (.06)	.52	.11
		First differences	.14 (.06)	1.77	.08
1872–1913	World	Levels	.43 (.04)	.32	.71
		First differences	.21 (.08)	1.79	.11
	British	Levels	.41 (.05)	.28	.67
		First differences	.24 (.09)	1.50	.14
1872–1938*	British	Levels	.36 (.02)	.40	.78
		First differences	.24 (.05)	1.57	.24
1921–38*	British	Levels	.31 (.06)	.62	.58
		First differences	.16 (.09)	1.97	.09

* The world price series covers only 1821–1913.

TABLE 2

Regression of Logarithm of Price Level on British Open Market Rate of Discount (Levels and First Differences)

Sample Period and Price Series	Levels/First Differences	Coefficients of Consol Yield	Durbin-Watson Statistic	$\bar{R}^2$
1826–1913:				
World	Levels	.07 (.01)	.35	.27
	First differences	.017 (.004)	1.68	.15
British	Levels	.08 (.01)	.36	.35
	First differences	.026 (.004)	1.82	.33
1826–71:				
World	Levels	.03 (.01)	.59	.22
	First differences	.02 (.01)	1.67	.20
British	Levels	.04 (.01)	.50	.29
	First differences	.02 (.01)	1.89	.31
1872–1913:				
World	Levels	.07 (.03)	.20	.14
	First differences	.012 (.009)	1.63	.02
British	Levels	.09 (.02)	.19	.26
	First differences	.04 (.01)	1.76	.39
1872–1938:				
British	Levels	.14 (.02)	.25	.33
	First differences	.05 (.01)	1.50	.22
1921–38:				
British	Levels	.10 (.03)	.48	.51
	First differences	.05 (.03)	1.28	.10

Source.—Homer (1977) for interest rate data; price data are described in the text.

Not only is the relation significant and stable during the peacetime, gold standard years from the 1821 resumption of the gold standard in Britain to the eve of World War I, but it completely breaks down during the Napoleonic war period of 1797–1820, when the gold standard was abandoned. Over this period, the correlation was negative in both levels and first differences. These findings are evidence against theories based on government purchases (Benjamin and Kochin 1984) or finance (Keynes 1930; Shiller and Siegel 1977) during wartime.[5]

Finally, the evidence of the Gibson correlation is weaker for the pre-Napoleonic period 1730–96 and the interwar years 1921–38 than for the classical gold standard period. It is plausible to relate the weak, but not nonexistent, evidence of the Gibson paradox from these periods to the rather restricted functioning of the gold standard during them. Although Britain was effectively on a gold standard between 1730 and 1796, most of the rest of the world was not. Likewise, the post-1921 gold standard was closely "managed" by central banks and encumbered by formal and informal restrictions limiting convertibility.

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 in levels. 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.[6] As becomes especially clear after 1965, the interest rate follows the rate of inflation rather than the price level. The complete disappearance of Gibson's paradox by the early 1970s coincides with the final break with gold at that time.

The results of this and the preceding subsection corroborate the view of Friedman and Schwartz (1982) that Gibson's paradox is largely, or perhaps solely, a gold standard phenomenon: "For the period our data cover [1880–1976] 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).

[5] Robert Barro, in private communication, informed us that a positive relationship between temporary government purchases and real interest rates holds throughout the nineteenth century, but a relationship between government purchases and the price level holds only for periods of suspension.

[6] Figure 2, which shows the 3-month Treasury bill rate alongside the level of the Consumer Price Index (CPI) and a 6-month moving average of inflation, extends a similar chart presented in Friedman and Schwartz (1976).

