The Intertemporal Nature of Information Conveyed by the Price System

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1 What My Grandfather Told Me

> Prices don't mean anything any more.
> It wasn't like that in my day.

It was 1980, and my grandfather, then 85, had just made these comments on the sale of his neighbour's house for $25,000. The house, built during the war, looked much like his own and all the others in the neighbourhood. They had grown like mushrooms to house the workers in the arms industry and their families near the end of World War II. My grandfather had paid about $3,000 for his house in 1945, and although small, it had been large enough for 13 children. He was becoming interested in house prices because he was hoping to sell his own house shortly. On the day he sold it for $27,000, he turned, perplexed, to my father as they left the notary's office and asked my father if he had robbed his buyer.

Since I was then finishing my PhD on the microeconomic foundations of monetary theory, I predictably and immediately diagnosed my grandfather as suffering from "money illusion." He was confusing nominal values with real ones. How could the price of a house, intrinsically,

* *The author benefited from discussions with Pierre Duguay, Tiff Macklem, Lloyd Paquin, and André Plourde; technical advice from Simon van Norden and Nicholas Ricketts; comments from David Laidler, Angela Redish, Agathe Côté, Benoît Carmichael, and the participants of this conference; and research assistance from Christopher Kuchciak and Valérie Gaudreault.*

mean anything? Are not relative prices the only pertinent source of information for rational agents? I tried once, in vain, to persuade my grandfather to take inflation into account. He answered that you sure learn a lot of amazing stuff in university, and that the modern world was more complicated than the one he had known.

This study aims to make amends to people of another generation, like my grandfather, who were labelled by economists as suffering from money illusion. I am now convinced that my diagnosis at that time was wrong. My grandfather was not suffering from money illusion. He had simply failed to adapt to the change in the monetary regime that had slowly, and at times chaotically, taken place since the early part of the 20th century. My grandfather still worried about the intrinsic price level, because in his day it had been rational to do so.

I base this analysis on a model of individuals' choices, described in the following section. The analysis shows that the price system does not play the same role as a vehicle of intertemporal information under different monetary regimes. For example, if the rate of inflation oscillates within a target range established by the central bank, the price level is integrated of order one, and all the information pertinent to the intertemporal allocation of resources is conveyed by the nominal interest rate. However, under a monetary regime where the level of prices is stationary, the price level conveys intertemporal information in a way similar to the interest rate. In Section 3, I show that we can use the relationship between the level of prices and the nominal interest rate that is predicted by the theoretical model for the case where the price level is stationary to estimate a real interest rate for the gold-standard period. The analysis in this section leads to a new interpretation of the observed empirical relationship, which is known as the Gibson paradox, between the nominal interest rate and the price level during that period.

To date, postwar monetary regimes have proved unable to preserve the value of fiat currencies. A sustained rise in prices, at first barely noticeable, began to rage, and finally skyrocketed, culminating in the first oil-price shock of the late 1970s. At that point, central banks declared out-and-out war on their common enemy, inflation. Since the early 1990s, inflation has receded in many countries, to the point that we are now concerned with the definition of a non-inflationary monetary regime. Given this context, this study contributes to our understanding of agents' behaviour under different monetary regimes. We need such an understanding if we are to define a monetary regime that will safely maximize the spoils of the victory over inflation. The study concludes by drawing some lessons from our analytical framework for the formulation of monetary policy objectives.

2 A Subjective Evaluation of Real Interest Rate and Monetary Regimes

In this section, we analyse a model of individual behaviour to illustrate the role of prices in conveying intertemporal information. We see that this role varies considerably according to the chosen monetary regimes. The analysis, in the tradition of Fisher, provides a microeconomic foundation of the behaviour of agents under alternative monetary regimes.

Consider the model of an individual who is planning consumption c for times t and $t+1$. The utility function is

$$U = U(c_t, c_{t+1}).$$

Assume that c is a non-storable composite good. Assume also that U is increasing in c, concave, and respects the Inada conditions. At time t, the individual receives an exogenous endowment of w_t in money, the numeraire, whose price is normalized to 1. The budget constraint for time t is

$$P_t c_t + s_t = w_t,$$

where P_t is the monetary price of the consumer good at time t. The savings at time t, s_t, generates the holding of an interest-bearing asset between the two periods. The agent consumes the savings at time $t+1$, plus accrued interest of r_t:

$$P_{t+1} c_{t+1} = (1 + r_t) s_t.$$

The individual makes plans for both periods at time t. P_t and r_t are then known. The asset that conveys the savings over time is a fixed-term contract in money terms. At time t, however, P_{t+1} is unknown.[1] The individual's problem, therefore, involves selecting a bundle of goods (c_t, c_{t+1}) that maximizes the following Lagrangian function:

$$L = U(c_t, c_{t+1}) - \lambda\left(P_t c_t + \frac{P_{a,t+1} c_{t+1}}{1 + r_t} - w_t\right),$$

where $P_{a,\, t+1}$ is the anticipated price level for $t+1$ at time t. From the first-order conditions of the maximization problem, it can be shown that individuals maximizing their utility will choose consumption over time to

1. Since the demand for assets comes solely from the need to save for retirement, a non-interest-bearing asset like money has no role to play. The model therefore abstracts from factors related to portfolio choices. It also ignores choices between labour and leisure, to focus on the relationship between the evolution of the price level and the intertemporal consumption choices of individuals.

equalize the marginal rate of intertemporal substitution, the ratio of the marginal utilities U_t and U_{t+1}, to a price ratio. This maximization rule is expressed in logarithmic form as

$$MRIS \equiv \log U_t - \log U_{t+1} = \log(1 + r_t) + p_t - p_{a,t+1},$$

where p and MRIS are the logs of, respectively, the price level and the marginal rate of intertemporal substitution.

The monetary regime affects the maximization problem through the expected price level, $p_{a,t+1}$. Let us assume that the individual forms expectations for p_{t+1} that are consistent with the rule chosen by the monetary authority. We consider two regimes: (R1) in which the monetary authority follows a policy of keeping the *rate of inflation* constant at a level close, or equal, to zero, and (R2) in which the central bank seeks to maintain the *price level* on a given deterministic path. We assume that the central bank achieves its objective and that the rule is perfectly credible.

Under the R1 regime, the central bank does not systematically correct price-level shocks. In this case, the price level is integrated of order one and the inflation rate is stationary. For illustration purposes and with no loss of generality, suppose that the price level can be described by the following stochastic process:

$$p_t = p_{t-1} + \pi + \varepsilon_t, \qquad \text{(R1)}$$

where π is the target inflation rate and ε_t is white noise. Since our aim is to determine the effect of the choice of the monetary rule on individual choices, we need not extend the analysis any further. The analysis proposed here can easily be adapted to a wide range of central bank reaction functions and relationships among the evolution of the production sector, the nominal interest rate, and the price level. To illustrate how an R1 path could be generated at the macro level, assume that y_t, the logarithm of the aggregate endowment of c_t, follows a random walk:

$$y_t = y_{t-1} + \eta_t, \qquad (y = I(1))$$

where η_t is white noise (a supply shock), and movements in the price level are explained by the quantitative theory of money (QTM):

$$m_t = p_t + y_t + \delta_t. \qquad \text{(QTM)}$$

The policy variable m_t is the log of the quantity of money at time t, and $\delta_t - \delta_{t-1}$ is white noise. The stochastic element, integrated of order one, captures a permanent shock to the velocity of money circulation. In this case, the price level will move along a path defined by R1 if the central bank keeps the growth rate of the money supply $(m_t - m_{t-1})$ constant at rate π (and $\varepsilon_t = \delta_t - \delta_{t-1} + \eta_t$).

