NBER WORKING PAPER SERIES

FORECASTING PRE-WORLD WAR I INFLATION: THE FISHER EFFECT REVISITED

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Working Paper No. 2784

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 1988

We are indebted to Robert Barro, Greg Mankiw, Jeff Miron, Christina Romer, Andrei Shleifer, Larry Summers, Robert Waldmann, David Weil, the participants in the 1988 NBER seminar on macroeconomic history and in seminars at Ohio State, Michigan State, Michigan, Texas, and the Federal Reserve Bank of Dallas for helpful discussions and comments. This research is part of NBER's research program in Financial Markets and Monetary Economics. Any opinions expressed are those of the authors not those of the National Bureau of Economic Research.

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ABSTRACT

We consider the puzzling behavior of interest rates and inflation in the United States and the United Kingdom between 1879 and 1913. A deflationary regime prior to 1896 was followed by an inflationary one from 1896 until the beginning of World War I; the average inflation rate was 3.8 percentage points higher in the second period than in the first. Yet nominal interest rates were no higher after 1896 than they had been before. This non-adjustment of nominal interest rates would be consistent with rational expectations if inflation were not forecastable, and indeed univariate tests show little sign of serial correlation in inflation. However, inflation was forecastable on the basis of lagged gold production. Investors' expectations of inflation should have risen by at least three percentage points in the United States between 1890 and 1910. We consider in an information processing context alternative ways of accounting for this failure of interest rates to adjust, for example the possible beliefs that increases in gold production might be transitory. We conclude that the failure of investors to exhibit foresight with regard to the shift in the trend inflation rate after 1896 is not persuasive evidence that investors were negligent or naive in processing information.

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I. INTRODUCTION

The issue examined in this paper—closely linked to Irving Fisher and no closer to resolution now than when it first arose a century ago—is the puzzling behavior of interest and inflation rates during the classical gold standard period before World War I. We focus on the years from 1870, when the post-Civil War United States declared its intention to adopt gold, to the breakdown of the international gold standard in 1914. This period ought to be an ideal laboratory for studying issues in monetary economics, as it included major changes in the money stock that arose from largely exogenous gold discoveries.

During the first half of this period the U.S. underwent deflation. From 1870 to 1896 the national product deflator of Friedman and Schwartz (1982) declined at an average rate of 1.1 percent per year, although shorter-term price changes were erratic. This trend was then reversed—over the period 1896-1914, the U.S. price level increased at 2.5 percent per year. A comparable shift in inflation is exhibited by the Warren-Pearson (1933) wholesale price index. A similar though less extreme shift for the United Kingdom is seen in the GNP deflator (Friedman and Schwartz (1982)), in the Sauerbeck-Statist wholesale price index, and in the Rousseaux WPI (Mitchell and Deane (1965)). Plots of the American and British price levels exhibit a pronounced "V," with a turning point in 1896.

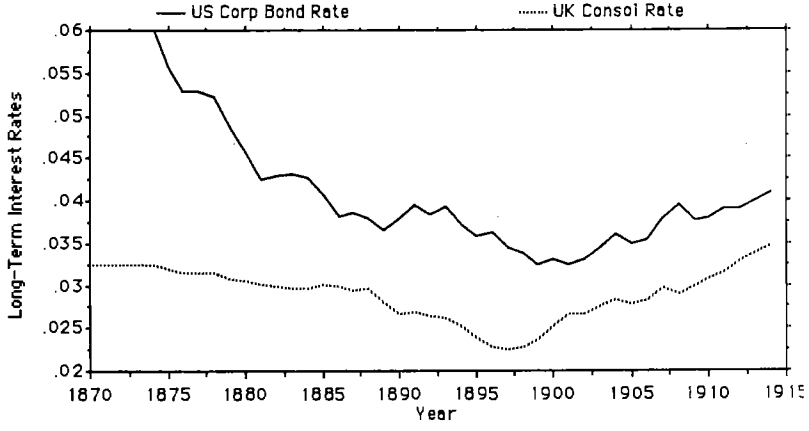
Irving Fisher's theory of interest (Fisher (1930)), according to which nominal interest rates adjust one-for-one to changes in steady-state inflation, suggests that nominal rates should have been some 300 basis points higher along the rising portion of the "V" than during 1879-1896. Although in the short run cyclical movements in real rates (e.g., Friedman's (1965) liquidity effect) might dominate the relationship between interest rates and inflation, in the long run there should be a one-to-one relationship between changes in inflation and

express considerable doubts about this line of thought, particularly the twenty-year lag in the formation of expectations needed if the Gibson paradox is seen as a delayed Fisher effect.

TABLE 1
AVERAGE INTEREST AND INFLATION RATES

	United Kingdom			United States		
Period	3-Month Rates	Consol Rates	Inflation Rate	3-Month Rate	RR Bond Rate	Inflation Rate
1870-1896	2.8%	3.0%	-0.6%	5.7%	4.7%	-1.8%
1897-1913	3.1%	2.8%	0.9%	4.6%	3.6%	2.0%
Change	+0.3%	-0.2%	+1.5%	-1.1%	-1.1%	+3.8%

FIGURE 3
US AND UK LONG-TERM INTEREST RATES, ANNUAL AVERAGES



Fisher (1906), perceiving a marked change in the secular rate of inflation which he saw as directly linked to the greatly-increased output of the world's gold mines, provided a scathing attack on the relevance of his own theory of the relation between interest rates and inflation:

during 1898-1905 the increase of prices in the United States is

> known to have been due largely to the increase in gold production.... There seems, therefore, no reason which would justify the low commodity [real] interest rate of 1.8 percent which we found to have been virtually paid during that period. This low rate must, in all probability, have been due to inadvertence. The inrushing streams of gold caught merchants napping. They should have stemmed the tide by putting up interest, not only to 4.6 percent, as they did, but two or three percent higher

Such inadvertence on the part of "merchants" is striking in view of Fisher's incredulity only twenty pages earlier in The Rate of Interest at the thought that agents might suffer from inflation illusion—i.e. that they do not notice that their nominal return i is different from their real return r:

> Foresight is clearer and more prevalent to-day than ever before. Multiples of trade journals and investors' reviews have their chief reason for existence in supplying data on which to base prediction. Every chance for gain is eagerly watched for. An active and keen speculation is constantly going on which, so far as it does not consist of fictitious and gambling transactions, performs a well-known and provident function for society. Is it reasonable to believe that foresight, which is the general rule, has an exception as applied to falling or rising prices?

Summers (1983) used several tools, notably spectral techniques that tried to capture the long run in which Fisher's effect should hold, and found no correlation between short-term or long-term rates and inflation rates in U.S. data before 1940. He concluded that nominal rates had not adjusted to changes in inflation and that real rates were persistently affected by changes in monetary growth:

> The data for 1860 to 1940 indicate no tendency for interest rates to increase with movements in expected inflation.... [The] facts... at least raise the possibility that some form of money

> illusion infects financial markets. All are explicable by the hypothesis that before the war agents ignored inflation in making financial calculations (Summers (1982), p. 232).

Barsky (1987) provided an alternative explanation for the lack of correlation between interest and inflation rates before 1914. He noted (as did others, e.g. Sargent (1973), Klein (1975), Shiller and Siegel (1977), Benjamin and Kochin (1984)) that inflation was serially uncorrelated during this period. Thus its one period univariate forecast was constant,[1] and consequently the Fisher effect could have been built into the pre-WWI economy yet not be visible because there were no shifts in expected inflation. Building on the analytics of McCallum (1983), he concluded that Summers' regressions did not bear on the truth of Fisherian theory. The lack of correlation between ex post inflation and interest rates could be due to the failure of inflation—largely noise—to convey information about future inflation.

Barsky noted that inflation was slightly forecastable by lagged gold production, but stopped short of examining fully the implications of this observation. Moreover, the restriction of analysis to parsimonious univariate models removed from consideration models with long lag structures that might have picked up a small but important forecastable component in inflation. De Long (1987) defended the view that pre-WWI data suggest a failure of the Fisher effect. He aligned himself with Fisher (1930), Friedman and Schwartz (1963, 1982) and Cagan (1984) in affirming the "traditional" view of price movements during the gold standard. The traditional view divides the period into two distinct régimes: an era of falling prices before and an era of rising prices after 1896, with the switch in régimes triggered by increases in gold production which were foreseen—or at least foreseeable—by investors at the time.

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[1]And in fact nearly zero. The average rate of inflation over 1879-1914 as measured by the implicit national product deflator in both the US and UK is close to 0.4 percent per year.

