The Gibson Paradox and Its Explanations

By

Lu Zhao

(3740897)

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Supervisor: Professor Mario Seccareccia

ECO 7997

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1. Introduction

The strong positive correlation between the nominal interest rate and the price level as well as the inflation rate is generally known as the Gibson paradox[1].

It was termed a paradox because it casts doubt on classical macroeconomic theory. In a conventional macroeconomic model (Mankiw, 1995), an increase in the money supply leads to a reduction of the interest rate, which would stimulate economic activity and therefore would presumably put upward pressure on price movements. Indeed, if aggregate demand is sensitive to interest rate, a decrease of the rate of interest would increase aggregate demand, and accelerate economic activities in society. This will lead to an increase in the rate of inflation according to the conventional macroeconomic framework. Yet we find that when prices rise, interest rates also rise; and vice versa. Therefore, the empirical observation of the positive correlation between the rate of interest and the rate of inflation has been termed a paradox.

Thomas Tooke, one of the founding members of the Banking School in the 19th century, was the first to maintain that there is a direct positive relationship between the rate of interest and price level. In his influential work A History of Prices and of the State of the Circulation from 1793 to 1837, Vol. II of History of Prices (Tooke, 1838), he first identified this positive correlation between interest rate and price level. In 1930, Keynes termed this positive interest rate-price level correlation the "Gibson

Paradox" in his famous A Treatise on Money (1930). Keynes regarded the Gibson paradox as "one of the most completely established empirical facts in the whole field of quantitative economics" (1930, p. 138). In much the same way, after surveying the previous empirical works, Friedman and Schwartz (1982) reported very strong evidence for its existence in the period before the First World War. While after doing a bivariate regression by using the available data from the United Kingdom, the United States, France, and Belgium, Dwyer (1984), suspected that the Gibson Paradox could be unstable and even spurious. "...in the sense of a stable relationship that persists over long periods of time, there is no Gibson Paradox" (Dwyer, 1984, p. 125). Lee and Petruzzi (1986) also found little correlation between prices and the rate of interest. But they found "convincing evidence for the presence of the Gibson Paradox in the gold standard era" (Lee and Petruzzi, 1986, p. 195). So they accounted for the existence of the Gibson Paradox as resulting from the gold standard.

As Benjamin and Kochin (1984, p. 589) remark, the Gibson Paradox is "one of the best known and least understood of all economic regularities". This question has vexed researchers for over 150 years. Many economists have sought to explain such a phenomenon. Tooke (1838) proposed his "cost-push" theory by including money interest among the determinants of normal money production costs, together with money wages and other production costs. This inclusion permitted him to explain the existence, in actual fact, of a direct positive relationship between the interest rate and level of prices. However, both Fisher and Wicksell rejected Tooke's crude "cost-push" explanation. To explore this paradox, Fisher (1907) first proposed his inflationary expectation hypothesis by providing a causality going from changes in the quantity of money (M) to changes in prices (P), and then via the inflationary expectations, to interest rates (i). At about the same time, Wicksell (1898) proposed his central bank reaction function explanation, identifying a reverse causality going from i to P via changes in M.

The rest of this paper is organized as follows. The second section elaborates the main explanations of the Gibson Paradox. In the third section, the author will carry out simple empirical tests to investigate the Gibson correlation between price level (or inflation rate) and interest rates. Interpretations of the three main explanations of the Gibson Paradox will be provided in the fourth section. The fifth section is the conclusion.

2. Main Explanations of the Gibson Paradox

2.1 Tooke's Cost-Push Theory

Some economists seek for provide an explanation that would be obvious at the purely phenomenological level: interest rates are a cost of production and prices are based on costs, therefore interest rate rises would be passed along to consumers in the form of higher prices. They thought: "this explanation suggests itself" (Hannsgen, 2004, p. 2).

However, this view has a checkered history. The early proponent, Tooke (1838), was the first author who was "equipped with an infinite amount of practical experience and unhampered by any very great theoretical ballast" (Wicksell, 1898. p. 69). Tooke insisted that there is a direct relationship between the rate of interest and the price level. In his influential work History of Prices, he first labeled the positive correlation between the interest rate and the price level. To explain this phenomenon, for the first time, Tooke listed the rate of interest among the causes of the high and low prices of the period under consideration (1793-1837). In Vol. II of the History of Prices, he pointed to: "A higher rate of interest constituting an increased cost of production" (Tooke, 1838, p. 847), and "A reduction of the general rate of interest leading to reproduction at a diminished cost" (Tooke, 1838, p. 849). In Tooke's theory, there are three crucial components determining production costs: money wages, interest cost, and production techniques. Taking interest cost into production costs explains the Gibson Paradox, which states the positive correlation between the interest rate and the price level. Moreover, he stated that it is difficult to find the evidence of a low rate of interest associated with rising prices. "The theory is not only not true, but the reverse of the truth" (1844, p. 84). On the basis of Tooke's theory, Pivetti (2001) proposed that if interest rates are a cost of production and prices are based on costs, then an interest rate hike would be passed along to consumers in the form of higher prices.

In more recent times, Taylor's Reconstructing Macroeconomics: Structuralist Proposals and Critiques of the Mainstream (2004, pp. 88-90) provides a similar formulation which treats interest as a cost that enterprises have to pay to hold inventories. Taylor considered it as "a useful point with which to begin our discussion" (Taylor, 2004, p. 88).