What happens when individuals form expectations for p_{t+1} that are consistent with the monetary rule? In this case, the anticipated price level for $t+1$ at time t is:

$$p_{a,t+1} = p_t + \pi,$$

and the individual maximizing utility adjusts the MRIS to:

$$MRIS = \log(1 + r_t) - \pi \cong r_t - \pi . \qquad (1)$$

Consumption is adjusted over time to make the MRIS equal to the real interest rate, which is subjectively estimated by the individual as the difference between the nominal interest rate and the expected rate of inflation.[2] The individual does not care about the *level* of prices. Since the price level no longer has any intrinsic meaning, we can consider those who attach importance to the information conveyed by the price level at a given point in time as suffering from money illusion. The nominal interest rate is the only market price that conveys information pertinent for intertemporal choices. A change in the expected inflation rate does not affect individuals' choices if the nominal inflation rate adjusts according to the usual Fisher effect, leaving the MRIS unchanged.

For the second regime we consider, R2, the central bank aims to keep the log of the price level stationary around a deterministic trend,[3] $\mu_t = p_0 + \pi t$. The target level of p_t increases at rate π over time. When the target trend growth rate is zero, long-term price-level stability is observed. To derive a specific formula for the price-level path and for expectations, assume for the sake of illustration, and with no loss of generality for the case under study, that the reaction function of the central bank is

$$m_t = m_{t-1} + \pi + \alpha(\mu_{t-1} - p_{t-1}),$$

where α falls between 0 and 1. The central bank therefore adjusts the money supply by following a partial error-correction process.[4] It is easily shown in this case that, assuming the QTM hypothesis and that $y = \mathrm{I}(1)$, the

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2. The approximation in equation (1) reflects the fact that for interest rates near zero (the interest rate here is calculated as a fraction), r is a close approximation of $log\ (1 + r)$.

3. A rule of this type—where the trend growth rate of prices is zero—was proposed by Simons (1936). See also Barro (1986) and Yeager (1992). A number of studies have focussed on price-level stationarity issues. In particular, see Fillion and Tetlow (1994); Gavin and Stockman (1988, 1991); Lebow, Roberts, and Stockton (1992); McCallum (1990a, 1990b); and McCulloch (1991).

4. McCulloch (1991) proposes a reaction function of this type to maintain price stability.

deviation between the price-level logarithm and its trend follows a stationary AR(1) process:

$$p_t - \mu_t = (1 - \alpha)(p_{t-1} - \mu_{t-1}) + \xi_t\ , \tag{R2}$$

where ξ_t is white noise. If the central bank succeeds in achieving its desired price path, and if individuals' expectations are consistent with the monetary rule, the MRIS of an individual seeking to optimize the return takes the following form:

$$MRIS \cong r_t + \alpha(p_t - \mu_t) - \pi. \tag{2}$$

The log of the current price level contributes to the individual's subjective evaluation of the real interest rate. If the price level at time *t* exceeds its trend value, agents expect a price-level decrease in the proportion $\alpha(p_t - \mu_t) - \pi$ for the following period. In this case, the real ex ante interest rate is higher than the difference between the nominal interest rate and the expected trend inflation rate. By the same token, if the price level is below its trend value, the expectation of its reversion towards long-term equilibrium decreases the subjective assessment of the real interest rate. Note, too, that the trend inflation rate always exerts the same effect on the subjective assessment of the real interest rate through a Fisher effect. This effect should not, however, be confused with the relationship between the *level* of prices and the nominal interest rate, which determines the subjective assessment of the real interest rate. We return to this issue in the next section.

The information pertinent for intertemporal choices emerges from a comparison of the price level p_t against a standard of value μ_t. The fact that this standard of value varies over time complicates the intertemporal choice problem, because individuals measure prices against a benchmark that decreases at rate π. Whether the trend inflation rate is zero or not has no bearing on the problems of choice individuals face when the price level is I(1), because the price level then contains no intertemporal information.

In the present case, however, the central bank should choose a standard of value that is constant over time to simplify the message conveyed by prices.[5] Under these circumstances, which we call price-level stability, equation (2) can be expressed as:

$$MRIS \cong r_t + \alpha(p_t - p_0)\ , \tag{2′}$$

5. Konieczny (1994, 15-18) discusses the role of a stable monetary standard to simplify intertemporal decisions. Howitt (1994, 599-600) remarks that inflation weakens the ability of money to serve as a means of communication, which could generate distortions in the allocation of capital.

where p_0 is the long-term equilibrium level of prices, or the standard of value. The individual can evaluate the real interest rate directly and subjectively on the basis of the information conveyed by the current price level and the nominal interest rate. Because the standard of value is constant, the price level can be considered an intertemporal relative price. To that end, the standard of value should ideally be defined in terms of a basket of goods whose intrinsic qualities do not change over time.[6]

If price-level stability is achieved, the money price of a house at time t intrinsically provides pertinent information on its real value, because it can be compared directly with its price at time $t - i$ without reference to either the price level or its previous growth rate. For example, a house bought for $3,000 at time t is “a good deal” for someone who sells it for $3,500 at time $t + i$. The increase in the money price of the house necessarily implies a relative price increase. If the price level does not change between time t and $t + i$, the price of houses has risen relative to the prices of other goods. If the relative price remains constant between time t and time $t + i$, the rise in the money price of the house implies an increase in its intertemporal value, namely that the price level at time $t + i$ is greater than that observed at time t. Under this kind of monetary regime, money prices have intrinsic meaning. If the price level is stationary around a trend μ increasing over time at rate π, intertemporal price comparisons require a calculator and a knowledge of logarithmic or exponential functions.

From the perspective of macroeconomic analysis, the modelling of the formation process of expectations is a key determinant of the adjustment dynamics. The preceding microeconomic analysis shows that the very nature of the formation process of expectations is substantially altered when one explicitly takes into account rational individual behaviour in a monetary regime where the price level is stationary. We conclude this section by analysing the consequences for the macroeconomic adjustment mechanism of modelling price expectations in a manner that is consistent with a monetary regime where price-level stability is observed.

The adjustment towards macroeconomic equilibrium requires an intertemporal substitution effect in order to balance savings and investment. Macroeconomists have long recognized the danger that a price decrease can have a destabilizing effect on the macroeconomic adjustment mechanism.[7]

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6. On this topic, see the discussion in Yeager (1992).

7. According to Blanchard and Fischer (1989, 548), this is because of the Keynes-Mundell-Tobin effect. In the following discussion, it is assumed that the wealth and debt effects stemming from price-level variations cancel each other out. See also the study by Tobin (1983, Chapter 1).

The traditional analysis suggests that, under conditions of excess supply of goods and services, a price-level decrease can prove destabilizing if it triggers deflationary expectations. These can cause a rise in the real interest rate, which could offset the drop in the nominal interest rate (especially if the nominal interest rate cannot adjust freely below a critical floor level). The signals sent by the price system under these circumstances could work against what is required to maintain equilibrium. Under a stationary price-level regime, the impact of price expectations on the real interest rate is reversed and necessarily stabilizing, because a drop (rise) in the level of prices is equivalent, to some degree, to a drop (rise) in the nominal interest rate.