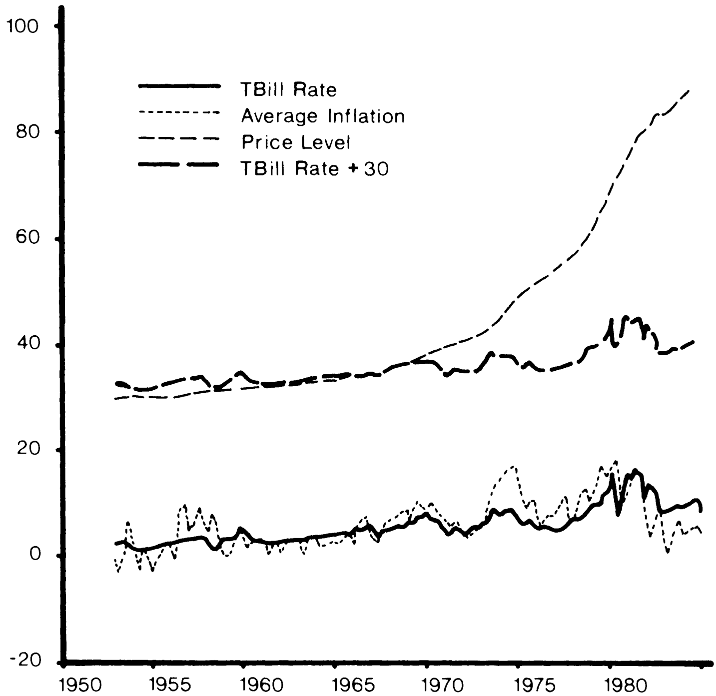

FIG. 2.—Gibson's paradox vs. the Fisher effect, 1953–84

Gibson's Paradox and Real Rates

In attempts to rationalize Gibson's paradox, it is critical to determine whether it applies to real, or merely to nominal, rates of return. Sargent (1973), Shiller and Siegel (1977), Benjamin and Kochin (1984), and Barsky (1987) provide some indirect evidence that the paradox held for real rates by arguing that observed nominal rates entirely reflected ex ante real rates and did not embody inflation premia. They show that inflation was serially uncorrelated during the Gibson paradox period, and thus the univariate properties of inflation alone did not justify the inclusion of an inflation premium in nominal rates.[7] Shiller and Siegel (1977) further demonstrate that nominal consol yields had no predictive power for subsequent long-term inflation, as they should have if nominal yields were set in anticipation of future inflation.

[7] Barsky (1987) 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.

Here we follow Sargent (1973) in presenting more direct evidence by studying equity yields. We examine both earnings/price and dividend/price ratios. Both should be proxies for long-term required real returns. The former have the virtue of reflecting any expected capital gains associated with retained earnings, while the latter are measured more accurately and are less likely to be distorted by transitory fluctuations in profits. An obvious alternative procedure would be the use of ex post equity returns. We did not use this procedure because prior analysis of the data indicated that almost all the variation in ex post returns reflects news rather than changes in ex ante returns. Friedman and Schwartz (1982) do briefly examine holding period returns with inconclusive results.

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 levels and first differences, comparable to the regressions in table 1. The coefficients of the regressions in levels are always positive, with conventional t-statistics typically between 5 and 15. The dividend yield regressions for 1872–1913, in particular, exhibit large conventional t-statistics. The estimated coefficients do tend to be smaller than those from regressions using the bond yield. The first-difference regression coefficients are significantly positive in half of the cases and insignificant in the remainder. Overall, the regressions support the view that Gibson's paradox involved the real rate.

It might be argued that fluctuations in dividend/price and earnings/price ratios reflect movements in the level of future dividends and earnings relative to current values. As a check against this possibility, we followed the procedures used in Blanchard and Summers (1984) and calculated the required rate of return necessary to justify the market's value given autoregressive projections of future dividends. The results of correlating this internal rate of return series with the price level are also displayed in table 3. The results parallel those obtained with the cruder dividend and earning yield proxies for real returns.