According to Taylor (2004), a modified version of the cost decompositions is as follows[2]:

$$wbX + \pi PX + iL = P(C + I + G) + P\dot{Z} + \dot{P}Z$$

Here w is wage, X is output, b is the labor output ratio, P is price, L is loans, π is the profit share, i is the nominal rate of interest, Z is stock of inventories held by firms. $\dot{Z}$ is the change of stock of inventories, and $\dot{P}$ is the change of prices. The left hand side of the function is the total cost of output: wage, profit share, and interest payment; while the right hand side of the equation is the total value of output, including the capital gain. It is apparent that the interest payment iL is treated as a component of the cost of the output.

By assuming that all inventories are financed by loans: $L = PZ$, and inventory is held in proportion to output: $Z = \xi X$, we obtain the pricing rule:

$$P = \frac{wb}{1 - \pi - (i - \hat{P})\xi}$$

"In words, the price level is formed as a markup on wage cost, with the markup rate increasing as a function of the profit share π and the real interest cost $(i - \hat{P})\xi$ of financing of inventory" (Taylor, 2004, p. 89). Hence, much as in Tooke's analysis, higher interest rates would put upward pressure on prices.

2.2 Fisher's Inflationary Expectation Explanation

Fisher's research on interest rates started in the late 19th century. In his Appreciation and Interest in 1896, he first postulated a line of causality going from changes in the quantity of money to changes in price. The effect of inflationary expectation plays the key role in this line of causality. In his 1907 Rate of Interest, he developed this idea, explaining the changes in interest rates as produced by shifts in the demand for loans arising from an unanticipated jump in inflation:

"Three general facts have now been established: (1) Rising and falling prices and wages are directly correlated with high and low rates of interest; (2) The adjustment of interest to price movements is inadequate; (3) This adjustment is more nearly adequate for long than for short periods. These facts are capable of a common explanation expressing the manner in which the adjustment referred to takes place. Suppose an upward movement of prices begins. Business profits will rise…Borrowers can now afford to pay higher 'money interest.' If, however, only a few persons at first see this, the interest will not be fully adjusted, and borrowers will realize an extra margin of profit after deducting interest charges. This raises an expectation of a similar profit in the future and this expectation, acting on the demand for loans, will raise the rate of interest. If the rise is still inadequate, the process is repeated, and thus by continual trial and error the rate approaches the true adjustment" (Fisher, 1907, pp. 284-85).

Fisher believed that it was the expected change in the price level that affects the demand for loanable funds and then the money rate of interest. It is very natural to think that a borrower or lender would be concerned about foreseeing variations in the general price level leading to variations in the buying power of money before making a decision even if it is an unconscious one. "If the price level falls in such a way that they may expect for themselves a shrinking margin of profit, they will be cautious about borrowing unless interest (rate) falls, and this very unwillingness to borrow, lessening the demand in the money market, will tend to bring interest down. On the other hand, if inflation is going on, they will scent rising prices ahead and so rising money profits, and will be stimulated to borrow unless the rate of interest rises enough to discourage them, and their willingness to borrow will itself tend to raise interest." (Fisher, 1930. p. 400)

Some 23 years later, Fisher (1930) expressed the problem in a more formal way by applying distributed lags to the problem in his The Theory of Interest (1930). He considered not only the demand for but also the supply of loanable funds. He made a very important distinction between real and nominal interest rates, on which he based his inflation expectation explanation of the Gibson paradox. As Friedman said later, "Any shortcoming of Fisher's explanation of the Gibson paradox does not, of course, in any way diminish the importance of his distinction between real and nominal interest rates, or his distinction between ex-post and ex-ante real rates, or his emphasis on the anticipated rate of inflation as affecting both the demand for and supply of loanable funds" (Friedman, 1982, p. 553).

As long as there is a tendency for price rises, sooner or later people will come to realize it. This introduces the distinction between nominal and real interest rates. The Fisher effect says that nominal interest rates exceed real rates by the rate of inflation:

$$i = r + \frac{\Delta p}{p}$$

where i is the nominal rate of interest, r is the real rate of interest, which will prevail in the absence of price change. It is simply the rate of return on loans net of depreciation due to inflation, and $\frac{\Delta p}{p}$ is the actual rate of price change. It is clear that i could be observed directly in the market when the borrower or lender make their decisions; however, $\frac{\Delta p}{p}$ and r cannot be known in advance. They can only be calculated after the event, when the security has matured and the rate of price change is known. Hence, what matters for the market is not the ex-post yield, which is realized after the event but what people anticipate in advance. Then we can rewrite the above formula as follows:

$$i = r^e + \left(\frac{\Delta p}{p}\right)^e$$

where r^e is the expected real rate of interest, and $\left(\frac{\Delta p}{p}\right)^e$ is the expected inflation rate. Note that $i = r + \frac{\Delta p}{p}$ is a definitional identity but $i = r^e + \left(\frac{\Delta p}{p}\right)^e$ is a market behavioral equation. Then Fisher's story is as follows: when there is price inflation, the value of nominal assets and liabilities in terms of real goods are lowered, that is a depreciation of loans denominated in money. The depreciation will bring capital gain to borrowers and capital loss to lenders, which are equal in amount. If lenders expect inflation before they lend the money, they will exchange money for goods to protect themselves from the capital loss, because the nominal price of goods will rise with the price level. Therefore, lenders will be willing to invest on nominal assets if and only if they can increase nominal interest rates largely enough to avoid their potential capital loss; and the borrowers will be able to pay higher nominal rate for they can get a capital gain from the inflation. "As the inflation comes to be anticipated, lenders will come to demand higher interest rates and borrowers will be willing to pay higher interest rates. The nominal interest rate must rise above its initial level"(Friedman and Schwartz, 1982, p. 490). If the lenders and borrowers have similar expectations, the nominal rate of interest will exceed the real rate by the expected rate of inflation.