Taking into account the stabilizing effect of expectations that the price level would return towards its standard of value sheds new light on Summers' (1991) analysis in which he recommends a monetary regime with a positive inflation rate on average. His argument is based on the assumption that the real interest rate cannot be negative in a regime where the trend inflation rate is zero, because the nominal interest rate cannot be lower than zero. In his view, this impossibility can block the maintenance of full employment under certain circumstances.

Summers' concern is justified if the price level is integrated of order one since the subjective real interest rate cannot be negative if inflation is nil $(\pi = 0)$ in the context of equation (1). If the trend inflation rate is positive, however, the subjective real interest rate can become negative in some cases. Summers' (1991) analysis, however, does not apply under a monetary regime where the level of prices is trend stationary, even if the trend inflation rate is zero. As equation (2′) shows, even if the interest rate r cannot drop below a certain threshold, for example r_{min}, the subjective real interest rate will indeed be negative if the price level drops far enough below its long-term equilibrium level:

$$p_t < p_0 - \frac{r_{min}}{\alpha} \; .$$

This analysis of the Summers (1991) effect and the macroeconomic adjustment mechanism illustrates the potential importance of the price level for the determination of the real interest rate. The nominal interest rate is perhaps not the ideal candidate to convey the full range of information pertinent to intertemporal choices. Under a regime where the price level evolves around a standard of value, prices can sustain interest rate movements if the nominal interest rate moves procyclically with the price cycle.[8] In the next section, we show that this is precisely what took place during the gold-standard period.

3 The Gibson Paradox Reconsidered

Historians of economic theory have traditionally described the evolution of the price level in Great Britain during the classical gold-standard period as a stationary process characterized by long swings.[9] From 1717 to 1914, the pound sterling was convertible into gold at a fixed rate. This type of institutional monetary policy framework can ensure a stationary price level if the relative price of gold is itself stationary.[10]

In this section, we seek to determine whether the relationship (2′) in the theoretical model described earlier can be used to explain the evolution of the price level and the nominal interest rate during the gold-standard period. The empirical approach used is simple; more sophisticated and thorough methods would certainly produce more precise and complete results. The statistical analysis attempts to determine whether the expectation of a price-level reversion towards its standard of value contributes plausibly to the subjective evaluation of the real interest rate. In the process, we view with a new perspective the positive correlation between the nominal interest rate and the price level observed during the gold-standard period.

Keynes (1930) called this correlation the Gibson paradox. Figure 1 provides a striking illustration of this phenomenon, which has been

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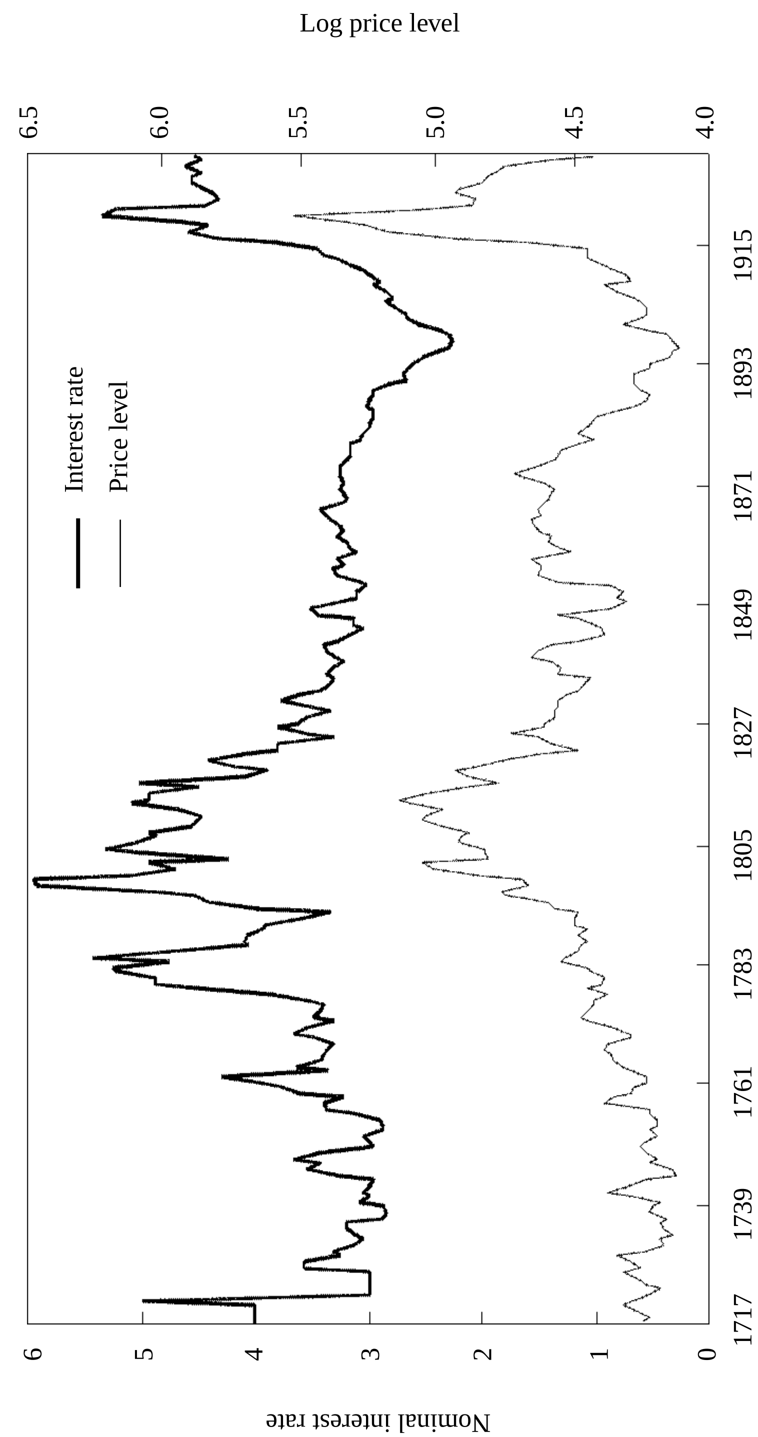
8. There is less need for the nominal interest rate to adjust in this case. This prediction is borne out by the results of the stochastic simulations of a macroeconomic model of the Canadian economy carried out by Black, Macklem, and Rose (this volume). Introducing a function for an anticipated partial price reversion like equation (2″), below, in the context of a monetary rule aimed at maintaining price stability greatly decreases the variability of nominal interest rates. It also stabilizes real production.

9. Mills (1990) comes to this conclusion. The discovery of the New World, however, caused a sustained price rise throughout the 17th century. Beginning in the 18th century, the price level fluctuated around a relatively constant value over time, once the inflationary period due to the massive influx of New World gold had ended. For a thorough study on the subject, see Jastram (1977).