We thus have two contrasting views of the pre-1914 link between inflation and interest rates. The view sympathetic to Fisher's theory emphasizes that hindsight is always 20-20, that the switch in the average rate of inflation which from an ex post viewpoint took place in 1896 was not necessarily seen as such at the time, and that there is little formal evidence that inflation before World War I was forecastable even with the tools of modern time series analysis. The alternative, not reconcilable with Fisher's theorizing—though it does fit his own rather nihilistic interpretation of the empirical evidence—seems more compatible with the historian's sense that investors perceived, or should have perceived, long swings in the trend of prices. The present paper brings together the elements of truth in both views, and assesses to what extent Fisher was correct in rejecting his own theory on the basis of pre-WWI evidence.

We try to infer what investors should have thought about future inflation and what investors did think as revealed in the reporting of the financial press. Most important, we assess the value of information on gold mining in forecasting changes in average inflation as they were occurring. Our finding that gold production helps to forecast inflation (albeit with a small R^2) may appear surprising in view of the fact that gold mining is persistent while inflation appears white noise. On reflection these observations are not incompatible. Gold mining conveys a signal about a subtle persistent component in inflation sufficiently buried in short-term noise as to escape detection by low-order univariate ARMA models. Gold production is a necessary cofactor to lend inflation a degree of forecastability as the shift in the drift of prices was occurring. The coincidence of the expansion of gold production and the shift to upward drift in the price level lends us confidence—through the force of the quantity theory—that the "V" in the price level is not a spurious trend like those that chartists find in random walks.

Because we find some forecastability in inflation and not the slightest hint

In this section we provide a brief survey of the historical circumstances surrounding the Australian and South African gold discoveries, and the development and commercial implementation of the cyanide process for gold extraction. The history of gold production in the nineteenth century is dominated by the two "rushes" of the 1850's and the 1890's From the perspective of a century or more, these rushes are perhaps best seen as endogenous responses to industrialization: the gold was there, and would be discovered and mined at some point if the price of gold were high enough. But from the standpoint of a decade or a generation, the two expansions in gold production take on the character of exogenous shocks to the world's monetary system. Figure 4 shows contemporaneously available estimates, reported in the Financial Review Annual supplement to the New York Commercial and Financial Chronicle, of world gold production from the Middle Ages to the outbreak of World War I; figure 5 concentrates on the period since 1800 and shows the same data in the form of the proportional rate of increase of the world's cumulative mined gold stock.

Annual gold production increased by a factor of five during the gold rushes of the 1850's, and then leveled off in the 1870's and 1880's. Gold production then doubled from its level during the 1870's and 1880's in the 1890's, and had doubled once again by 1910. The proportional rate of increase in the world's gold stock thus exhibits two peaks, in the 1850's and 1910's, and an intermediate trough. The two rushes are not of negligible magnitude: they each increased the world's total mined gold supply relative to trend by a third.

FIGURE 4
ANNUAL LEVEL OF GOLD PRODUCTION

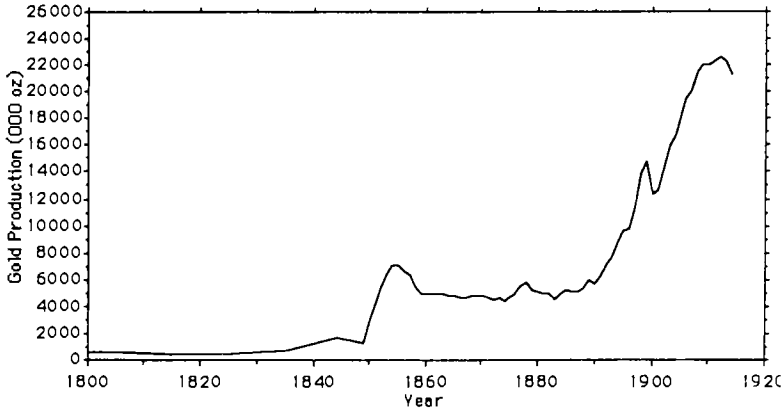
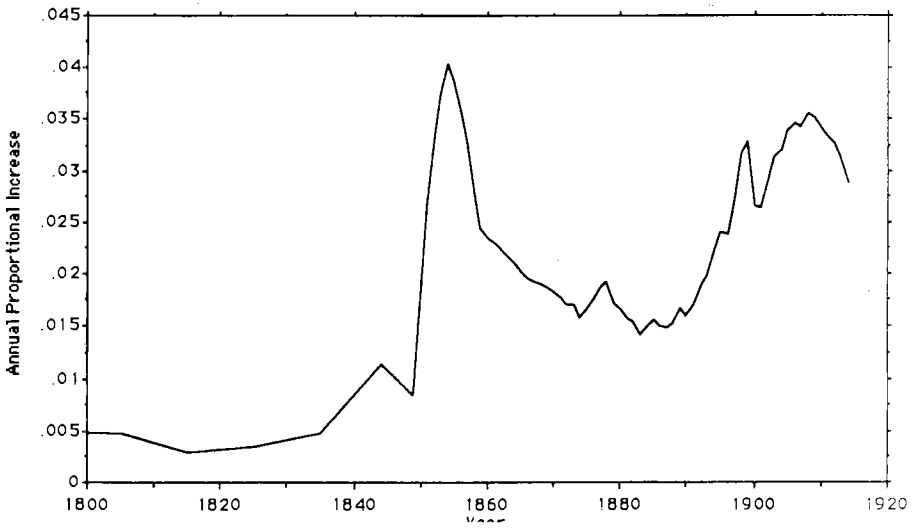


FIGURE 5
RATE OF INCREASE OF CUMULATIVE MINED GOLD STOCK



The gold rushes of the 1850's raised North America and Australia to the ranks of the world's largest gold producers. The expansion of gold production was very rapid. Gold deposits were rich and could be mined by hand. No great input of capital or infrastructure was required before Australia and North

America could begin producing gold in large quantities.

The 1880's saw the three largest gold producers—North America, Australia, and Russia, in that order—produce more than three quarters of the total addition to the world's gold supply (Financial Review Annual (1913)). A small discovery of deposits in South Africa led to prospecting which culminated in the discovery of the main reef of gold deposits in the Rand region of South Africa—present day Johannes-burg—in 1886 (Wheatcroft (1985)). The 1890's saw significant discoveries in Australia and in North America. By 1906-1910 Australian and North American production had each tripled relative to their 1886-1890 levels. Of the "big three" of gold producers before 1890, only Russia had failed to significantly increase its gold output. But the most dramatic addition to gold output in the post-1890 period came from the exploitation of South African gold deposits in particular the Rand.

In spite of the discovery of the Rand gold reef in 1886, it took almost a generation for mining operations to become fully established. In 1887 South Africa produced only 28,000 ounces of gold. By 1890 production was up to 480,000 ounces. This was less than ten percent of the world's gold produc-tion in 1890, only twelve percent of what the Rand would produce in 1899, and only a twentieth of what the Rand would produce in the years immediately preceding World War I. The long lapse of time between the discovery of the Rand on the one hand and the full establishment of gold mining on the other stems from two causes: the poor quality of the Rand's gold deposits, and the isolated location of the gold field. By contrast, the gold discoveries of the 1850's were quickly exploited.

The Rand gold deposits are the largest and among the poorest in the world. By 1889—only three years after the discovery of the gold field and after only some 600,000 ounces had been recovered—gold production in South Africa faced a technological barrier. The remaining gold was spread thinly throughout

quartz and sulfur-iron pyrite; previous standard methods of extraction could not be used. The telluride ores of Australia and Colorado can contain up to 40 percent gold by weight, but ores in South Africa contained less than one percent gold (Wheatcroft (1985)).

The only way to recover gold from such ores is the cyanide process. Finely-ground ore is added to a solution of calcium cyanide and lime. The gold combines with cyanide, and can then be precipitated by adding zinc. The cyanide process can extract up to nineteen-twentieths of the gold in the ore (Wise (1964)).[1] Profitable use of the cyanide process requires the processing of enormous amounts of ore.