2.3 Wicksell's Central Bank Reaction Function Explanation

As pointed out by Seccareccia (1998): "neoclassical economists showed strong concern with analyzing the causal mechanism between money, interest, and prices that focused on the causality going from interest rates to the money stock. The most celebrated of these neoclassical endogenous money theorists was Wicksell, who, perhaps more than any other provided a coherent theoretical framework" (Seccareccia, 1998, p. 182). Some economists view Wicksell's model as a milestone in the quantity theoretic monetary analysis for it provides the seminal rigorous explanation of how loan created stocks of bank money translate interest rate differentials into price level changes.

Patinkin considers Wicksell's monetary theory as an attempt to extend the application of the quantity theory of money to an economy which has moved beyond the use of metallic money to the use of credit and loans (Patinkin, 1965, pp. 587-8). As Wicksell argues: "If, then, we test the assumptions on which the quantity theory rests, we easily find that this doctrine would be quite true, assuming a state of affairs where everybody buys and sells for cash and with money of their own, that is to say, neither commodity credits nor money loans exist…under these conditions the quantity theory is perfectly true and correct; but it need hardly be pointed out how little they conform to reality, at any rate with present day developments in the monetary system…in reality, at least in the business world proper, all purchases are made against credit for a longer or shorter period, and every businessman, however solvent, repeatedly has occasion to seek monetary credit for his business" (Wicksell, 1989, pp. 73-5).

Nevertheless, Wicksell argues that in a credit money system, it is not only changes in the quantity of money which cause changes in the price level, as postulated by the quantity theorists. Movements in the natural rate of interest could cause movements in the price level even with a fixed stock of metallic money. Wicksell developed his original monetary theory along the lines of loanable fund theorists in the 19^{th} century, for whom the capital market plays the key role in determining the stability of the overall macroeconomy, and inflation results from the discrepancy between investment and saving. It is believed that whenever the potential rate of return on loanable funds exceeds the interest cost of these funds, investment will exceed saving, and then inflation follows. From this, Wicksell got his famous conclusion that interest-rate pegging is a crucial determinant of price fluctuations.

Wicksell's monetary theory rested on his well-known two-interest rate analysis. There were two groups of interest rates in a Wicksellian economic world. The first group was characterized as the "natural rate of interest"[3], which is derived from some Austrian writers; while the second group was named as the "bank rate of interest"[4] (Seccareccia, 1992, p.182). A natural rate is "the rate of interest which would be determined by supply and demand if no use were made of money and all lending were effectuated in the form of real capital goods" (Wicksell, 1898, p. 102). It is the rate of return on the capital advanced, and it is "the rate of interest at which the demand for loan capital and the supply of savings exactly agree"(Wicksell, 1906, vol. II, p. 193). The money rate of interest is the rate set by banks, especially by central banks. In a highly elastic monetary system, the money rate of interest and the natural rate are relatively independent. The relationship between the money and natural rate of interest was then presented in terms of the following general principle:

"At any moment in time in any income situation there is always a certain rate of interest, at which the exchange value of money and the general level of commodity prices have no tendency to change. This can be called the normal rate of interest; its level is determined by the current natural rate of interest, the real return on capital in production, and must rise or fall with this. If the rate of interest on money deviates downwards, be it ever so little, from this normal level, prices will, as long as the deviation lasts, rise continuously; if it deviates upwards, they will fall indefinitely in the same way." (Wicksell, 1898, p. 82)

Seccareccia (1998) provides us with a consistent Wicksellian framework of the central bank reaction function. According to Seccareccia (1998), whenever there is a rise in the natural rate, following a technical improvement in production, the potential profit increase leads to production expansion. Firms must borrow money to finance. Then investment exceeds savings, credit money is created. Wicksell's famous analysis of the cumulative process, according to which price level movements stem from the differential between natural and money rates of interest and continue as long as the differential persists, can be represented in the following equation:

$$I(\rho) - S(i) = \Delta M \qquad (1)$$

where investment I is determined by natural rate ρ, and saving S is determined by money rate i. ΔM is the net money creation. The rate differential is of key importance to Wicksell. It generates a gap between new capital investment and household saving, a gap that manifests itself in the form of an excess aggregate demand for goods that bids up prices cumulatively until the differential vanishes, due to changes in either ρ or i.

Then the price movement can be like this:

$$\frac{\Delta P}{P} = \psi(\rho - i), \quad \psi' > 0. \qquad (2)$$

From equation (2) one could find it clearly that whenever ρ remains above i, there will be inflation; and whenever ρ remains below i, deflation will ensue. As long as there is a discrepancy between ρ and i, the price level will either rise or fall cumulatively.