Summary

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 paradox that is more than a spurious correlation between two random walks. (2) Far from being primarily a wartime phenomenon, Gibson's paradox characterizes the gold standard years 1821–1913, and those years represent the only long period over which the

TABLE 3

REGRESSION OF LOGARITHM OF PRICE LEVEL ON COWLES COMMISSION STOCK YIELDS (1872–1913)

Price Series	Levels/First Differences	Coefficient of Stock Yield	Durbin-Watson Statistic	$\bar{R}^2$
		Dividend/Price Ratio Yield		
World	Levels	.14 (.01)	1.17	.74
	First differences	.03 (.01)	1.84	.12
British	Levels	.13 (.02)	.70	.61
	First differences	.03 (.01)	1.43	.11
U.S.	Levels	.12 (.02)	.82	.44
	First differences	−.02 (.02)	1.61	.01
		Earning/Price Ratio Yield		
World	Levels	.07 (.01)	.61	.38
	First differences	−.01 (.01)	1.26	.01
British	Levels	.08 (.01)	.59	.52
	First differences	.02 (.01)	1.34	.09
U.S.	Levels	.08 (.01)	.79	.45
	First differences	.00 (.01)	2.14	−.02
		Internal Rate of Return Yield		
World	Levels	.08 (.01)	.53	.67
	First differences	.02 (.01)	1.75	.07
British	Levels	.07 (.01)	.40	.57
	First differences	.02 (.01)	1.42	.05
U.S.	Levels	.07 (.01)	.31	.43
	First differences	.02 (.01)	1.56	.03

correlation held continuously. Gibson's paradox had clearly vanished by the 1970s. (3) The paradox appears to involve the real rate. Regressions using the Cowles stock yield data suggest that the price level was correlated with the expected return on capital.

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

This section develops a simple model of the determination of the real price of gold, and hence the general price level, under a gold standard. We then discuss the response of the model to a disturbance 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 drops his partial adjustment formulation and emphasizes explicitly the role of the real interest rate.

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), it is the demand for the existing stock, as opposed to the new flow, that must be modeled. 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 and bonds, both earning a real return of r. 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. Interpreted as shocks to the production function, these sorts of disturbances also play a crucial role in the equilibrium real business cycle models surveyed by Prescott (1986).

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 (possibly time-dependent) service flow or marginal "dividend," which is denoted $D(G_n, t)$ with $D_{G_n} < 0$. Consumers equate the marginal service flow $D(G_n, t)$ to the user cost $rP_g - \dot{P}_g$ (we assume no depreciation), so that at all times the real gold price must satisfy

$$\dot{P}_g = rP_g - D(G_n, t), \tag{1}$$

where we have suppressed the time subscripts for convenience.

The monetary side consists of a conventional demand for real balances,

$$\frac{M}{P} = L(i, t) = L\left(r - \frac{\dot{P}_g}{P_g}, t\right), \quad L_1 < 0, \tag{2}$$

and a relation between monetary gold reserves and the money stock,

$$M = \mu G_m, \tag{3}$$

where μ is a fixed parameter. Finally,

$$G_m + G_n = \bar{G}, \tag{4}$$

the total existing gold stock.

Equations (1)–(4) determine the real price of gold as a negative function of current and future real interest rates r, and gold supplies G, and determine the allocation of gold between monetary and nonmonetary uses at each point in time.

The price level may rise or fall over time depending on how the stock of gold, the dividend function, $D(G_n, t)$, and the demand for money, $L(i, t)$, evolve over time. Secular increases in the demand for monetary and nonmonetary gold caused by rising income levels tend to create an upward drift in the real price of gold, that is, secular deflation. Tending to offset this effect would be gold discoveries and technological innovations in mining such as the cyanide process. The fact that the average growth of prices between 1870 and 1913 was close to zero might have been something of a historical accident, with gold discoveries and mining innovations just offsetting, on average, the effects of growth in the nongold sectors (see Barro 1979; Rockoff 1984).

For ease of exposition, we focus only on steady states in which the demand for gold is stable and its quantity is fixed,[8] so that its real price

[8] For a more elaborate analysis in which gold mining is endogenous, see Barsky and Summers (1985). Endogeneity of gold mining does not play a central role in any version of this paper, nor does it appear in the work of Lee and Petruzzi (1986). The key difference between our theoretical development and theirs is our emphasis on the crucial distinction between monetary and nonmonetary gold and on the service flows from nonmonetary gold. Both of these elements are necessary for a satisfactory theoretical demonstration of our Gibson paradox result.