10. For a theoretical analysis of the gold standard, see Barro (1979); for a detailed chronology, refer to Hawtrey (1947). The relative price of gold could be shown to be stationary in comparison with other commodities by using a classical theory of value (see Smith [1776] 1937, Chapter 7), where the natural price of a good is based on its production costs. If the relative price of gold rises above its long-term equilibrium price, resources from other sectors of the economy shift to gold exploration and mining. For the model presented in Section 2, this phenomenon represents an implicit error-correction mechanism.

Figure 1

The Gibson Paradox: The Case of Great Britain



Source: Data for the nominal interest rate are from Homer (1963). The price level is measured as the commodity price index developed by Mitchell and Deane (1962) and Mitchell and Jones (1971).

observed by many economists and the topic of a host of studies.[11] Keynes (1930, 198) defined the Gibson paradox as "one of the most completely established empirical facts within the whole field of quantitative economics." More recently, Benjamin and Kochin (1984, 587) noted that the Gibson paradox was still "one of the best known and least understood of all economic regularities." Economists using a relationship like that of equation (1) to evaluate the real interest rate subjectively will find it paradoxical that a statistical relationship can then be found between the *level* of prices and the interest rate, two variables that are apparently not of the same nature. As Friedman and Schwartz (1982, 527) put it:

> On theoretical grounds, there is no reason to expect any direct relation between the nominal rate of interest and the level of prices. The rate of interest is a pure number.… The level of prices is not a pure number; it has the dimensions of dollars.

As a starting point for our study, we assume that price-level movements during the gold-standard period in Great Britain can be represented as a stationary process in level.[12] We also assume that individuals form price-level expectations that are consistent with an estimated autoregressive moving average (ARMA) process.[13] In this way, we can use an equation like (2′) from the previous model to measure the real interest rate as subjectively determined by agents. The period of analysis starts in 1717 when, de facto, Great Britain was on a gold standard following the undervaluation of silver by Sir Isaac Newton, the Master of the Mint.

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11. In particular see Wicksell (1907); Fisher (1907, 1930); Keynes (1930, Chapter 30); Cagan (1965); Sargent (1973); Shiller and Siegel (1977); Friedman and Schwartz (1982, Chapter 10); Lee and Petruzzi (1986, 1987a, 1987b); Barsky and Summers (1988); Corbae and Ouliaris (1989); Chen and Lee (1990); Mills (1990); and Sumner (1993). Since Lee and Petruzzi (1987a) and Barsky and Summers (1988), the Gibson paradox has been interpreted as a phenomenon associated with the gold standard.

12. A stationary time series characterized by long swings can be represented by a stochastic, autoregressive process with a quasi unit root. It is therefore difficult to determine in this case whether the series is stationary or integrated of order one. On the basis of Said-Dickey tests, Mills (1990) nevertheless shows that the unit-root hypothesis can be rejected for the price level in Great Britain for the period 1729-1931 at the 5 per cent significance level. Kuchciak (1997) comes to a similar conclusion on the basis of Phillips-Perron and augmented Dickey-Fuller (ADF) tests carried out for the period 1717-1931. We tested the unit-root hypothesis for the log of the level of prices for the period 1717-1931 using the ADF test. We used the procedure proposed by Perron (1992) to select the lag number k for the parametric correction. The t-statistic for the ADF test (without trend, with constant term) for $k = 1$ (the optimal number) is –2.95. The unit-root hypothesis can be rejected in this case at the 5 per cent level. Price-level stationarity represents a reasonable hypothesis in this case.

13. According to Bordo and Kydland (1995, 426), the gold standard in Great Britain could be considered as a policy rule that was fully understood and anticipated by the public.

The period ends in 1914 with the suspension of the convertibility and the outbreak of war. For the purpose of statistical estimates, we divide the years from 1717 to 1914 into two parts to exclude the Napoleonic wars period (between 1793 and 1815). This period experienced a return to bimetallism and a temporary suspension of convertibility. De jure, Great Britain adopted the gold standard in 1816 and fixed the return to convertibility to 1819 at the exchange rate established in 1717 by Newton. The model underlying the creation of expectations in our analysis cannot be used for the 1793-1815 period, therefore, since the model assumes a continuous regime in which individuals expect the price level to reverse towards a standard of value.

We have used the time series of the log of the price level and the rate of return on consols, which are usually used by researchers working on the Gibson paradox.[14] The Box and Jenkins (1970) method was used to identify the ARMA process describing the evolution of p_t for each of the two subperiods: an AR(1) process was selected for the first, and an AR(2) process for the second. For the first period, the estimated process is

$$\underset{}{p_t} = \underset{(88.96)}{0.47} + \underset{(16.97)}{0.89}\, p_{t-1} .$$

For the second period, the AR(2) process was estimated as follows:

$$p_t = \underset{(49.78)}{0.27} + \underset{(11.64)}{1.14}\, p_{t-1} - \underset{(-2.04)}{0.20}\, p_{t-2} .$$

The t ratio is shown in parentheses. For the second period, the AR(2) process has two real characteristic roots of 0.91 and 0.22. Since the dominant root is close to 1, the process is marked by long swings similar to those predicted by the AR(1) process for period 1. For the first period, equation (2′) can be used directly to estimate the real interest rate. For the second, in the case where the price-level logarithm conforms to the following AR(2) process,

$$p_t - p_0 = (1-\alpha_1)(p_{t-1} - p_0) + \alpha_2(p_{t-2} - p_0) + \varepsilon_t ,$$

14. The nominal interest rate for British government consols over the period is that calculated by Homer (1963). The commodity price index developed by Mitchell and Deane (1962) and Mitchell and Jones (1971) is used as a measure of the price level.

where ε_t is white noise, it can be easily shown that equation (2′) becomes:[15]

$$MRIS \cong r_t + (\alpha_1 - \alpha_2)(p_t - p_0) + \alpha_2(p_t - p_{t-1}) \,. \tag{2″}$$

This equation was used to estimate the real interest rate for the post-Napoleonic period. Given the estimates for α_1 and α_2 (1.14 for $1 - \alpha_1$ and – 0.20 for α_2), we can see that, interestingly, the real subjective interest rate is equal to the nominal interest rate plus 6 per cent of the gap between the current price level and its standard of value, minus 20 per cent of the current inflation rate. To determine the real interest rate, a weight is assigned to the gap observed between the price level and the standard of value, as well as a weight to the current inflation rate.

The results of the exercise are presented in Figures 2a and 2b and in Table 1a. For the pre-Napoleonic period, the real interest rate shows a standard deviation of 1.67 per cent, an average of 3.55 per cent, and a minimum-maximum range of 1.16 to 7.8 per cent.[16] The nominal return for this period shows a standard deviation of 0.64 per cent, and minimum-maximum values of 2.83 and 5.41 per cent. The correlation coefficient between the contribution of prices to the nominal interest rate (here referred to as the price contribution) and the nominal interest rate is 0.59. Of the real rate's variance, 53 per cent is due to price-contribution variance, 14 per cent to nominal interest rate variance, and 33 per cent to the covariance.