However, for Wicksell, this was not the end of the story. "Once the entrepreneurs begin to rely upon this process continuing – as soon as, that is to say, they start reckoning on a future rise in prices – the actual rise will become more and more rapid" (Wicksell 1898, p. 148). Then he introduces entrepreneurial inflationary expectation into this model. Equation (1) becomes:

$$I(\rho, \frac{\Delta P^e}{P}) - S(i) = \Delta M, \qquad (3)$$

where $\frac{\Delta P^e}{P}$ is the entrepreneurial inflationary expectation. Supposing a simple positive linear relation between the actual price movement and the expectation, equation (2) becomes:

$$\frac{\Delta P}{P} = \psi(\rho - i) + \gamma \frac{\Delta P^e}{P} \qquad (\gamma > 0). \qquad (4)$$

And then Wicksell assumed a simple one-period extrapolative model of inflationary expectations:

$$\frac{\Delta P^e}{P} = \alpha(\frac{\Delta P}{P})_{-1} \qquad (0 < \alpha < 1). \tag{5}$$

Then we put equation (5) into equation (4), we get:

$$\frac{\Delta P}{P} = \psi(\rho - i) + \gamma\alpha(\frac{\Delta P}{P})_{-1}. \tag{6}$$

From this equation, we can see that inflation becomes cumulative as long as there is a discrepancy between investment and saving.

Wicksell's other contribution is his celebrated feedback policy rule, which provides the Gibson Paradox an excellent explanation. Wicksell thought that the theoretically ideal policy rule was for the central bank to maintain its bank rate in continuous equality with the natural rate. But he also believed that such a rule was not feasible because it required knowledge of the natural rate, an unobservable variable that is impossible to target. Then, he contended that the bank could target the price level. It could determine from movements in the price level whether the bank rate was too low or too high as compared with the unseen natural rate and thus needed adjustment. Under the Wicksellian feedback policy rule, the central bank stabilizes the price level by adjusting its interest rate in response to price level deviations from target, stopping only when prices converge to target. This is the precursor of all feedback policy rules of the monetary theories today. The Wicksellian central bank behavior is as he himself said, "So long as prices remain unaltered the banks' rate of interest is to remain unaltered. If prices rise, the rate of interest is to be raised; and if prices fall, the rate of interest is to be lowered; and the rate of interest is henceforth to be maintained at its new level until a further movement of prices calls for a further change in one direction or the other" (Wicksell, 1898, p.189). Then we can conclude that: "as long as the central bank follows a policy of linking the bank rate to the rate of change in prices, then empirically one would find, as Tooke noticed, a positive correlation between the movement in interest rates and the movement in prices, financed by a flow of endogenous credit-money." (Seccareccia, 1992, pp. 148-49).

The Wicksellian central bank feedback function should be as follows:

$$i = \delta_0 + \delta_1 \frac{\Delta P}{P}. \qquad (7)$$

In this function, we can get a clear positive correlation between interest rate and price movement. So inflation, as well as deflation, is nothing but the effect of the central bank's inability to adjust the bank rate accordingly. If the purpose of the monetary policy is to stabilize the value of money, and the central bank can carry out its monetary policy properly, then the Gibson phenomenon will be observed. Thus, the Gibson paradox is no longer a paradox; it is the outcome of the effectiveness of central banks' monetary policy when they are pursuing price stability.

Many scholars support Wicksell's view on monetary economics. Patinkin (1965) explains how the differential of the natural rate over the bank rate engenders profit opportunities and leads investors to "increase their bank borrowings. The new demand deposits...placed at their disposal will enable them to increase their 'demand for goods and services as well as for raw materials already in the market for future production',"(Patinkin 1965, p. 589-90) and then prices level rises. "By increasing the quantity of money in this way, the banks can bring about any specified price level by maintaining a discrepancy between the market and real rates until the desired price level is reached, and then equalizing the rates at that point"(Patinkin 1965, P. 594). Rate differential leads to money creation, which determines price movement. Earlier still, Marget (1938) derived the same conclusion, arguing that the price level "depends upon the total amount of bank money issued, which in turn, depends upon the relation of bank rate to natural rate" (1938, p. 263), and he suggested that central banks can stabilize the price level by adjusting the bank rate (the bank's loan rate), the mechanism giving rise to changes in money stock created by the loans. This is just what Wicksell's central bank reaction function says. As Myhrman said, Wicksell "explained the role of ... inside money and the rate of interest in the transmission of monetary impulses to the price level. Causation runs from the monetary system to the price level." (1991, p. 272). Moreover, Sargent (1973) developed Wicksell's explanation by generalizing it from changes in supply and demand for loans, which led to a positive correlation between interest rate and prices to changes in aggregate supply and demand.

2.4 Summary

To summarize, in the late 19th century, the finding of the famous Gibson Paradox overthrew the whole classical economic world. The economic theory in existence and the newfound empirical fact are in great contradiction. There are three main theories to explain the Gibson Paradox. As antithesis to the quantity theory, Tooke (1838) brought forward his cost-push theory, which attributes price inflation not to excess money growth, but rather to underlying rises in factor-input prices that enter into unit costs of production. These costs are passed on to consumers in the form of higher prices. The cost-pushers reason that an increase in the rate of interest increases the cost of all products and therefore enhances prices. In response to Tooke's cost-push explanation, Fisher (1907) advanced his inflationary expectation explanation, which states that when investors expect inflation, they will be willing to increase the rate of interest to protect them from capital loss. When there is inflation, the borrowers can gain more profit by investing during inflation, so they are able to afford higher interest rates. Also in response to Tooke's cost-push theory, Wicksell (1898) put forward his celebrated central bank feedback policy explanation based on the existence of interest rate differentials between the natural and money interest rates which then translate into changes in prices.

If any of these three ideas explains the Gibson Paradox which states that there is a positive correlation between the price level (or the inflation rate) and the rate of interest, the Gibson Paradox is no longer a paradox, but a phenomenon. In order to examine these explanations, we should first investigate the Gibson correlation. The following section will fulfill this task.