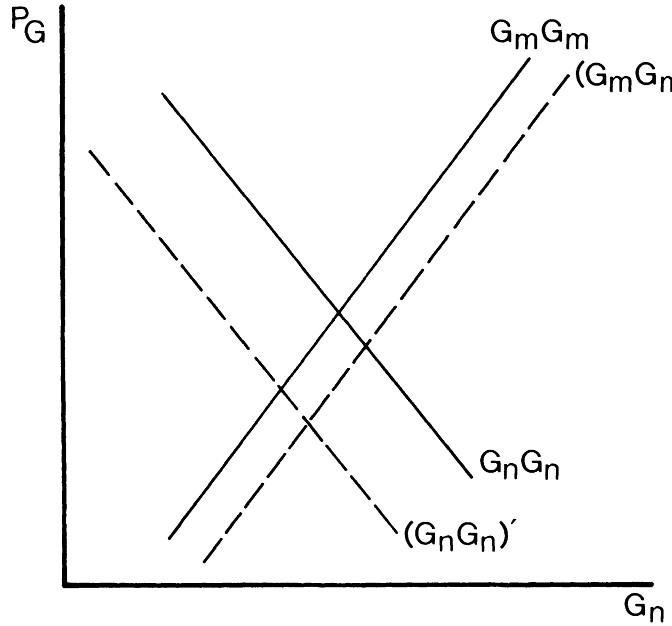

FIG. 3.—The determination of the gold price

is constant. In this case (1) becomes

$$D(G_n) = rP_g, \quad D'(G_n) < 0, \tag{1'}$$

and (2), (3), and (4) together yield

$$L(r) = \mu(\overline{G} - G_n)P_g, \quad L'(r) < 0. \tag{5}$$

Figure 3 shows graphically the determination of equilibrium. The real price of gold (inverse of the general price level) appears on the vertical axis, and the nonmonetary gold stock is measured along the horizontal axis. The negatively sloped G_nG_n locus, which represents equation (1′), shows that as the real price of gold falls (for given r), the desired stock held for nonmonetary purposes rises. The upward-sloping G_mG_m locus, which represents equation (5), shows that (for a given total gold stock) an increase in nonmonetary holdings is consistent with monetary equilibrium only at a higher P_g (lower general price level). This is because the increase in G_n comes at the expense of monetary holdings, creating an excess demand for real balances at the initial price level.

Response to an Increase in the Real Interest Rate

Differentiating the system (1′) and (5) with respect to the real rate of return r yields[9]

$$\frac{dP_g}{dr} = \frac{-D'(G_n)\eta\mu G_m P_g r^{-1} - \mu P_g^2}{-D'(G_n)\mu G_m + r\mu P_g} < 0, \tag{6}$$

$$\frac{dG_m}{dr} = \frac{(1+\eta)\mu P_g G_m}{-D'(G_n)\mu G_m + r\mu P_g}, \tag{7}$$

where $\eta < 0$ is the interest elasticity of real money demand. Equation (6) shows that, as illustrated in figure 3, an increase in the real rate unambiguously reduces the relative price of gold P_g. Since the general price level is the inverse of P_g, shocks to the real rate lead the interest rate and the general price level to covary positively, the Gibson phenomenon. The economic mechanism is clear. Increases in real interest rates raise the carrying cost of nonmonetary gold, reducing the demand for it. They also reduce the demand for monetary gold as long as money demand is interest elastic. The resulting reduction in the real price of gold is equivalent to an increase in the general price level.

Equation (7) demonstrates that a rise in r will cause the monetary gold stock to increase at the expense of the nonmonetary stock unless the interest elasticity of demand for real balances exceeds unity in absolute value. Available empirical estimates suggest that this elasticity is much smaller than unity (see Friedman and Schwartz 1982). Thus the rise in prices will be associated with an increase in the monetary gold stock, in accordance with Cagan's stylized fact. The rise in velocity further reinforces the Gibson correlation, but (6) shows that Gibson's paradox continues to hold for $\eta = 0$.