Gold mining in South Africa was thus a very different industry from the placer, hydraulic, or lode mining of Australia or North America. Gold mining in South Africa involved the large scale use of recently-discovered organic chemical processes: South African gold production was one of the high-tech industries of the 1890's. The sophistication of the technology and the large size of efficient scale quickly led to the consolidation of the South African gold industry into a tight oligopoly under the leadership of Rhodes and Oppenheimer (Wheatcroft (1985), Flint (1974)).[2]

When the sophistication of the technology required to exploit the Rand is combined with the reef's location far from transportation to Europe, it seems natural that it might take more than a decade for exploitation to reach full intensity. In 1886 there were some 1800 miles of railroad laid in South Africa, but they were concentrated near the Cape of Good Hope to provide a network for the export of agricultural products. The furthest north the railroad line

[1]One major source of increased production in Australia and North America after 1890 was the use of the cyanide extraction process on the tailings left behind by earlier gold mining operations

[2]The rapid concentration of the South African gold industry is strongly suggestive of the presence of economies of scale of the sort that Chandler (1978) argues lie behind the formation of large, hierarchically-managed, oligopolistic business organizations in the U.S. in the late nineteenth century.

from Cape Town reached in 1886 was the diamond town of Kimberly on the border of what was then the Orange Free State, still some 300 miles from Johannesburg (Hobson (1900), Wheatcroft (1985)).

By 1895 railroad mileage had doubled from 1886, and Johannesburg was connected by rail to seaports from Cape Town on the Atlantic to Lorenço Marques in Mozambique (Wheatcroft (1985)). The tremendous investment required to establish the South African mining industry and link it to industrial Europe was being made. By 1913 British capital invested in South Africa amounted to some £27 per capita—about equal to a year's worth of South African gross national product. More Western European capital was invested per capita in South Africa than in any other area of the globe outside the regions of mass European migration and settlement of Argentina, Australasia, and Canada (De Long (1988)).

There is reason to believe that analysts could have foreseen the expansion in production before it was well under way (Wheatcroft (1986)). This point is reinforced by parallels between the gold discoveries at the end and in the middle of the nineteenth century. The gold booms of the 1850's and the 1890's involved very similar sudden shifts in the rate at which the world's total supply of gold was increasing. Anyone who believed that investors and traders have to learn how prices respond to shocks still has to confront the fact that investors and traders could learn about the shifts in the monetary environment likely to come in the 1890's by studying the 1850's before she can conclude that the effects of the Rand took the world by surprise.

From the perspective of an investor in the 1890's, uncertainties intervene. Before anyone could conclude that the rush of the 1890's was of a magnitude similar to the rush of the 1850's, she would have had to resolve three questions: First, how fast would the gold of South Africa be mined? Second, how long would the gold last? Third, would there be any offsets from central bank beha-

vior? Would the increase in total gold induce an increase in private gold reserves, an increase in sterile public gold holdings, a substitution of gold cash for fiduciary money, or even an expansion in the gold area itself? Disturbing causes at any one of these points could interrupt the transmission mechanism that leads from the gold stock to the price level.

III. STATISTICAL FORECASTS OF INFLATION

ARIMA Characterizations of Price Level Dynamics

As Barsky (1987) argued, the absence of any correlation between ex post inflation rates and nominal interest rates may not be strong evidence against the Fisher effect. If inflation was unforecastable, there would be no correlation between ex post inflation and interest rates even if the Fisher effect did hold. One way to assess the forecastability of inflation is to estimate univariate stochastic processes for inflation and see how much of inflation variance is predictable from its own past. A lack of serial correlation in inflation might be a sign that investors before WWI found inflation very difficult to forecast. Box-Jenkins procedures do identify the price level over 1870-1914 as a random walk with little drift, and the inflation rate consequently as approximately zero-mean white noise, in both the U.S. and the U.K.:

TABLE 2
PRE-WORLD WAR I INFLATION AUTOCORRELATIONS, 1870-1914, QUARTERLY DATA

United States								
Lag 1-8	.02	-.03	.10	-.03	-.09	-.08	-.02	.07
Lag 9-16	.08	.06	.00	.14	-.06	-.21	-.10	.08
United Kingdom								
Lag 1-8	.20	.03	.21	-.07	-.19	.03	-.08	-.11
Lag 9-16	.14	.00	-.06	.12	-.11	-.23	-.06	.04

These tests do not reject the null of white noise inflation. For the U.S., statistics are in fact smaller than expected under the null of no serial dependence: Q(8)=3.2, compared to an expected value of 8 and a .05 cutoff of 15.5, for the United States. The test statistics suggest some deviations of UK inflation from white noise: Q(8) = 14.6 compared to the .05 cutoff of 15.5. But test statistics against the null that inflation is an MA(1) at quarterly levels are all well within their expected ranges; whatever deviations from white noise do exist in the UK price level appear to be at short horizons.

The Correlation Between Gold Production and Inflation

Inflation under the gold standard shows little persistence, and the pace at which gold was mined exhibits great persistence. Yet inflation and gold production are correlated. The simple correlation between this year's inflation and last year's gold production is .4 for the United States and .2 for the United Kingdom using the 1870-1914 sample period, and .3 for either the United States or the United Kingdom over the 1879-1914 period. A small, but nonzero part of the year-to-year variance in inflation is forecastable from knowledge of one lag of gold production.[1]

The correlation between the persistent gold production series and the volatile inflation series comes from the association of the upward leap in gold production in the 1890's with the upward shift in average inflation. But the correlation is not solely the result of this one shift in gold production. Wholesale price indices for the U.K. reveal that the correlation between price changes and gold production holds, for the gold standard country of Great Britain, just as strongly for the pre-1870 as for the post-1870 period.

[1]The only troubling note is the size of the estimated coefficient of the response of the price level to an increase in gold production. The quantity theory would lead one to expect a coefficient of one, yet for the U.S. NP deflator and the British WP index, the coefficient is closer to two—albeit imprecisely estimated. We discuss the non-structural nature of these regressions in the next section.

FIGURE 6
US INFLATION AND WORLD GOLD PRODUCTION

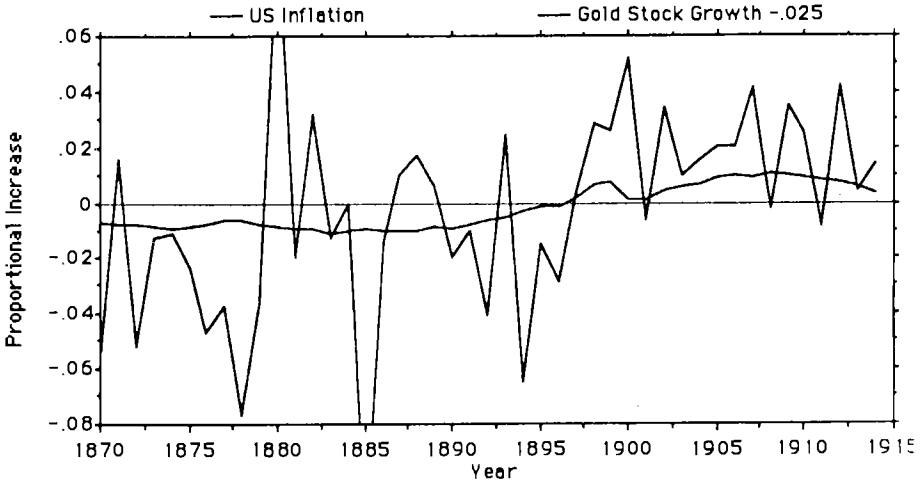


FIGURE 7
BRITISH INFLATION AND WORLD GOLD PRODUCTION

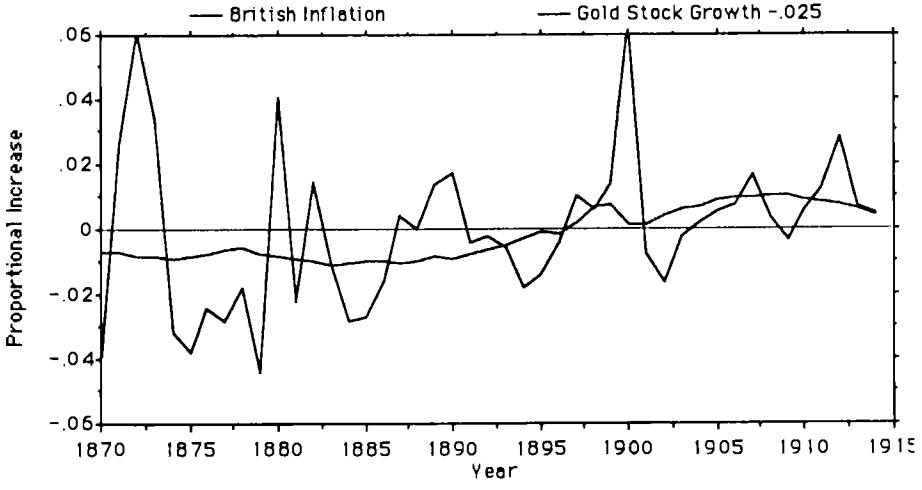


TABLE 3
INFLATION REGRESSED ON GOLD PRODUCTION

Dependent Variable	Period	Coefficient	Standard Error	Durbin Watson	R2
US GNP Deflator	1870-1913	2.11	0.70	2.20	.16
	1880-1913	1.65	0.76	2.38	.10
UK GNP Deflator	1870-1913	0.79	0.46	1.66	.05
	1880-1913	0.75	0.41	2.17	.08
UK WPI (Sauerbeck-Statist)	1848-1913	2.59	0.78	1.72	.12
	1870-1913	2.17	0.98	1.64	.09
	1880-1913	2.47	0.91	1.81	.11

The predictability of inflation from gold production leads one to expect a correlation between nominal interest and that portion of inflation which is itself correlated with gold production. But as table 4 below shows, instrumental variable regressions of interest on ex post inflation rates—which would produce coefficients of unity if past gold production was being properly used to forecast future inflation and if the Fisher relationship held—in every case produce coefficients that are almost zero.