3. Empirical Study

Firstly, in the section, I will investigate the correlation between price level and rate of interest and the correlation between inflation rate and interest rate as well.

Model

From Section Two, we can see that there should be two models in our consideration, which are slightly different but highly related.

In Tooke's explanation, the rate of interest enters prices as a part of unit cost, thereby suggesting that the levels of interest rate and a general price index ought to be moving together; we can express the linear relationship in this way:

$$p_t = \alpha + \beta i_t + e_t$$

where e_t is the error term. Its semi log-linear form is commonly used, because taking the log of prices converts an exponential trend into a linear trend. However, it is unnecessary to take logs of variables that are rates, such as interest rate r in the above equation. Then the model becomes:

$$\ln p_t = \alpha' + \beta' i_t + e_t$$

where e_t is the error term. On the other hand, according to Wicksell and Fisher, there ought to be a positive correlation between the inflation rate and interest rate, consequently we should also test the following linear model:

$$\frac{\Delta p_t}{p_t} = \gamma + \delta i_t + u_t$$

where u_t is the error term.

Software, Econometric methodologies, and Hypothesis

I will use the well-established statistical software, Eviews 5.0 in the following empirical tests, which blends "the best of modern spreadsheet and relational databases technology with the traditional tasks of statistical software." (www.eviews.com)

In this section, we will use the econometric approach to investigate the Gibson correlation: the correlation between the price level and interest rate and the correlation between the inflation rate and interest rate. The empirical approach will first be followed by examining the correlations between the price level (p_t) and the interest rate (i_t) on one hand, and between the inflation rate ($\frac{\Delta p_t}{p_t}$) and the interest rate (i_t) on the other.

The first step of time series analysis is to investigate the stationarity of the series. The Dickey-Fuller Test with GLS Detrending (DFGLS), and the Phillips-Perron (PP) test are used to determine the presence of unit roots (see Eviews 5.0 help file).

The original Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the series follows an AR (p) process and adding lagged difference terms of the dependent variable to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \cdots + \beta_p \Delta y_{t-p} + v_t$$

with y and x being the dependent and independent variables respectively. The null and alternative hypotheses may be written as,

$H_0 : \alpha = 0; \qquad H_1 : \alpha < 0$

Dickey and Fuller (1979) have shown that the distribution of the t-statistic under the null hypothesis is nonstandard, and the critical values for the test depend on whether or not a constant (or/and trend) is included in the regression. For these cases, Elliott, Rothenberg, Stock (1996) propose a simple modification of the ADF tests in which the data are detrended so that explanatory variables are "taken out" of the data prior to running the test regression. They define a quasi-difference of y_t that depends on the value representing the specific point alternative against which we wish to test the null:

$$y_t^{\bar{\alpha}} = y_t \qquad if\ t = 1$$
$$y_t^{\bar{\alpha}} = y_t - \bar{\alpha} y_{t-1} \qquad if\ t \geq 2$$

Next, consider an OLS regression of the quasi-differenced data $d(y_t|\alpha)$ on the quasi-differenced $d(x_t|\alpha)$:

$$x_t^{\bar{\alpha}} = x_t \qquad if\ t = 1$$
$$x_t^{\bar{\alpha}} = x_t - \bar{\alpha} x_{t-1} \qquad if\ t \geq 2$$

Then define the GLS detrended data: $y_t^{\bar{\alpha}} = y_t - \hat{\psi}^{GLS} x_t$ Hence the DFGLS test involves estimating the standard ADF test equation, after substituting the GLS detrended y_t^d for the original y_t:

$$\Delta y_t^d = \alpha y_{t-1}^d + \beta_1 \Delta y_{t-1}^d + \cdots + \beta_p y_{t-p}^d + v_t$$

The DFGLS-ratio follows a Dickey-Fuller distribution in the constant only case, the asymptotic distribution differs when you include both a constant and trend. The null hypothesis is rejected for values that fall below these critical values.

Phillips and Perron (1988) propose an alternative method of controlling for serial correlation when testing for a unit root. The PP method estimates the non-augmented DF test equation

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \varepsilon_t$$

And modifies the t-ratio of the α coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. The PP test is based on the statistic:

$$\tilde{t}_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0}\right)^{\frac{1}{2}} - \frac{T(f_0 - \gamma_0)(se(\hat{\alpha}))}{2 f_0^{\frac{1}{2}} s}$$

where $\hat{\alpha}$ is the estimate, and t_α the t-ratio of α, $se(\hat{\alpha})$ is coefficient standard error, and s is the standard error of the test regression. In addition, γ_0 is a consistent estimate of the error variance in $\Delta y_t = \alpha y_{t-1} + x_t'\delta + \varepsilon_t$ (calculated as $(T-k)s^2/T$, where k is the number of regressors). The remaining term, f_0, is an estimator of the residual spectrum at frequency zero. The asymptotic distribution of the PP modified t-ratio is the same as that of the ADF statistic (Eviews 5 Users' Guide, pp. 506-509).

After undertaking the unit root test, I will run a regression of prices and inflation rates on rates of interest respectively to investigate the Gibson relationship for three countries: the United States, Canada, and the United Kingdom.