The mechanism we have highlighted provides a possible explanation of Gibson's paradox that, like the Keynes-Wicksell explanation, accounts for the observation that the correlation held for real rates of return but avoids the principal difficulty with earlier resolutions: their counterfactual dependence on changes in the money multiplier or the central bank's gold ratio. Our approach also accounts for the coincidence of the Gibson paradox observation and the gold standard.

An important limitation of our theory is that the Gibson correlation arises only from shocks to the real rate. A gold discovery would, of course, take the form of an increase in $\bar{G}_t$ for all t greater than some t_0. In our model, this leads to a permanent increase in the price level without a corresponding change in r. Shocks of this sort weaken the

[9] Note that this corresponds to examining the effect of an equal change in all forward interest rates. Empirically, we think of a change in *long-term* real interest rates.

Gibson correlation, but it is important to understand that gold discoveries do not contribute correlations opposite in sign to that of Gibson. The strength of the observed Gibson correlation will depend on the relative importance of gold discoveries and shocks to real interest rates.

III. Real Interest Rates and the Relative Price of Gold, 1973–84

The model of the price level under a gold standard in Section II is essentially a theory of the relative price of gold. Omitting the monetary demand for gold, we see that the theory continues to hold 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.

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.[10] Box-Jenkins analysis suggests that the inflation rate in the 1970s is well modeled as an IMA(1, 1) process, resulting from a mixture of permanent and transitory shocks (Muth 1960). This yields the same k-step-ahead forecast for all horizons $k \geqslant 1$ (see Sargent 1979, p. 265), which has an interpretation as "permanent expected inflation." The forecasts are based on a "rolling autoregressive integrated moving average (ARIMA)" procedure so that only information available as of the forecast date is used.

Figure 4 displays the (log) inverse real gold price and our estimate of the expected pretax real interest rate. The strong comovement 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

[10] Instead of relating the relative price of gold to the real interest rate, Lee and Petruzzi (1986) construct a "gold-denominated" interest rate using futures market data. Our analysis in Sec. II of this paper points to the real interest in terms of goods, which we use in our empirical work.

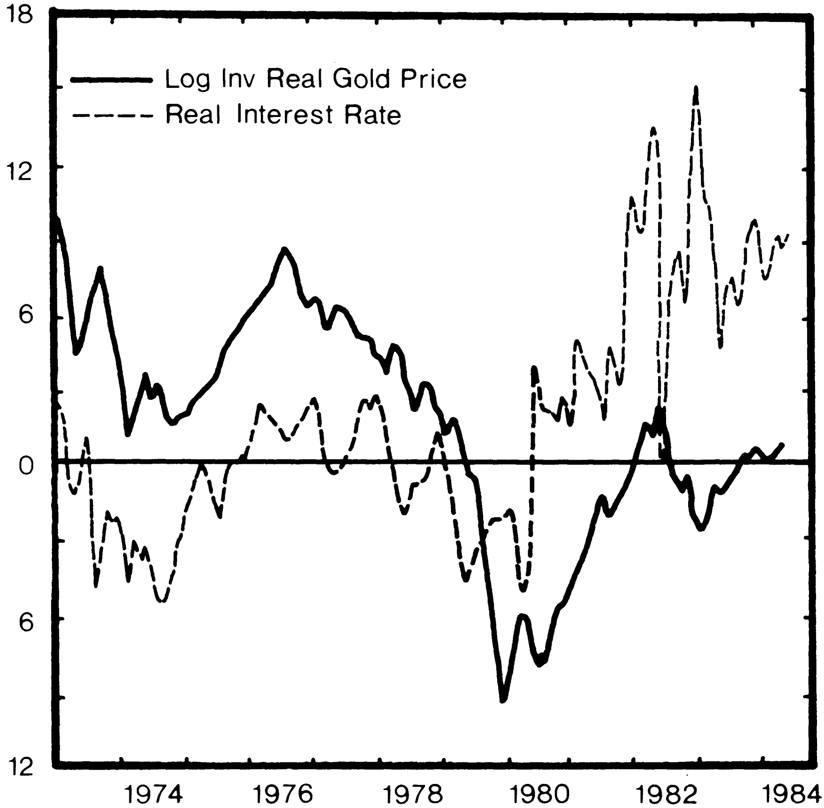

FIG. 4.—The (pretax) real interest rate and the inverse relative price of gold

interest rate than it was during the 1970s. Real interest rates are not the only determinant of the relative price of gold. Yet the impression that real rates were high after 1981 and that these high rates were associated with a low relative price of gold vis-à-vis the 1980 level is unmistakable.[11]

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

[11] One 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 following 3 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 were considerably higher in the United States than in the rest of the world.