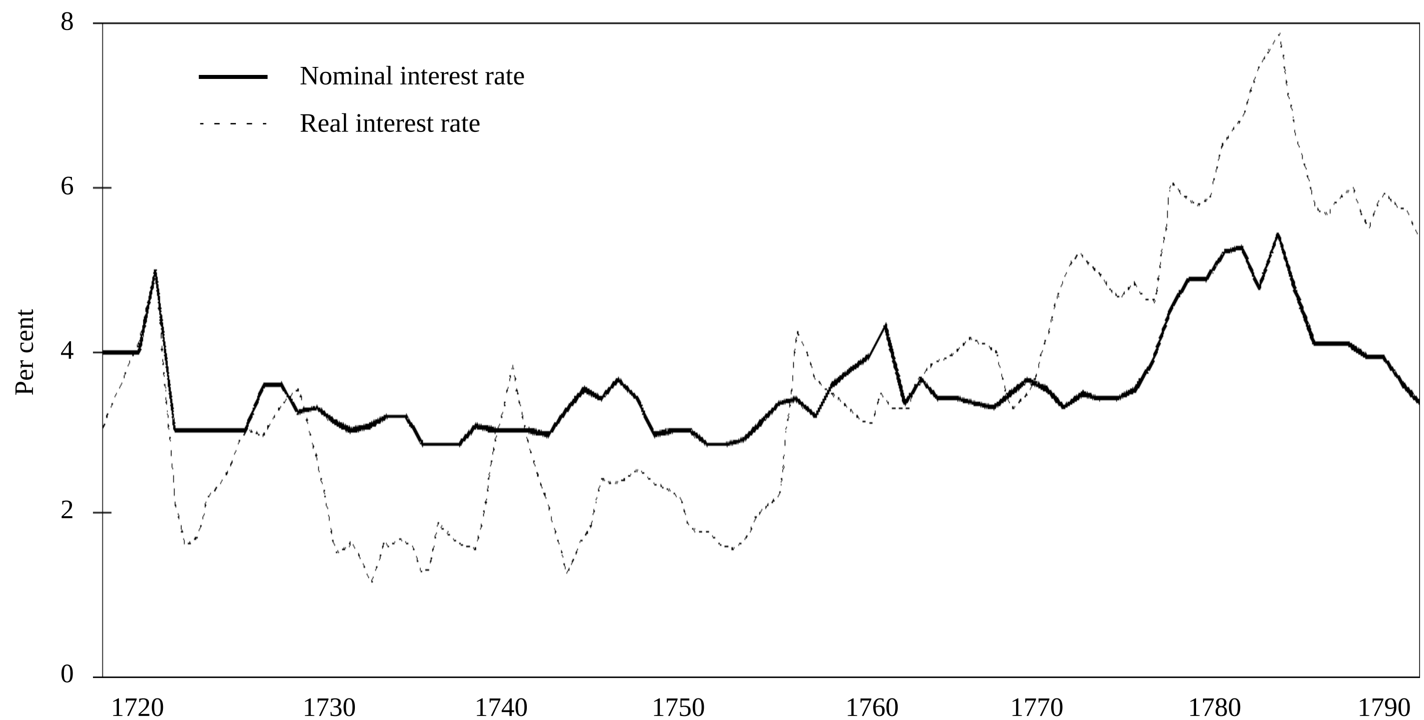
The interest rate is somewhat more variable during the post-Napoleonic period, 1818-1913: the standard deviation is estimated at

15. For example, in the framework of the stylized macroeconomic model of Section 2, an equation like (2″) can be easily derived if the y = I(1) equation is replaced by $y_t = y_{t-1} + \rho(y_{t-1} - y_{t-2}) + \varepsilon_t$. In this case, the theoretical MRIS equals $r - \rho(p_t - p_{t-1}) + \alpha(1 - \rho)(p_t - p_0)$. Given the estimated parameters for the AR(2) process, the point estimate of the autocorrelation coefficient ρ, for the growth rate of output, equals 0.20 and the point estimate of the error-correction coefficient α equals 0.075.

16. It should be noted that, even though the real interest rate estimated through this exercise is calculated from the return on consols, it cannot be considered to be the long-term real interest rate. Because it is determined on the basis of the expectation that prices will move back partially towards their standard of value in the following year, it is a subjective evaluation of the real interest rate for the next year on the basis of the real rate of return, discounted for the holding of consols for a one-year period. It is implicitly assumed that the expected capital gain for the holding of the consols is zero. Ideally, we should have used the data on the nominal return of a one-year debt security at the start of the year to estimate the real interest rate. Only data on the rates of return on consols, however, can be used to reconstruct a reasonably reliable chronological series to track interest rate developments in the 18th and 19th centuries. Rate-of-return observations are annual averages. On this topic, see Homer (1963).

Figure 2a

Estimation of the Real Interest Rate in Great Britain from the Long-Run Yield, 1717-92

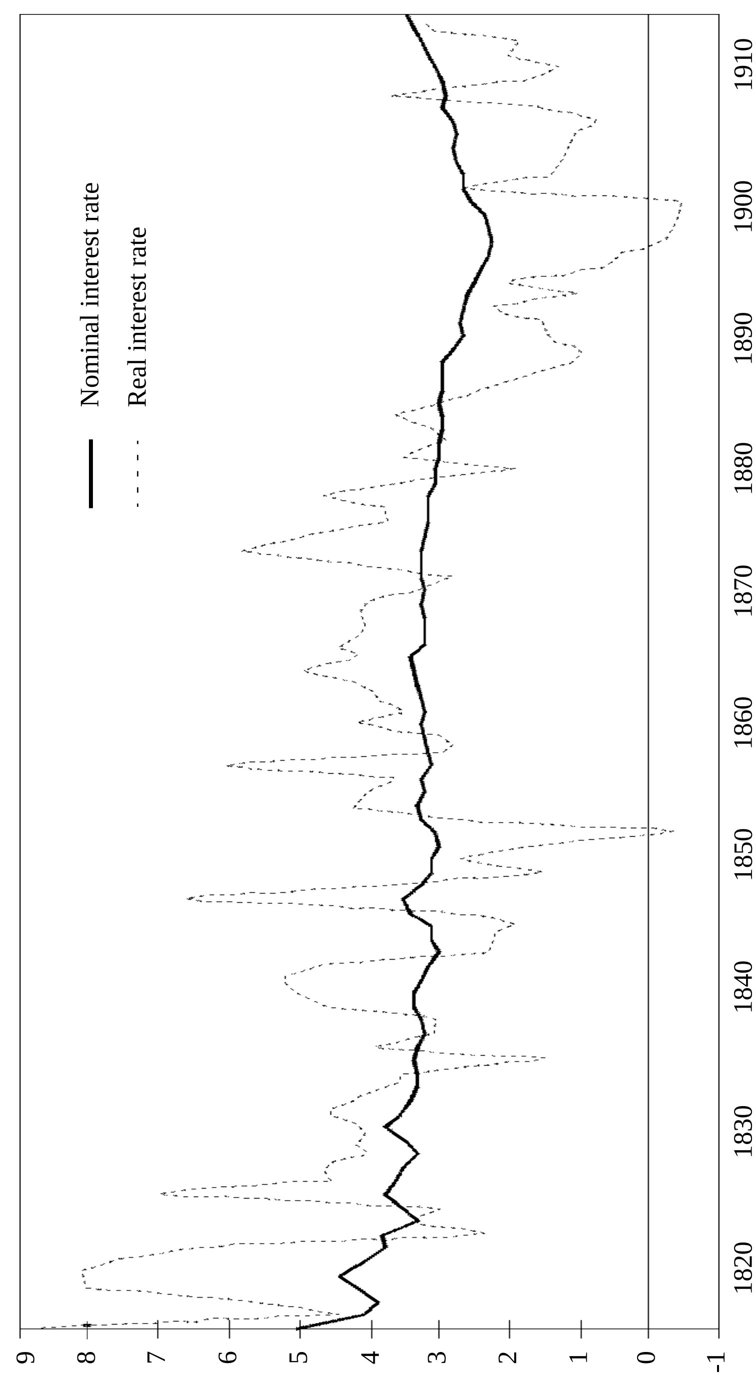


Note: The nominal interest rate is the rate of return on consols (Homer 1963).