3.1 USA

Data and Graphs

The Board of Governors of the Federal Reserve System offers an abundance of time series data on interest rates for the United States. I used Moody's Seasoned Aaa Corporate Bonds rate to represent the long-term rate of interest. From the US Bureau of Labor Statistics, I obtained the consumer price index (CPI) for all items to represent the price level for the period from 1919 to 2005[5]. Both of them are monthly data. I computed the annual data by averaging the monthly data. The rate of inflation is computed as follows:

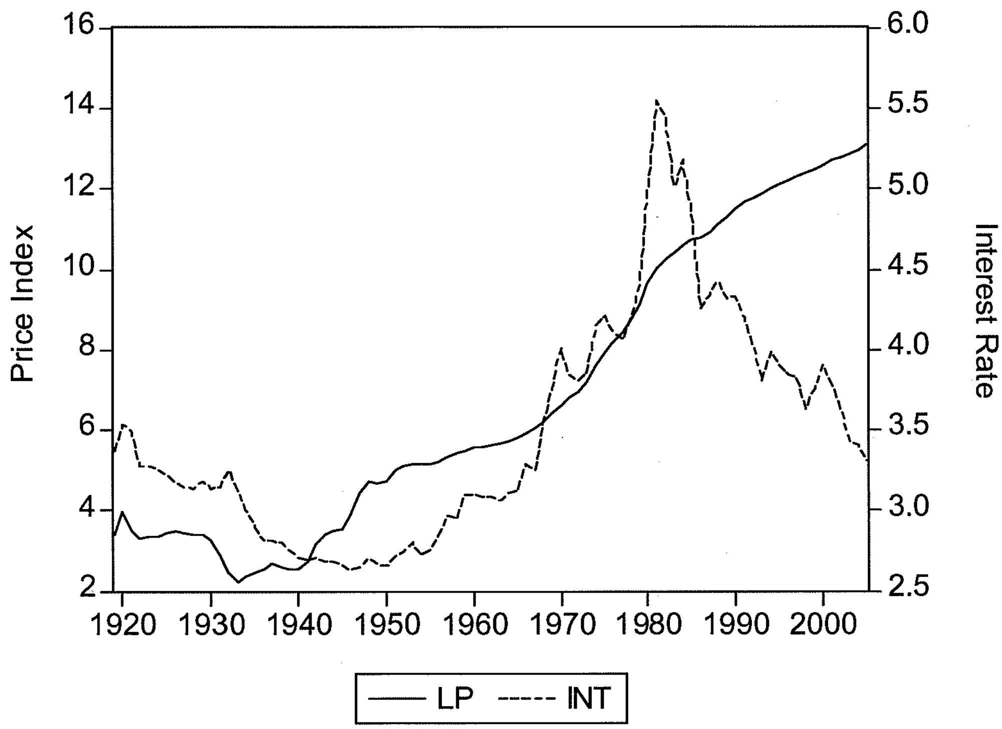
$$\pi_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}}$$

where CPI_t is the annual CPI obtained by averaging monthly data.

In Figure 1, the graph shows comparative time series from 1919 to 2005 for the log of the consumer price index and Moody's Seasoned Aaa Corporate Bonds rate.

FIGURE 1

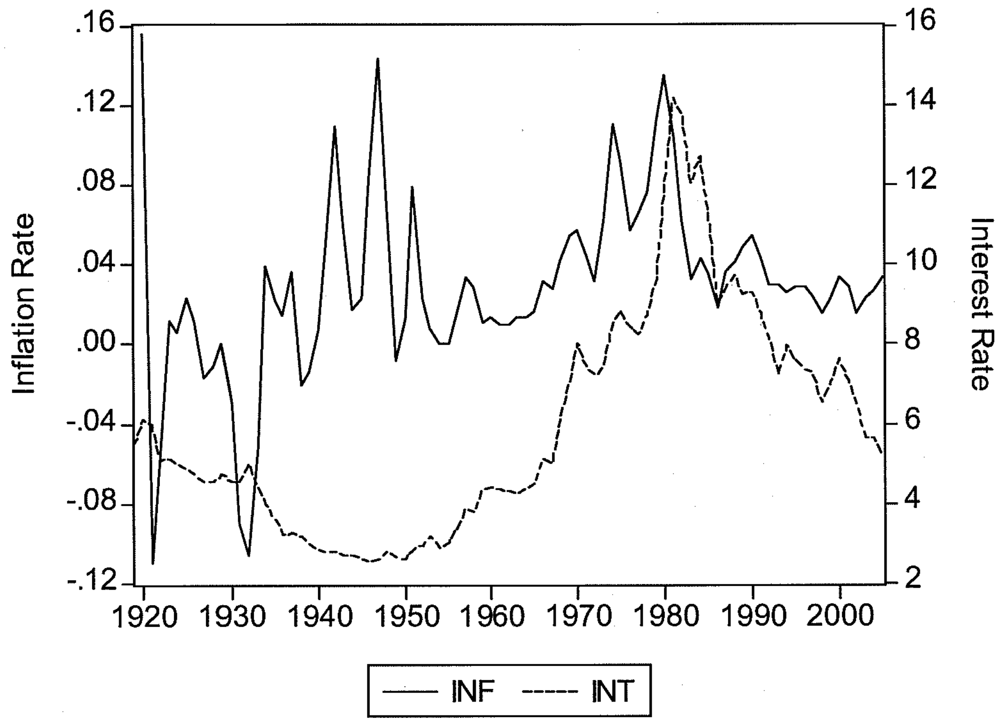
Log of CPI and Interest Rate For US



Just as the Gibson Paradox states, the two curves have similar patterns. However, the interest rate series fluctuates more, especially after 1980.