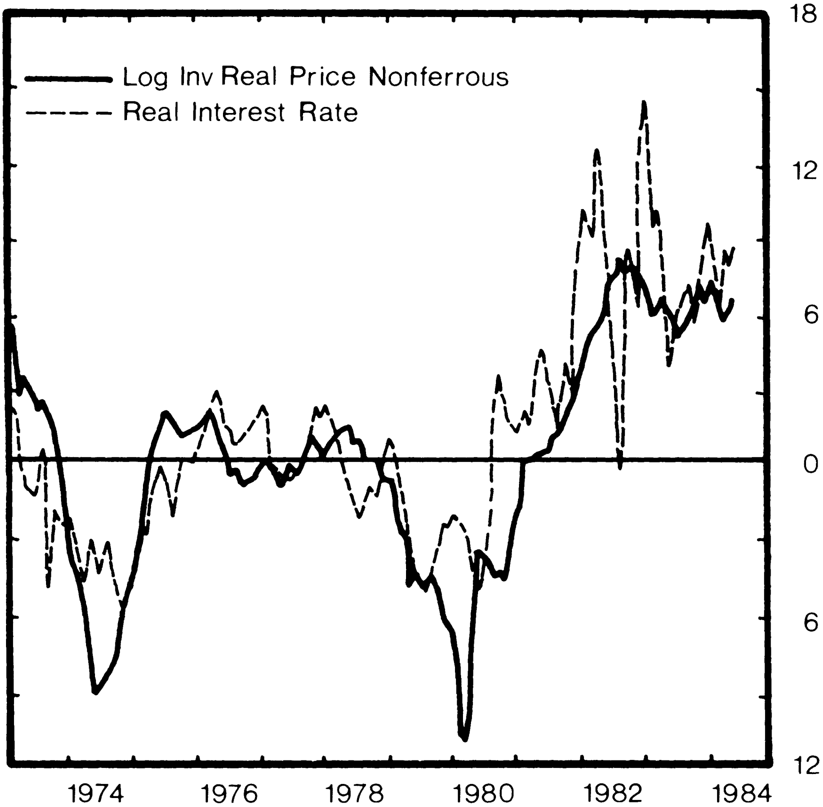

FIG. 5.—The (pretax) real interest rate and the inverse relative price of nonferrous metals.

$$\log\left(\frac{\text{Gold Price}}{\text{CPI}}\right) = \underset{(.03)}{4.54} + \underset{(.06)}{.84} \text{ Post 1980} - \underset{(.01)}{.06} \text{ Real } R,$$

$$R^2 = .81, \text{ Durbin-Watson} = 1.13.$$

The data strongly reject constancy of the intercept term before and after 1980. The slope estimate, however, is quite stable across subperiods. Alternative specifications, not reported here, using an after-tax real interest rate variable provided even stronger evidence of interest sensitivity of gold prices.

To ensure that we are capturing the general tendency of increases in real 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 5 shows our long-term real interest rate variable along with the level of the producer price index of prices of nonferrous metals 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.

IV. Monetary and Nonmonetary Gold Stocks and Productivity Shocks

Two important elements of our model are productivity shocks and substitution between monetary and nonmonetary gold. Here we present some indirect evidence that these elements of our model were plausibly present during the Gibson paradox period.

We have already noted that the movements in the consol yield cannot be attributed to expected inflation and that this is true for stock yields as well. It would be almost impossible to attribute the changes in yields to monetary factors. Indeed, that would tend to imply a negative correlation between interest rates and prices. It appears that real shocks to productivity or thrift are the likely sources of movements in both the consol and the stock yields.