Source: Homer (1963) and author’s calculations.

Figure 2b

Estimation of the Real Interest Rate in Great Britain from the Long-Run Yield, 1816-1913



Note: The nominal interest rate is the rate of return on consols (Homer 1963).

Source: Homer (1963) and author's calculations.

Table 1a

Descriptive Statistics: Estimation of the Real Interest Rate in Great Britain from the Long-Run Yield

Level	Average	Standard deviation	Minimum	Maximum
		per cent		
1718-92				
Nominal rate of return	3.57	0.64	2.83	5.41
Price contribution	0.03	1.22	–2.06	2.66
Real rate of return	3.55	1.67	1.16	7.81

Correlation coefficient (nominal rate of return, price contribution) = 0.59
Correlation coefficient (real rate of return, price contribution) = 0.96

Level	Average	Standard deviation	Minimum	Maximum
		per cent		
1818-1913				
Nominal rate of return	3.17	0.40	2.25	4.42
Price contribution	0.07	1.57	–3.47	3.88
Real rate of return	3.25	1.90	–0.40	8.15

Correlation coefficient (nominal rate of return, price contribution) = 0.67
Correlation coefficient (real rate of return, price contribution) = 0.987

Source: Homer (1963) and author's calculations.

1.90 per cent, the average at 3.25 per cent, and maximum-minimum values at 8.15 and –0.40 per cent respectively. Interestingly, the standard deviation of the nominal rate of return during this period reaches only 0.40 per cent. Its correlation coefficient with the price contribution is 0.67. For these two subperiods, therefore, price-level expectations amplify real interest rate variations because they are strongly correlated with the nominal interest rate. For the post-Napoleonic period, however, most real interest rate movement (70 per cent) is explained by the direct contribution of price expectations, since the nominal interest rate varies very little.

In general, the estimated real interest rate peaks during periods of war.[17] It reaches a historical high of more than 8 per cent at the end of the Napoleonic wars and is generally high during the tumultuous second half of the 18th century, which saw the Seven Years War, the War of American Independence, and the French revolutionary wars. The only two periods where a negative real interest rate is observed coincide with major gold

17. The relationship between the estimated real interest rate and periods of war throws new light on the "martial solution" put forward by Benjamin and Kochin (1984) to explain the Gibson paradox. These authors suggest that nominal interest rates and the price level in Great Britain during the gold-standard period can be related to military expenditures.

Table 1b

Descriptive Statistics: Estimation of the Real Interest Rate in Canada from the Long-Run Yield

Level	Average	Standard deviation	Minimum	Maximum
			per cent	
1952-94				
Nominal rate of return	8.25	2.87	3.63	15.22
Expected inflation	4.25	2.95	1.17	11.51
Real rate of return	3.99	2.71	–2.32	9.46

Correlation coefficient (nominal rate of return, expected inflation) = 0.57
Correlation coefficient (real rate of return, expected inflation) = –0.49

Notes: The expected inflation is an annual average estimated from a Markov model (see Laxton, Ricketts, and Rose 1994 for a similar model). The nominal rate of return is the average return on Government of Canada bonds with terms of 10 years and over.

Source: Data were provided by Nicholas Ricketts, Research Department, Bank of Canada.

discoveries and a rapid increase in the world gold supply. According to Hawtrey (1947, 47), the increase in the world's gold supply in 1853, just following the gold rushes in Australia and California, was the most rapid of the century until the 1890s. The end of the 19th century saw the Alaskan and Yukon gold rushes and, especially, the South African gold rushes, as well as the development of the cyanide extraction process (Barsky and Summers, 1988, 598).[18]

Considered in the context of equations (2′) and (2″), the positive correlation between price level and nominal interest rate during the gold-standard period is not paradoxical at all. The nominal interest rate does not need to adjust to variations in the MRIS as much, because it evolves procyclically with the price cycle. Part of the MRIS adjustment follows from the impact on the real interest rate of expectations that the price level would return towards its standard of value.

For comparison purposes, estimates of the expected real interest rate in Canada for the inflationary period 1952-94 are shown in Table 1b. During that period, the price level is not stationary and the real interest rate is estimated on the basis of an equation like (1). The nominal rate of return is the average return on long-term Government of Canada bonds, since this is

18. Between 1880 and 1896, the level of prices in the United States fell by 23 per cent. It was in response to this drop in prices that Frank Baum created the character of Dorothy in *The Wizard of Oz*, published in 1900. The book is an allegorical critique of the gold standard. On this subject, see Rockoff (1990) and Mankiw (1994, 168).

the closest to the return on the consols used during the gold-standard period. The expected inflation rate is taken from a Markov model used by the Bank of Canada Research Department to estimate future inflation in models of the Canadian economy.[19] The real interest rate ranges from −2.32 to 9.46 per cent, and its standard deviation is 2.71 per cent. The real interest rate since 1952 thus shows greater variability than that estimated for the gold-standard period on the basis of the expected price-level return. The nominal interest rate is much more variable than during the gold-standard period, with a standard deviation of 2.87 per cent. Most of the nominal interest rate variability occurs in the 1970-82 period, which saw very strong interest rate fluctuations. Even the periods before 1970 and after 1982, however, show greater nominal interest rate variability than during the gold-standard period. The standard deviation of the nominal rate is 1.13 per cent from 1956 to 1969, and 1.38 per cent during the post-1982 period.

This comparison shows just how far the nominal interest rate has had to adjust in an inflationary world. Under a regime of price-level stability, the nominal interest rate needs to adjust less, for two reasons: the expected trend rate of inflation is constant at zero, and part of the intertemporal information is conveyed by the price system. Finally, the expected real interest rate series has the same episodic character as that observed during the gold-standard period. Up until 1970, the real interest rate fluctuates around the 3 per cent mark. During the 1970s, it is generally negative or zero; and since the early 1980s, it is relatively high, with an average of over 6 per cent.