TABLE 4
INSTRUMENTAL VARIABLES REGRESSIONS OF INTEREST RATES ON INFLATION RATES, 1880-1914

Nation	Maturity	Frequency	Coefficient	Standard Error
U.S.	Short-term	Quarterly	.054	.213
U.S.	Short-term	Annual	-.239	.140
U.S.	Long-term	Annual	-.269	.100
U.K.	Short-term	Annual	.086	.073
U.K.	Long-term	Annual	.004	.028

Learning About the Relationship between Gold and Prices

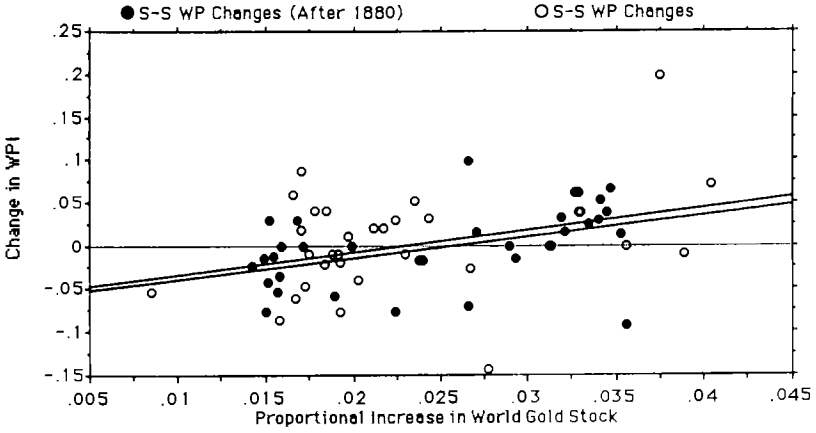
One objection to table 4 is that even if gold production is useful for forecasting inflation over 1870-1914 ex post, it is not necessarily the case that

rational traders and investors could have, or should have, ex ante expected gold production to be useful for forecasting inflation. But this objection is hard to sustain if one analyzes the 1895-1913 gold boom in the context of the gold boom of the 1850's. Wholesale price indices are available for the entire nineteenth century, and gold has a positive correlation with inflation over every part of the nineteenth century for the United Kingdom, which was on the gold standard from the end of the Napoleonic Wars until the beginning of World War I. A similar exercise cannot be carried out for the United States, which inflated to fight the Civil War.

TABLE 5
REGRESSIONS OF UK INFLATION ON INCREASE IN WORLD GOLD STOCK
SAUERBECK-STATIST WPI

Period	Coefficient	Standard Error
1848-1913	2.59	.78
1848-1900	3.29	.98
1848-1890	3.06	1.10
1848-1880	2.97	1.34
1848-1870	3.20	1.53
1870-1913	2.17	.91
1880-1913	2.47	.91

FIGURE B
STABILITY OF THE RELATIONSHIP BETWEEN GOLD AND THE STATIST WPI



The constancy of the relationship between the rate of increase of the world's gold stock and price increases over the nineteenth century is extraordinary. An investor using the standard hypothesis-testing methodology would by 1900 have been able to reject the null of no relationship between gold production and inflation at the .05 level. The fact of association before 1900 should have led investors to pay close attention to gold production in forming forecasts of likely future price changes in the 1890's and after.

IV. ACTUAL EXPECTATIONS OF INFLATION BEFORE WORLD WAR I

Future inflation is correlated with past gold production. Past gold production is in investors' information sets. Yet there is no positive relationship between that portion of inflation forecastable from lagged gold production and nominal interest rates. It might appear that we can conclude that there is strong evidence that money illusion was the rule, rather than the exception, before World War I even among that critical mass of well-informed speculators that economists argue will tend to drive prices in financial markets toward their

fundamental values (Friedman (1953)).

But the case for the conclusion that investors ought to have been using gold production to forecast future inflation rates may not be as strong as it appears. We have followed the accepted canons of procedure by assuming that investors know the parameters of the model—that inflation is correlated with lagged gold production. But if investors are uncertain about the parameters, then it is no longer clear that the instrumental variables regressions of table four are powerful evidence against the Fisher effect. Only if investors know a priori the rate at which changes in the world's gold production translate into changes in the drift of the price level is it clear that the optimal forecast of inflation would pick up the shift in the mean rate of inflation in the decade of the 1890's in which it took place.

In this section we consider not what inflation expectations should have been but what actual inflation expectations were and with why such expectations were held. We examine two bodies of evidence, first the academic debate over the quantity theory and the causes of secular changes in prices carried out in the forerunners of the American Economic Review, and second the journalistic assessments of gold, prices, inflation, and interest rates contained in the London Economist. Although we find a great deal of interest in the rate of gold production and the causes of secular price changes, we find no consensus of informed positions and no explicit forecasts of positive inflation in the years before WWII.

Academic Opinion

An American bond trader who turned to academic opinion for inflation forecasts for a model on which to base an analysis of price level changes faced no easy task, for economists in the U.S. were divided. One could not read the literature put out by economists in search of an answer unless one was willing to

become an economist and judge the monetarist-antimonetarist debate for oneself. We have argued above that attachment to the quantity theory would have allowed investors to recognize the shift in average inflation. However, no investor approaching the economics debate with an uninformed mind would come away convinced that the quantity theory was the proper framework to use to analyze inflation. On the monetarist side of the debate stood economists like Irving Fisher who were strong believers in the quantity theory and in the close dependence of the quantity of money on the gold stock. On the antimonetarist side stood economists like Laurence Laughlin and David Wells who believed in a "cost of production" theory of the price level.

Laughlin (1894) claimed that "it is arrant demagogism to try to make cotton growers believe that the free coinage of silver can in any way restore the price of cotton, when the fall is due to excessive crops." Wells (1895) argued that "the recent phenomenal decline in prices [over the preceding twenty years] is due so largely to the great multiplication and cheapening of commodities through new conditions of production and distribution, that the influence of any or all other causes combined in contributing to such a result has been inconsiderable." Wells attributed the decline in the nominal price of wheat to declines in freight charges, claiming that reductions in transportation costs were "an agency which sufficiently accounts for a great part of the decline in the price of wheat, and which would have operated all the same even if the relative values of the precious metals... had remained unaltered."

Orthodox monetarist critiques of Laughlin and Wells appear, to us, convincing. Kinder (1899), for example, points out that transportation costs had been falling and production growing for decades before 1870 and had not then been accompanied by falling prices. Irving Fisher (1911) convincingly decomposes changes in prices into changes caused by movements in real income, by movements in velocity, and by movements in the money stock. Yet the anti-

monetarists are not convinced. Of the five joint discussants of Fisher (1911) and Laughlin (1911) at the 1910 American Economic Association meetings, three criticize Fisher and support Laughlin on the grounds that the money supply is endogenous and has at best a tangential relationship to the gold stock.[1]

The assessment of American economists as evenly split between supporters and opponents of the quantity theory is not ours alone. Keynes (1912), lecturing his students before World War I, declared that in Britain the dominance of the quantity theory was complete but that in America the profession was fairly evenly split.[2] Keynes himself had no doubt but that the expanded pace of world gold production meant, given the long-run trends in real production and in financial sophistication, slow inflation. He predicted that "...it seems likely that the annual rise of prices during the next few years can hardly be less than two or three percent. Credit booms and depressions are likely... to make the upward movement irregular."