In Figure 2, the graph shows comparative time series from 1919 to 2005 for the inflation rate and Moody's Seasoned Aaa Corporate Bonds rate

FIGURE 2
Inflation Rate and Interest Rate for US



There is very little trend in the inflation rate, certainly much less than in the behavior of the price level.

Empirical Results

From Figure 1, I found that clearly, the LP (log of CPI) series is not stationary. Then I took the first difference of LP, which was named DLP, and ran a Dickey-Fuller unit root test with GLS Detrending (ERS test) on DLP with Modified Akaike info criterion (MAIC)[6]. The ERS statistic value is -1.072048. EViews reports the critical values at the 1%, 5% and 10% levels. Notice here that the statistic value is greater than the critical values so that we do not reject the null hypothesis that DLP has a unit root at conventional test sizes[7].

Then I took a second difference of LP to see if one could obtain a stationary series. I chose to use the PP test with AR Spectral - GLS detrended as the spectral estimation method and the MAIC [8]. Since the graph of DDLP of the USA does not show any trend or intercept, I chose to include none of them for the PP unit root test. Since the t-statistic falls below the critical value even at 1% significance level, and the p value is 0.0000. So we can reject the null hypothesis that there is a unit root in DDLP.

After have proceeded in testing for the stationarity of the price level, I then followed the same procedure to get a stationary rate of interest. From graph 1 and 2, it is very clear that the interest rate series is not stationary. So I took its first difference, and ran a unit root test on the first difference series. The PP statistic value is -9.720821 and the associated one-sided p-value is 0. In addition, EViews reports the critical values at the 1%, 5% and 10% levels. Here the statistic value is smaller than the critical values so that we can reject the null hypothesis that DI has a unit root. In other words, DI is stationary.

Moreover, I did an ERS test with MAIC on the inflation rate, and found that it is not stationary. Then I took the first difference of the inflation rate series and redid a PP test with MAIC on the first difference of the inflation rate (DINF). I found that the p value is 0.0000, which indicates DINF is stationary.

Finally, I regressed DDLP and DINF on DI respectively to investigate the Gibson correlation, and obtained the following results:

Table 1: Regression Results: Gibson Correlation for USA: 1919-2005

Dependent Variable	Constant Term	DI	R^2	p value of DI
DDLP	-0.001251 *-0.277764*	0.006124 *0.889308*	0.009439	0.3764
DINF	-0.001368 *-0.297477*	0.6762 *0.961897*	0.011025	0.3389

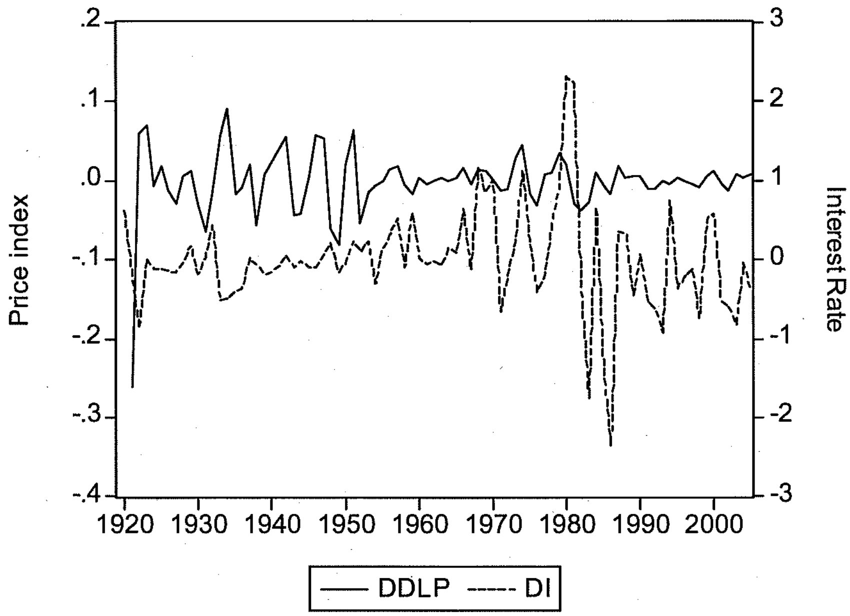
Numbers in italic under the estimated coefficients are the t-ratios, respectively.

From these results, which show that there is a slightly positive correlation between interest and prices, but according to the high p values, we cannot reject the null hypotheses that the correlations are not significant. Then we conclude that there is no Gibson correlation in the United States for the time period under consideration: 1919-2005.

Figure 3 displays the comparative stationary time series data.

FIGURE 3

Second Difference of Log of CPI and First Difference of Rate of Interest



Canada:

Data and Graphs

Statistics Canada provides the long period data that I need. The monthly series of bank rate (the discount rate) of the Bank of Canada to represent the interest rate, and CPI for all items to represents the prices for the period from 1935 to 2005 were used. I computed the annul data by averaging the monthly data. The rate of inflation is computed as follows:

$$\pi_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}}$$

where CPI_t is the annual CPI obtained by averaging the monthly data.