Some evidence of productivity shocks in particular can be inferred from the financial markets. In the absence of news about increased profitability, increases in the long-term real interest rate would cause stock prices to fall. In that case we would expect a strong negative correlation between changes in the bond yield and stock price changes. In fact, the correlation was essentially zero. For 1872–1913, the correlation between log changes in the consol yield and log changes in the Cowles (1939) composite real stock price index was −.06. The corresponding number for the U.S. railroad bond yield from Macaulay (1938) was .12.

Monetary and Nonmonetary Gold

The canonical model of the world price level under a gold standard, as developed by Friedman (1953) and Barro (1979) and reflected in Section II of this paper, involves substitution between monetary and nonmonetary gold as a prominent feature. Much informal discussion of the gold standard, however, appears to embody the presumption that the production of new gold was a sufficient statistic for changes in the monetary gold stock and thus ignores the role of changes in the desired stock of nonmonetary gold.

While quantitative data of sufficient quality to justify statistical analysis of flows between alternative uses of gold do not exist,[12] there is

[12] Kitchin (1931*a*, 1931*b*) presents some estimates of industrial demand. As Rockoff (1984) notes, these numbers, having been constructed mainly by interpolation, are artificially smooth.

literary evidence suggesting that the demand for nonmonetary gold was an important determinant of the monetary gold stock. Probably the best-known student of world gold stocks, Joseph Kitchin (see Kitchin 1931*a*, 1931*b*), wrote:

> 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 manufacturers of money have to accept it, whether they will or no. [1931*a*, p. 61]

Writing 50 years earlier, Del Mar (1880) struck 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).

There is some quantitative evidence that the fraction of the gold stock in nonmonetary use was large. Del Mar (1880) presents numbers extending back into the seventeenth century that indicate that nonmonetary gold accounted for about two-thirds of the total gold stock and that this fraction varied over time. The work of Kitchin (1931*a*, 1931*b*), covering a shorter period, suggests smaller numbers for the ratio of nonmonetary to total gold, somewhere between a third and a half. Edie (1929) attempted a direct count of the gold in world central banks in two benchmark years and concluded that Kitchin had underestimated the extent of nonmonetary use. 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 percent has become available as money; the remaining 70 percent 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. [1929, pp. 34–35]

In summary, a sizable fraction of the gold stock was held in nonmonetary form, and this fraction was not constant over time. We therefore conclude that the size of the monetary gold stock was determined both by the level of gold production and by the allocation of gold between monetary and nonmonetary use.

V. Summary and Conclusion

The Gibson paradox has proven to be an especially stubborn puzzle in monetary economics. We believe that taking account of the role of gold as an asset contributes significantly to our understanding of the anomaly. Our model accounts for the historical coincidence of the Gibson paradox and the gold standard, an observation made by Friedman and Schwartz (1982) but not incorporated in previous attempts to rationalize the Gibson phenomenon. Like the resolutions proposed by Keynes and Wicksell, ours involves the underlying real rate of return, as the data suggest Gibson's paradox did. However, our explanation, unlike those of Keynes and Wicksell, does not depend on counterfactual changes in private banks' reserve ratios or the ratio of high-powered money to the monetary gold stock. The price level under the gold standard behaved in a fashion very similar to the way the reciprocal of the relative price of gold evolves today. Data from recent years indicate that changes in long-term real interest rates are indeed associated with movements in the relative price of gold in the opposite direction and that this effect is a dominant feature of gold price fluctuations.

The principal problem with our resolution of Gibson's paradox is the minimal role that it accords gold discoveries. New gold production accounted for a significant share of the variation in the price level during the nineteenth and early twentieth centuries. In particular, the post-1896 rise in prices, after more than two decades of deflation, is usually attributed to gold discoveries in combination with the development of the cyanide process for extraction. If this is correct, the comovement of prices and interest rates during the period 1896–1913 remains something of a puzzle, and thus our proposed resolution of the Gibson paradox cannot be the whole answer. To reach a verdict on the quantitative importance of the mechanism in this paper would require better methods for proxying movements in the stocks of monetary and nonmonetary gold, and this might be an appropriate topic for further research.

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