The lesson we draw from this is that any American trader who, before World War I, turned to the literature of academic economics for help in untangling the determinants of price level changes faced a difficult task. In the United States a respected economist could be found to set forth either the conclusion that changes in the long-run rate of drift of the price level were due to changes in the volume of gold production, or that changes in the long-run rate of drift of the price level were not due to changes in the volume of gold production but to "such things as labor unions, monopolies, extravagance, the tariff, general prosperity, etc." (Houston (1911)). Even in Britain, where the community of academic economists was effectively united, they perceived themselves as having little influence on the thinking of people of affairs. Keynes (1912)—then still a strong monetarist— lamented the fact that :

[1]Fisher's preeminence in this company, although obvious to us, was apparently not clear to contemporary observers, especially those outside academic economics.

[2]Keynes attributed this fact to the failure of American economists to read Alfred Marshall.

> a rise in prices always appears to be due to 'conditions of trade,' and in the case of every article taken by itself a rise in its price is always due to an increase in the demand for it or to a decrease in the supply... as a proximate cause. This is the chief reason why some bankers and many businessmen have always been inclined to doubt the connection of the level of prices to the volume of money—because they cannot perceive through what channels the influence of the one upon the other is exerted.

The disarray of the economics profession in the United States and the lack of authority of the economics profession in the United Kingdom made it unlikely that participants in the financial markets would be taught by economists to use the quantity theory as a basis for analysis and forecasting.

The Economist and Its Forecasts

We also searched for signs that the commercial and financial world had reached practical conclusions about the structure of the economy that the academic world had not. We sought for some sign that the presence of lagged gold production in agents' information sets did lead at least some to anticipate rises in prices as a result of gold discoveries.

Our search took us to the London Economist, as the natural place to find such anticipations if they were held. The London Economist stands out as a stronghold of the quantity theory throughout the period of the pre-WWI gold standard. It (August 14, 1897) heaps scorn on Sir Robert Giffin, who had set himself to demonstrate that "it is the range of prices... which helps to determine the quantity of money in use, and not the quantity of money in use which determines prices," and argues that Giffin's articles themselves demonstrate the falsity of Giffin's doctrine that the money supply is sufficiently endogenous that fluctuations in gold production have little influence on the level of prices. As a

stronghold of the quantity theory, this newspaper should be the locus of much writing that gold discoveries will change the long-run rate of drift of the price level. Yet the quantity-theoretic Economist does not forecast that the wave of gold discoveries in the 1890's will have an appreciable effect on prices.

It is not clear how much weight we should place on our inability to find explicit forecasts of future prices that recognize the shift in inflation that took place around 1896. We have negative evidence only: the dog did not bark in the night. Nevertheless the fact that this newspaper, with its commitment to the quantity theory and its intellectual predisposition to analyze and theorize about the economy rather than merely report, did not make the inflation forecasts we regard as natural—did not take the linear projection of inflation on past gold production and use this projection to assess likely future price changes—suggests that few if any investors in the pre-WWI period saw the two relationships between gold and money and between money and prices as sufficiently strong and reliable to be useful for forecasting purposes.

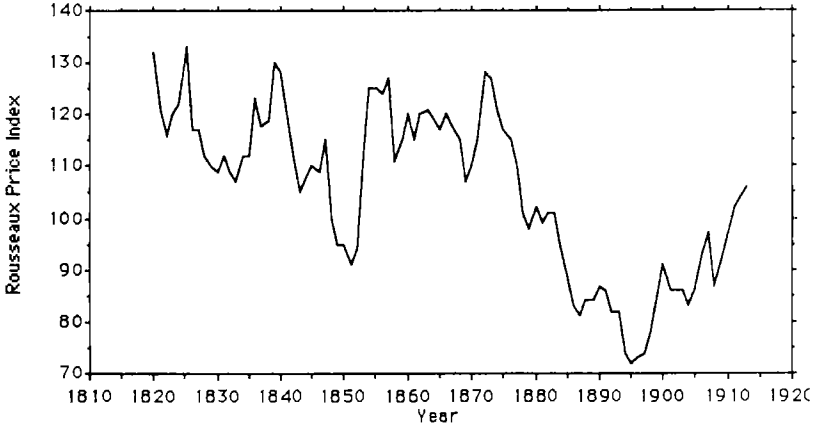
The Economist does recognize that the world's rate of gold production has undergone a substantial shift even before the trough of the price level in 1896. In 1895, when the newspaper attempts to assess the likely effect of the gold discoveries of the 1890's, it looks back to the Australian and Californian gold rushes of 1848-1851. Some then thought that such a wave of gold discoveries must have had large effects on prices. An 1872 letter to the editor (Thomas Hankey, June 15, 1872) notes that gold production from 1850-1870 was equal to the amount of gold brought to Europe from Latin America over 1500-1800, and asks whether "a great effect [on prices] must not now be experienced by the additional production of an equally large amount during so comparatively a short time as twenty years?"

The Economist's 1872 answer is that it did not, that the rise in gold production in the 1850's had no appreciable influence on the course of the

general price level. It stresses how "neutralizing circumstances... the great increase of population and wealth which has occurred... since 1848" raised the demand for gold sufficiently that the increased supply did not lead to any price rises. The conclusion ultimately arrived at is that "we should be inclined to doubt whether it could be proved that the general purchasing power of the sovereign has much diminished since 1850" (June 29, 1872).

According to the available price indices, this assessment by the Economist is wrong. Table 5 above reveals that the gold rushes of the 1850's did have an effect on prices—an effect not statistically significant over 1848-70 in spite of its large magnitude. The break in the 1850's in the declining trend in prices that characterizes the rest of the century should have kept the Economist from concluding that there had been no rise in prices as a result of the gold discoveries of the 1850's. Perhaps distrust of price indices as measures of the true price level accounts for the position that the 1850's rushes had little effect on prices.

FIGURE 11
BRITISH WHOLESALE PRICES



In 1895 the Economist bases its judgment of the likely effect of increased gold mining on its perception that the burst of mining around 1850 had little

effect on the price level:

> "When some fifty years ago, first California and then Australia began to pour out... gold, the Gold Question... came... to be the great economic question of the day.... Broadly speaking, the general expectation was that, owing to the enormous increase in output... there would be a great diminution in the purchasing power of gold or... a great rise in the prices of commodities.... It did not take long, however, to prove that... the hopes and fears excited by... new gold... were greatly exaggerated.... Thus Professor Jevons, writing in 1863, pointed out that 'even after the lapse of ten or twelve years, men who give their whole attention to monetary matters... remain in a state of doubt as to whether any depreciation of gold is really taking place'. And as late as 1873, while maintaining that he had been right in predicting a depreciation of gold, Professor Cairnes wrote 'It is now generally agreed that within twenty years a substantial advance in general prices has taken place. But beyond the general conviction there is little accord. People differ as to the extent of the advance and as to its cause.... Amongst economists... it is pretty well agreed that the advance is... due to... gold discoveries. But... there is, on the part of commercial writers and... all who view the question from the standpoint of practical business, a strong disposition to ignore... the influence of this cause'" (September 28, 1895).

The quantity-theoretic link between the quantity of gold and the level of prices is thus seen as weak in general. The Economist is doubtful that gold mining will raise prices in the particular instance of the South African gold discoveries for at least three reasons. The first is its—ex post false—assessment that the extent of the Rand discoveries will never match in total volume of gold those of the Californian and Australian discoveries of mid-century. The second is the Economist's belief that what matters for the price level is the proportional increase in gold and the gold stock is much larger. And the third arises from the fact that conditions of production are different, that South African gold mining

is a very capital intensive industry (September 28, 1895) as discussed in section II above. From our perspective, the Economist was wrong ex post. But it is not clear that the Economist was wrong ex ante. It certainly is not the case that the Economist's position can be classified as "irrational" in the sense of having clearly failed to take account of and consider the arguments for the belief that the gold discoveries would raise the price level.

Two further years of gold production do not change the newspaper's unwillingness to see the Rand gold discoveries as a source of inflation. On January 16, 1897 the newspaper congratulates itself on having avoided speculating about the likely effects of increased gold production: "When the first important spurt in the new supplies of gold took place... there was a good deal of talk about the possible effect of the increased production upon the prices both of commodities and of securities; but no such result has yet made itself apparent.... [T]he fact is that this large increase in the output of gold has produced very little appreciable effect... for the... reason that... an increased production of three or four millions a year is, relatively speaking, a small matter." And by July the Economist suspects that the entire Rand gold field is close to the edge and is only marginally profitable: "Of the 46 Witwatersrand mines which were crushing during the first quarter... the yield of no less than eighteen was under 30s a ton, and only ten mines yielded over 40s a ton. Until very recently the average total cost on the Rand for working a ton of ore was quite 30s" (July 10, 1897). The only hope they see for a continuation, let alone expansion, of the pace of mining on the Rand is if the employers' cartel is successful at reducing the wages of Black miners.