To verify the robustness of the empirical analysis presented in this section, we re-estimated the real ex ante interest rate using a series of short-term nominal interest rates, again for the case of Great Britain.[20] This series consists of the monthly averages of 3-month rates since 1824. We used the same AR(2) process estimated for the post-Napoleonic period. The results are shown in Figures 3 and 4 and in Table 2. The short-term nominal interest rate series is much more variable than the rate of return on consols, with a standard deviation almost three times higher. The correlation coefficient between the two series is 0.49. The correlation between the price contribution and the short-term nominal interest rate remains positive (0.24), but it is much weaker than that observed with long-term rates of return (0.67).[21] The real interest rate estimated from short-term rates is only slightly more variable than the rate estimated from long-term rates (the standard deviation is 2.02 compared with 1.90), and the correlation between

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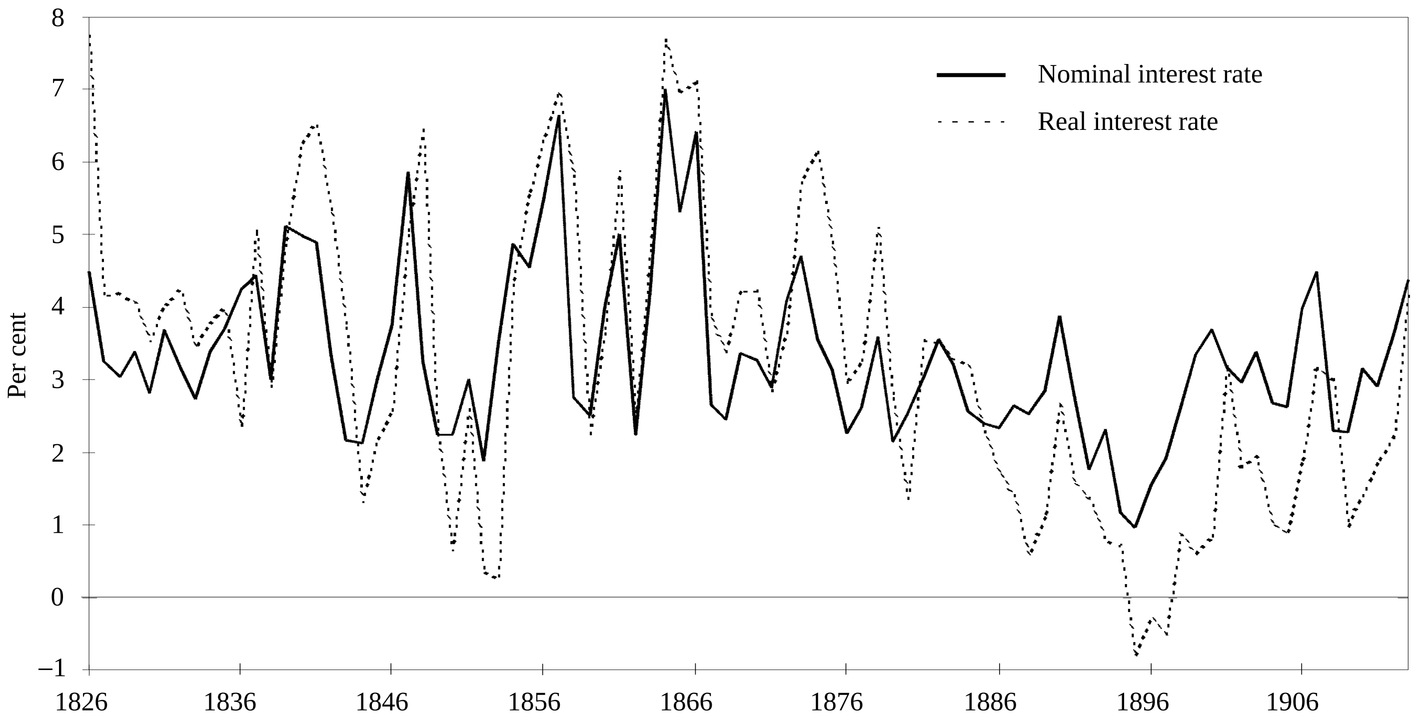
19. On this topic see Laxton, Ricketts, and Rose (1994) and Ricketts (1996).

20. From Mitchell and Deane (1962).

21. Shiller and Siegel (1977, 892-93) call the positive correlation between the short-term nominal interest rate and the price level the Kitchin phenomenon, referring to Joseph Kitchin, who noted this correlation in 1923.

Figure 3

Estimation of the Real Interest Rate in Great Britain from the Short-Run Yield, 1825-1913



Note: The nominal rate is an annual average of the rates of 3-month bills (from Mitchell and Deane 1962).

Figure 4

Comparison of Real Interest Rates Estimated from Short-Run and Long-Run Yields, Great Britain, 1825-1913

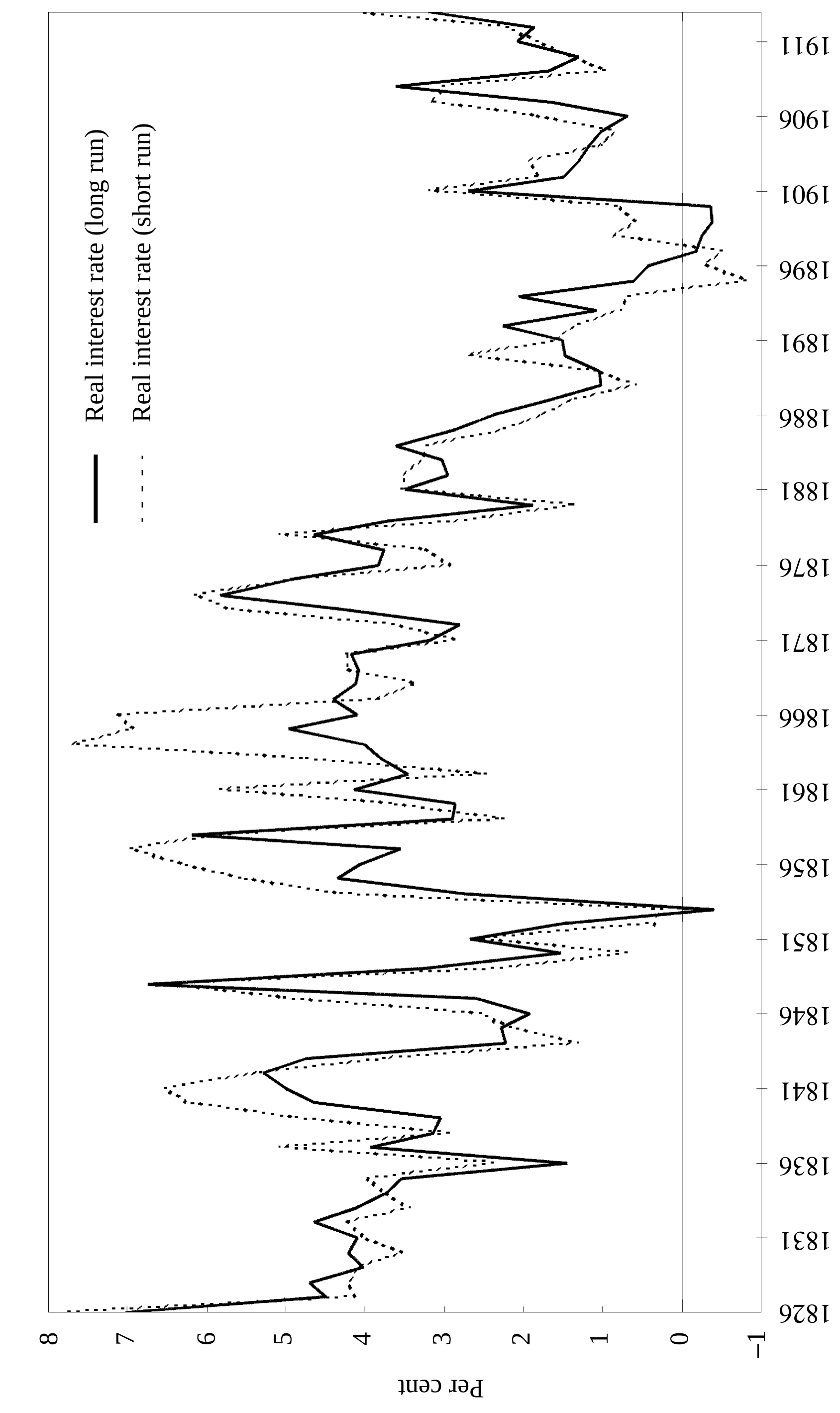


Table 2

Descriptive Statistics: Estimation of the Real Interest Rates in Great Britain from the Short-Run Yield