The Economist's distrust of the permanence of the higher level of gold production is still apparent as late as 1904, when its South African correspondent writes: "The world's output of gold this year will be... not less than £70,000,000 and is likely to be the greatest on record.... But the discovery of

new mines is not keeping pace with the exhaustion of those now being worked, and it seems to me that in a few years the output must reach its zenith and then gradually decline" (September 17, 1904). If the shift in production was not seen as permanent, then there is less reason for expecting it to affect the price level.

Some South African mines did close unexpectedly. Wheatcroft (1986 notes in particular the large losses incurred by speculators in the shares of South African mines in the late 1880's as allegedly promising mines closed. South African mines continued to be perceived on the London capital market as highly speculative investments throughout the pre-WWI period, perhaps reflecting uncertainty about the likelihood of widespread mine closings.[1]

Only in 1908 do we find forecasts of inflation. The first comes in a lette to the editor. C.H. Bennett predicts that "there will be a rise in about ten years of between 5 and 15 percent in general prices... if no other great influence interferes.... The great stimulation of industry, causing a high rate of interest, will naturally lower the price of fixed interest-bearing securities in the long run" (April 11, 1908). He sees not only a link between gold mining and prices but also a link between inflation and the rate of interest. But he speaks of the Fisher effect—the lowering of the price of fixed interest-bearing securities—as something that has not yet occurred but that will come to pass "in the long run." And on December 5, 1908 comes the Economist's attribution of the rise in prices since 1896 to the increase in the gold stock. In response to the question "Has Gold Depreciated?" the newspaper answers in the affirmative: "The quantitative theory of money, with such modifications as have become necessary with the wider use of credit, undoubtedly holds the ground." But even here the newspaper eschews forecasts of future inflation.

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[1]These investments turned out ex post to have been disappointing. Frankel (1967) calculated tha the realized return to all South African gold mining equity over 1887-1913 was 2.1% per year, which is to be contrasted with a realized return on South African banking equity of 10.5% pe year over 1870-1913. See Edelstein (1982).

The Economist notes that modern economies can successfully economize or not on expensive gold: "The spread of banking.. and the development of the use of cheques, have checked a demand for gold which might otherwise have sprung up.... The effect of this economy is very difficult to measure, but its direct tendency is unmistakable, and must have been very powerful." Stress is placed on the increased demand for gold arising from an enlargement of the area covered by the gold standard. "If other commodities are unchanged, and population and business are the same, then if a sovereign is reduced to the value of half-a-sovereign, double the number of sovereigns will be required to make the same payments," but "the qualification that other things must be the same is very important..." (December 28, 1872).

To place the concerns of the Economist's editors in an analytical framework, consider the forward-looking version of the simple monetary model of Cagan (1956) (see Sargent (1979)). Let money demand be given by:

$$(1) \qquad m_t - p_t = -\lambda(E_t p_{t+1} - p_t)$$

where m and p are the logs of the money stock and the price level, respectively. The log of the money stock is the sum of the log of the gold stock and the log money multiplier:

$$(2) \qquad m_t = \mu_t + g_t$$

We assume that the money multiplier may bear a systematic negative relation to the gold stock: both central banks and private institutions economize on gold when it is scarce.

$$(3) \qquad \mu_t = -\theta g_t$$

Last, we assume that the proportional rate of increase in the gold stock $\Delta g_t = g_t - g_{t-1}$ is very persistent from year-to-year with a high probability ρ, but that with a small probability $1-\rho$ in any given year any current bulge in mining may disappear and production may drop down to its trend level. In either case, there

is also a white-noise disturbance v_t:

$$(4) \qquad \Delta g_t = \begin{cases} g_{t-1} + v_t & \text{with probability } \rho \\ v_t & \text{with probability } 1-\rho \end{cases}$$

In this model the expected inflation rate is given by:

$$(5) \qquad E_t\left\{\Delta p_{t+1}\right\} = \frac{\rho(1-\theta)}{1+\lambda(1-\rho)}\Delta g_t$$

Expected inflation is proportional to the rate of increase of the gold stock, with a coefficient not in general equal to one. The coefficient depends on three parameters: the money demand elasticity λ, the probability ρ that gold mining will persist at any present high level, and the value θ of the parameter governing the endogenous offset of gold discoveries by changes in the gold ratio within the world's banking system. If a current high rate of gold mining is thought very likely to persist indefinitely (ρ close to one) and if endogenous offset is small (θ near zero), then inflation will move point-for-point with gold mining. However, if the exhaustion of mines is thought a serious possibility or if the endogenous offset is seen as large, then a rational Economist would not believe that the expansion of gold production in the 1890's signaled a commensurate rise in the inflation rate.

Consider what happens in a period in which gold production does in fact collapse. In such a period, actual inflation exhibits a large negative deviation from trend with a consequent large real capital gain to the holders of nominal assets. This small probability of a collapse in gold production is sufficient to keep the inflation premium in nominal interest rates below the rate that prevails during a gold rush.

Moreover, from the perspective of an analyst in the 1890's, the past relationship between gold and prices carries little information about what either

the offset parameter θ will be in the changed monetary environment of the end of the nineteenth century or what the persistence ρ of gold mining is likely to be in the new and technologically untried mines of South Africa. Accordingly, a refusal to take any past correlation between gold and prices as indicative of the future is comprehensible.

If any set of investors and writers were using lagged gold production to forecast future inflation, one would expect to find traces in the Economist. It was a newspaper that had long cherished close connections with the dismal science. It had no institutional or political bias against the quantity theory—its very refusals to forecast inflation are in general justified by the language of the quantity theory. And it paid great attention to the rate at which gold was being mined throughout the world.

Yet the newspaper always, up until 1908, assesses the confused and complex situation in such a way as to reject the conclusion that the gold discoveries of the 1890's will be followed by price inflation. And it has good reasons, or at least defensible rationalizations, for its judgments: the money multiplier is changing, the velocity of money is changing, the rate of growth of real output in the world is changing as industrialization spreads, the increase in gold mining will have no appreciable influence on the rate of growth of the gold stock, or the Rand deposits cannot be mined for long without becoming exhausted. Though the newspaper's forecasts are wrong ex post and use of them would lead to rejection of the joint null of rational expectations and the Fisher effect at standard significance levels, we cannot bring ourselves to say that the Economist was not processing available information in a reasonable fashion. Ex post, their judgments about the structure of the economy and the lessons to be learned from the 1850's were wrong. But when considered from an ex ante standpoint, their forecasts and arguments appear to be a serious and theoretically-informed attempt to assess the likely future course of the price

level.

V. ADDITIONAL CONSIDERATIONS

We have argued that the lack of correlation between interest rates and that component of inflation forecastable from gold production suggests, according to the standard rules of rational expectations econometrics, a failure of investor rationality. Yet this conclusion hinges on two assumptions: that the real interest rate was stationary over the classical gold standard, and that there is no "peso problem"—a small probability event that does not occur in the sample and yet is important enough to have significant effects on expectations embodied in interest rates.

Marginal Product of Capital

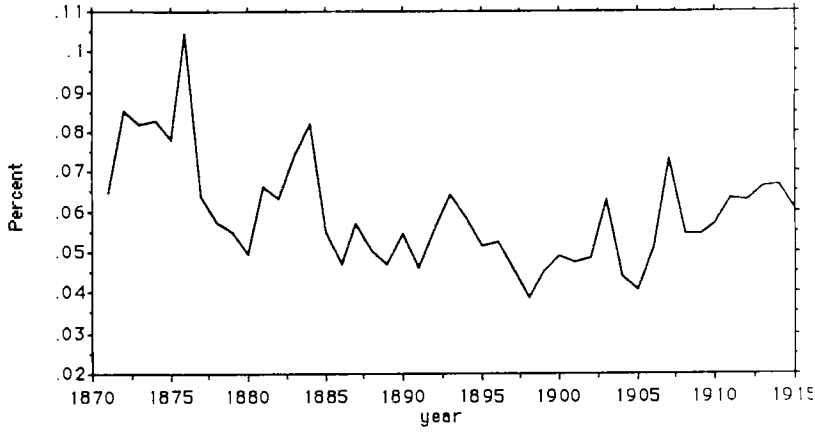
Our conclusions could be reversed if there was a persistent, downward shift in the underlying relevant marginal product of capital around 1896. If there was such a downward shift, then the Fisher effect could have held and would in fact have predicted no significant movement in nominal rates: the downward movement in the ex ante real rate being offset by the upward movement in the drift in the price level. But Barsky and Summers (1988) and Hirschfeld (1988) find no trace of such a movement in required real rates of return. Indeed, they find the required rate of return in the stock market mirrored the price level, starting to rise a bit after 1896 in both the U.S. and the U.K, as can be seen in the U.S. dividend yield plotted in figure 12.