Level	Average	Standard deviation	Minimum	Maximum
		per cent		
1825-1913				
Nominal rate of return	3.35	1.16	0.96	7.00
Price contribution	−0.13	1.39	–3.47	3.23
Real rate of return	3.22	2.02	−0.81	7.73

Correlation coefficient (nominal rate of return, price contribution) = 0.244
Correlation coefficient (real rate of return, price contribution) = 0.855

the two estimations is extremely strong (0.85). Figure 4 indicates to what extent the estimations of the real interest rate produced by the two methods are comparable. The series generated by long-term rates closely follows the series produced by short-term rates, with a short lag. From a theoretical point of view, the two series should be fairly comparable, since they both measure the real ex ante interest rate associated with holding debt instruments that are, at least to some extent, mutual substitutes.[22]

According to the explanation of the Gibson paradox offered in this section, if the price level is positively correlated with the nominal interest rate, it should also be correlated with the real interest rate. This prediction is compatible with the conclusions of Sargent (1973) and Barsky and Summers (1988), who calculated the real interest rate on the basis of equity returns. Sargent (1973, 446-47) concludes his exhaustive study of the Gibson paradox as follows:

> The Gibson paradox appears to have characterized nominal and real interest rates alike. It follows that it is desirable to have an explanation of the Gibson paradox that focuses on the relationship between movements in real rates of return and the price level.… Our empirical results imply that to explain the Gibson paradox it is not adequate to hypothesize a one-way influence directed from inflation to the interest rate (or, for that

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22. The variance of the contribution, a component common to both estimated real interest rate series, accounts for 69 per cent of the covariance between the series. The remainder is associated with the positive covariances between the contribution and the long-term nominal interest rate (11 per cent), between the contribution and the short-term nominal interest rate (12 per cent), and between the two nominal interest rate series (7 per cent).

> matter, from interest to inflation). Instead, within the context of bivariate models, interest and inflation appear mutually to influence one another.

A unidirectional causal relationship between the expected rate of inflation and the nominal interest rate is the result of the Fisher effect, as shown by equations (1) and (2) of the previous model.

Lastly, the analysis in this section leads to the conclusion that if an economy switches from a stationary price-level regime to an inflationary regime where the price level is integrated of order one, we gradually leave Gibson's world and enter Fisher's. This prediction is consistent with Friedman and Schwartz's (1982, 535) observation about the 1960s—an observation they found so surprising—that "[w]hen interest rates start to parallel price *changes*, they start departing from parallelism with the price *level*" (emphasis in the original). Klein has analysed in depth the transition from the gold standard to the new post–World War II monetary regime. He writes that the change in expectations explains why the St. Louis macroeconomic model included a dummy variable in its interest rate equation for the post-1960 period (Klein 1975, 477). He also notes, like Gordon (1973, 462), that on the basis of Livingston's surveys of economists' price expectations, economists consistently expected a price decrease from 1946 to 1952, except for 1951-52, the two years of the Korean War (Klein 1975, 472). Friedman and Schwartz (1963, 584) also observed this phenomenon from 1946 to 1948 on the basis of a comparison of equity and bond rates of return. During the transition period from the stationary-price monetary regime to the postwar monetary regime, agents' long-expected price declines had never materialized.[23]

My grandfather also probably waited in vain for a price decrease between 1948 and 1954. He retired in 1960, at the time when individuals finally began to take inflation into account. Largely retired from active economic life, he never adjusted his subjective price evaluation system. He never did suffer from money illusion. The model I had used to understand his behaviour had not been appropriate for the monetary regime he had known.[24]

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23. It is not surprising, therefore, that nominal interest rates remained very low during this period, since the expectation of a reversion of prices towards their standard of value increased agents' subjective evaluation of the real interest rate.

24. The Lucas (1976) critique therefore applies to the analyses of economists who used an equation like (1) rather than like (2) or (2′) to evaluate the behaviour of agents in the post-war period, and diagnosed money illusion.

4 The Memory of Prices

The analysis presented in this study affords a new perspective of the problem of the intertemporal choices of agents under different monetary regimes. It improves our understanding of the concept of money illusion, and provides a non-paradoxical explanation for the observed relationship between the price level and nominal interest rates during the gold-standard period. It has also been shown that it is theoretically possible for the real interest rate to become negative under a monetary regime where the trend inflation rate is zero. This actually occurred twice in Great Britain—in 1853 and again from 1896 to 1899. All conclusions in this study follow from a single idea: if the price level follows a stationary path, it conveys some of the information necessary for intertemporal choices, just as the interest rate does.

The recent success of several countries in the fight against inflation raises the question: What is the operational definition of a non-inflationary monetary regime? This study highlights the importance of the price system as a vehicle for intertemporal information on the choice of the optimal monetary regime. Under a monetary regime where the price level is integrated of order one, the nominal interest rate is the only price that contains intertemporal information. The nominal interest rate must, therefore, adjust freely to movements in the marginal rate of intertemporal substitution (MRIS).

If the analysis is limited to the question of intertemporal choice, the Summers effect is the only relevant theoretical argument for choosing a somewhat inflationary regime over another with an average inflation rate of zero. Discounting the nominal interest rate's ability to adjust freely, there is no substantial difference between a situation where the inflation rate remains within a range of 1 to 3 per cent and another where it varies between –1 and 1 per cent. The elimination of the trend inflation rate is really immaterial, since the price level contains no intertemporal information as long as it is integrated of order one.

It has also been shown that only in the context of price-*level* stability does the objective of zero rather than low inflation become truly significant. The elimination of trend inflation then allows agents to use money as an intertemporal unit of account, which greatly simplifies economic calculations. This point is even more important under a regime where the price level is stationary, since the price system then conveys complex information. And since the Summers effect does not apply to a regime of price stability, we must conclude that there is no theoretical reason to choose a regime with a trend stationary price level that is increasing over time. A regime with price-level stability is clearly superior from a theoretical standpoint.

Since the early 1990s, despite a depreciation of the Canadian currency, Canada's inflation rate has fallen and apparently stabilized at the lower end of the Bank of Canada's 1 to 3 per cent target range. This study shows that a stricter and more rigorous monetary objective than that followed since 1992 could only be achieved through a radical change of regime. Indeed, trying to further reduce the target inflation rate, which is already quite low, without opting for a stationary price level appears to be not very useful. In any case, a marginal reduction in the inflation rate target would not be able to eliminate the real problem caused by inflation on intertemporal resource allocation. This is not a problem intrinsic to the inflation rate, as long as the rate is low and stable. It exists because, without a monetary error-correction mechanism, whether automatic, institutional, or discretionary, that could restore a price-stability objective, prices lose their ability to convey pertinent information on intertemporal choices to individuals. Such an objective would restore the memory of prices.

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