There are signs that the productivity of capital in Britain may have declined significantly in the second half of our sample. Between the peaks of 1898 and 1929, output per capita in Britain rises at the slow pace of 0.3 percent per year, substantially less than either the 1.4 percent per year recorded over

1870-1898 or the 1.6 percent per year recorded over 1929-1973 (Feinstein (1972)). And according to Edelstein (1982), sixteen out of seventeen industries have a lower real rate of return over 1897-1909 than over 1887-1896.

Nevertheless, a real interest rate-based explanation of the apparent failure of the Fisher effect would require that the marginal product of capital in Britain determine the required real rate of return worldwide. In view of the size of capital outflows from the U.K. before World War I to countries of European settlement (e.g., Argentina, Canada, Australia, and the U.S.), we find this possibility unlikely.

FIGURE 12
COWLES DIVIDEND YIELD ON US EQUITIES

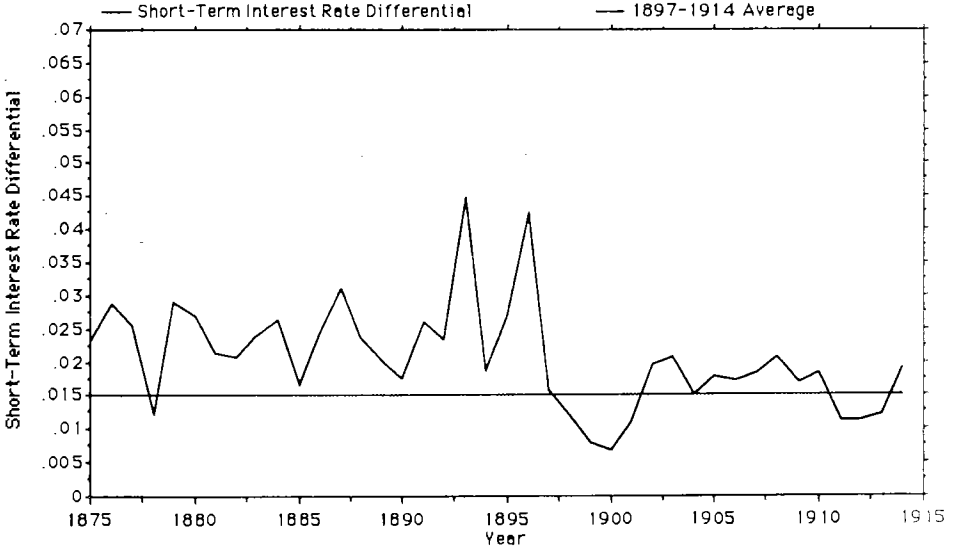


Free Silver

The assumption that the sample distribution matches the population distribution (i.e., no peso problem) is on more shaky ground. We have already discussed the potential peso problem associated with an unobserved collapse of gold production. There is one additional event that was possible and did not

occur: a political victory for free silver forces in the United States and a consequent devaluation. The failure of a Fisher effect is stronger in United States than in United Kingdom data. It may be that for the United States the magnitude of the apparent failure of the Fisher effect is doubled by the coincidence of the shift in inflation and the defeat of the free silver movement.

FIGURE 13
SHORT-TERM INTEREST RATE DIFFERENTIAL BETWEEN US AND UK



Before 1897 it was not certain that the United States would remain on gold. An investor in London seeking an equivalent sterling rate of return would have demanded a premium face interest rate on dollar-denominated assets to compensate for the perceived possibility of United States abandonment of the gold standard and free coinage of silver. Although the United States did stay on gold, it would have been irrational ex ante to assume that it would remain on gold with certainty (Goodwyn (1978)). After 1897, populism disappeared as a

political force and free silver disappeared from the political agenda. The expected depreciation premium that United States nominal interest rates arguably commanded over British rates before 1897 was most likely gone by the decade and a half before World War I (see figure 13).

United States interest rates during the first half of our 1870-1913 sample may thus suffer from a peso problem. Ex ante sterling-denominated United States interest rates were persistently lower than ex post sterling denominated interest rates. Calomiris and Hubbard (1987) document the association between changes in United States and United Kingdom short interest rates after 1898. Using quarterly data, the correlation between changes in commercial paper rates is .61 and the slope of a regression of changes in United States on United Kingdom rates is .86 with a standard error of .14. Using annual average data, the correlation between changes in year-to-year averages is .89, and the regression slope is .87 with a standard error of .12.

Such tight relationships do not hold for the pre-1896 period, when populism was strong. Using annual average data, the correlation between changes in short-term commercial paper rates is .53 and the correlation between long-term bond rates is .04. A considerable part of the shifts in yields calculated for United States long-term bonds is due to changing perceived probabilities of bankruptcy for United States corporations. However, the failure of anything like interest parity to hold for New York and London commercial paper rates before 1896 suggests that perceived exchange risk was breaking the link between short-term rates that one would expect to see under the gold standard.

A difficulty with attributing shifts in the London-New York nominal interest rate differential to a free silver peso problem is that such an explanation implies an implausibly high probability of success for the free silver movement. While the United States was on the international gold standard—1879 to 1913—nominal commercial paper interest rates averaged 2.6% higher in the United

States over 1879-1896 and 1.6% higher over 1897-1913. If we attribute the post-1896 drop in the average interest differential by one percentage point to the removal of a free silver peso problem and agree that the dollar was solidly established on the gold standard after 1896, then the expected depreciation of the dollar over the 1879-1896 interval was about one percent a year. The sixteen to one ratio of silver to gold proposed by free-silver advocates implied a maximum devaluation of the dollar by 25% should a free silver victory occur. Thus the probability that the gold standard would collapse in any given year must have been at least four times the expected depreciation of the dollar, or a four percent chance per year on average. Thus the probability that the gold standard would survive intact from 1879 to 1896 ws no greater than $(0.96)^{17} \approx 0.50$.

Such a high probability of free-silver victory fits uneasily with the assessment of American historians that the populist, free-silver Democrats had little chance of putting their policies into effect. They were a regional, pro-inflation interest that developed little support outside their midwestern heartland (Goodwyn (1976); Hofstadter (1948)). The fact that backing out depreciation expectations from London-based interest differentials gives such a different assessment of the probabilities of populist success from the interpretations of historians gives us pause. It might well be the case that historians, writing with hindsight, have given the dominance of sound money policies an air of inevitability which they did not possess at the time, or it might be that other factors are influencing the New York-London interest differential.

VI. CONCLUDING REMARKS

Many tests reject rational expectations because orthogonality conditions are not satisfied (Rotemberg (1984)). These conditions have the natural interpretation that forecast errors should be uncorrelated with variables known

to be in agents information sets. In the historical situation studied here, orthogonality conditions fail. The expectations of inflation found in interest rates do not depend on gold production in the same way that actual inflation depends on production. Such a finding is indicative of suboptimal forecasting if investors can determine the workings of the economy. But we do not necessarily see the actual discussion of the relationship between gold discoveries and the price level contained in the Economist as showing a failure to rationally process available information. The Economist's model of the economy did turn out to be incorrect ex post. But this does not mean that the Economist was irrational in believing that increases in gold production were not likely to be of enough magnitude to change the long-term drift of the price level. The Economist's failure to predict inflation cannot be easily traced either to an obvious flaw in logic or to an obvious failure to note pieces of readily available information.

We have argued that the failure of agents to exhibit "foresight" with regard to the change in the trend inflation rate after 1896, while inconsistent with some tests of "rational expectations," is not persuasive evidence that investors were negligent or naive in processing information. Rather, the absence of a pre-1914 Fisher effect is not completely surprising once one realizes that previous experience with gold discoveries did not necessarily provide an adequate basis on which to judge either the extent to which the flow of new gold would continue at its rapid rate or the extent to which the institutions governing the velocity of gold might adjust endogenously to the change in the rate of mining. The fact that there had been a (weak) correlation between gold production and price changes in the 1850's would not necessarily lead one to expect this correlation to hold in the different mining and monetary environment of the 1890's.

From the perspective of the mid-1890's, how would an investor rationally decide what structural parameters would be appropriate for understanding the

future relationship between gold and inflation? These issues are easily overlooked by the econometrician, who can with hindsight estimate the "true model" and may ignore the range of parameter values that may have appeared possible to investors at the time. Economists today reach little agreement on the structure of the economy. Different economists believe that expectational errors are orthogonal to different information sets. It thus seems overly harsh to conclude that a failure of expectations implicit in prices to match up with a particular favorite model is evidence of a failure by investors to adequately use the information at their disposal.

APPENDIX: THE FISHER EFFECT AS A LONG RUN PHENOMENON

Suppose that one-period investments in real capital yield a risky expected real rate of return of ρt, and let δt be the net real risk premium required on nominal bonds. Then by definition:

$$(A1) \qquad i_t = E(\Delta p_{t+1}) + r_t$$

where:

$$(A2) \qquad r_t = \rho_t + \delta_t$$

The nominal rate equals the required real rate r_t plus expected inflation $\Delta pt+1$. Imposing rational expectations:

$$(A3) \qquad i_t = \Delta p_{t+1} - \varepsilon_{t+1} + r_t$$

where $\varepsilon t+1$ has the usual properties of an expectational error. In the absence of evidence to the contrary, it seems reasonable to assume that r_t is a stationary stochastic process. The inflation rate $\Delta pt+1$, however, will in general fail to be stationary. Over a sufficiently long time interval, policies will change or the underlying structure will change and impart some drift or jump to average inflation.

The assumptions that the real rate is stationary and the inflation rate is an integrated process themselves guarantee that in the long run the economy will exhibit a Fisher effect, that a properly-instrumented regression of nominal rates on inflation rates will produce a coefficient of one.[1] Consider such an instrumental variables regression of i_t on $\Delta pt+1$, using a valid[2] instrument[3] x_t

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[1] If the inflation rate is stationary, then the Fisher coefficient will be less than one and will be closely linked to the persistence of the inflation process. See McCallum (1984) and Barsky (1987).

[2] x_t possesses a nonzero correlation with $\Delta pt+1$ (and thus must be itself non-stationary) but is uncorrelated with ε_t.

[3] We can allow this instrument to be correlated with ex ante real interest rates without changing the asymptotic results.

over some time interval [0, T]. The expected value of the regression coefficient $\hat{\beta}$ is:

$$(A4) \qquad E(\hat{\beta}) = 1 - \frac{\sigma_{\varepsilon x}}{\sigma_{(\Delta p)(x)}} + \frac{\sigma_{rx}}{\sigma_{(\Delta p)(x)}}$$

where σ's represent population values over the interval [0, T] conditional on the state of the economy at time zero. As the time interval [0, T] becomes longer, the second and third terms of the right hand side of (4) disappear. Because x is a valid instrument, $\sigma_{\varepsilon x}=0$. And since r_t is stationary while Δp_t and x_t are not:

$$(A5) \qquad \lim_{T\to\infty} \left\{ \frac{\sigma_{rx}}{\sigma_{(\Delta p)(x)}} \right\} = 0$$

by the Cauchy-Schwartz inequality, and so:

$$(A6) \qquad \lim_{T\to\infty} \left\{ E(\hat{\beta}) \right\} = 1$$

This is simply a restatement of the point that the Fisher effect is a proposition about the long run reaction of interest rates to permanent shifts in the mean rate of inflation. As long as inflation is subject to permanent shocks and real interest rates are subject to only transitory shocks, an instrumental-variable regression of interest rates on inflation should yield a coefficient of one over a sufficiently long sample.[1]

[1]Summers' (1983) use of band-spectral regression was motivated by a desire to make convergence of this coefficient to one more rapid by improving the small sample properties of the estimate.

REFERENCES

Barro, Robert B. (1979), "Money and the Price Level under the Gold Standard," Economic Journal.

Barsky, Robert B., N. Gregory Mankiw, Jeff Miron, and David Weil (1988), "The Worldwide Change in the Behavior of Prices and Interest Rates," European Economic Review.

Barsky, Robert B. (1987), "The Fisher Effect and the Forecastability and Persistence of Inflation," Journal of Monetary Economics.

Barsky, Robert B., and Lawrence H. Summers (1988), "The Gibson Paradox and the Gold Standard," Journal of Political Economy.

Benjamin, Daniel, and Levis Kochin (1984), "A Martial Solution to Gibson's Paradox," in Michael Bordo and Anna J. Schwartz, eds., A Retrospective on the Classical Gold Standard (Chicago: University of Chicago for NBER).

Cagan, Phillip (1984), "Comment on Benjamin and Kochin," in Bordo and Schwartz.

Cagan, Phillip (1956), "The Monetary Dynamics of Hyperinflation," in Milton Friedman, ed., Studies in the Quantity Theory of Money (Chicago: University of Chicago).

Calomiris, Charles, and R. Glenn Hubbard (1987), "International Adjustment under the Classical Gold Standard" (Cambridge: NBER mimeo).

Chandler, Alfred (1978), The Visible Hand (Cambridge: Harvard).

De Long, J. Bradford (1988), "Have Productivity Levels Converged?" American Economic Review.

De Long, J. Bradford (1987), "Was Inflation 'White Noise' Before World War I?" (Cambridge: M.I.T. mimeo).

Edelstein, Michael (1982), Overseas Investment in the Age of High Imperialism (New York: Columbia).

Flint, John (1974), Cecil Rhodes

Financial Review Annual (various years 1875-1914), (New York: William P. Dana and Co.).

Fisher, Irving (1911), "Recent Changes in Price Levels and Their Causes," American Economic Review 1.

Fisher, Irving (1905), The Rate of Interest (New York: Macmillan).

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

Frankel, S. (1967), Investment and the Return to Equity Capital in the South African Gold Mining Industry (Oxford: Basil Blackwell).

Friedman, Milton (1953), Essays in Positive Economics (Chicago: University of Chicago).

Friedman, Milton, and Anna Jacobson Schwartz (1963), A Monetary History of the United States (Princeton: Princeton University for NBER).

Friedman, Milton, and Anna Jacobson Schwartz (1982), Monetary Trends in the United States and the United Kingdom (Chicago: University of Chicago for NBER).

Friedman, Milton (1969), "Factors Affecting the Level of Interest Rates," Proceedings of the Conference on Savings and Residential Financing (Chicago: The League), pp. 11-27.

Goodwyn, Lawrence (1978) The Populist Moment (Oxford: Oxford).

Harrison, J. Michael (1985), Brownian Motion and Stochastic Flow Systems (New York: Wiley).

Hirschfeld, Mary (1988), "Gibson: A Stubborn Paradox," (Cambridge: Harvard mimeo).

Hobson, J.A. (1900), The War in South Africa

Hofstadter, Richard (1948) The American Political Tradition (New York: Vintage).

Houston, D.F. (1911), "Money and Prices—Discussion," American Economic Review 1.

Keynes, John Maynard (1912), "Lecture Notes for the Lent Term, 1912," in Collected Works, vol. XIII (London: Macmillan).

Kinder, Francis S. (1899), "The Effects of Recent Changes in Monetary Standards Upon the Distribution of Wealth," Economic Studies 4:6.

Laughlin, J. Laurence (1894), Facts About Money

Laughlin, J. Laurence (1911), "Causes of the Changes in Prices Since 1896," American Economic Review 1.

Maddison, Angus (1982), Phases of Capitalist Development (Oxford: Oxford).

McCallum, Bennett (1984), "On Low Frequency Estimates of 'Long Run' Relationships in Macroeconomics," Journal of Monetary Economics.

Rockoff, Hugh (1984), "Some Evidence on the Real Price of Gold," in Bordo and Schwartz.

Rotemberg, Julio (1984), "On Interpreting Some Failures of Rational Expectations Models," American Economic Review Papers and Proceedings.

Sargent, Thomas J. (1973), "Interest Rates and Prices in the Long Run: A Study of the Gibson Paradox," Journal of Money, Credit, and Banking 5,2: 385-449.

Sargent, Thomas J. (1979), Macroeconomic Theory (New York: Academic).

Shiller, Robert J., and Jeremy J. Siegel (1977), "The Gibson Paradox and Historical Movements in Real Interest Rates," Journal of Political Economy 85: 891-907.

Summers, Lawrence H. (1983), "The Nonadjustment of Nominal Interest Rates," in James Tobin, ed., Macroeconomics, Prices, and Quantities: Essays in Memory of Arthur Okun (Washington: the Brookings Institution).

Wells, David A. (1895), Recent Economic Changes

Wheatcroft, Geoffrey (1985), The Randlords

Wise, Edward, ed. (1964), Gold: Recovery, Properties, and Applications