Empirical Results

Following the same test procedure, I found that the first difference of the interest rate, the second difference of the price level and the first difference of the inflation rate are stationary series in the Canadian case. Then I regressed the price level and the inflation rate on the interest rate respectively, and obtained the following results:

Table 2: Regression Results: Gibson Correlation for Canada: 1935-2005

Dependent Variable	Constant Term	DI	R^2	p value of DI
DDLP	4.78E-05 *0.006190*	0.003803 *0.004954*	0.008720	0.4454
DINF	4.74E-05 *0.005439*	0.004092 *0.731005*	0.007913	0.4673

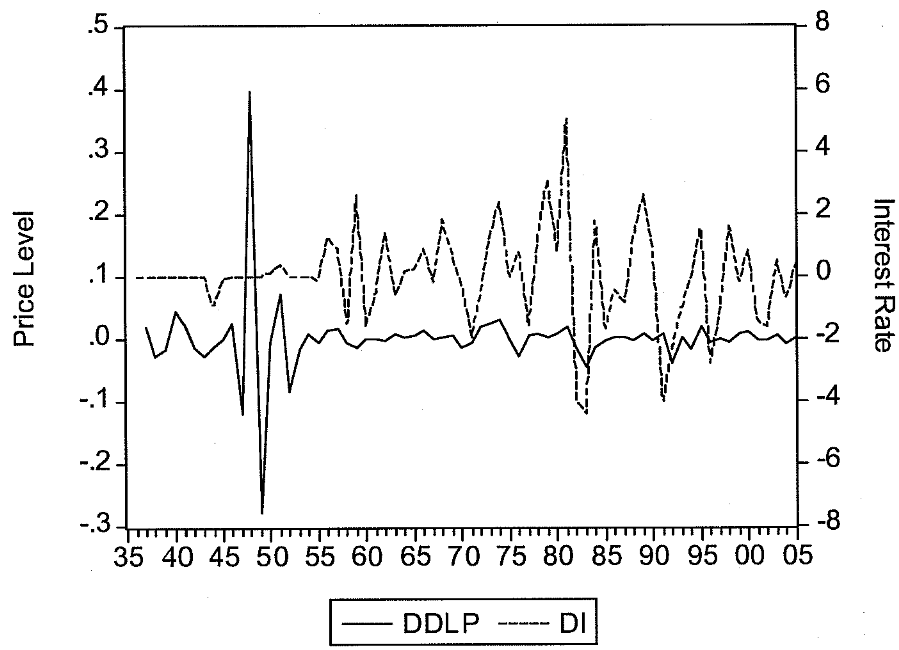
Numbers in italic under the estimated coefficients are the t-ratios, respectively.

Again, the results show that there is a slightly positive correlation between interest and prices, but according to the high p values, we cannot reject the null hypotheses that the correlations are significant. I can get the conclusion that there is no Gibson correlation in Canada for the period under examination: 1935-2005.

Figures 5 and 6 display the comparative stationary time series data.

FIGURE 4

Second Difference of Price Level and First Difference of Interest Rate for Canada



United Kingdom:

Data and Graphs

Data for the United Kingdom are from the IMF International Financial Statistics (IFS). I chose the bank rate to represent the rate of interest, and the CPI for all items to represent prices. Upon availability, the data are taken from 1948 to 2004. Both are monthly data. As before, I computed the annual data by averaging the monthly data, with the rate of inflation being computed as follows:

$$\pi_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}}$$

where CPI_t is the annual CPI obtained by averaging monthly CPI data.

Empirical Results

Using the same empirical techniques, I found for the United Kingdom, the first difference of the interest rate and the second difference of the price level and the first difference of the inflation rate are stationary series. Regressions of the price level on the interest rate and the inflation rate on the interest rate gave me the following results:

Table 3: Regression Results: Gibson Correlation for the United Kingdom: 1948-2004

Dependent Variable	Constant Term	DI	R^2	p value of DI
DDLP	-1.54E-05 *0.003977*	-0.000332 *-0.196567*	0.000729	0.8449
DINF	-5.43E-06 *-0.001262*	-0.000551 *-0.293271*	0.001620	0.7705

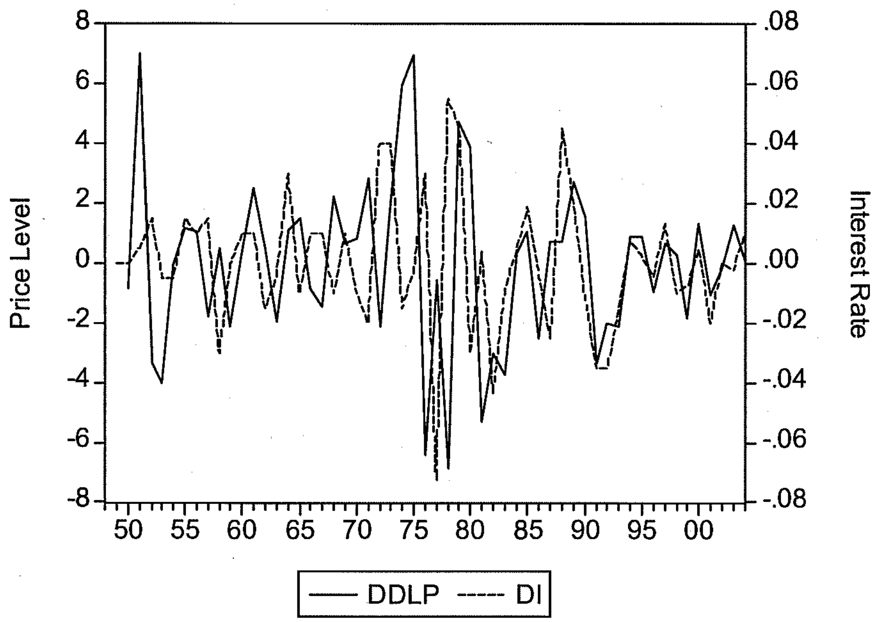
Numbers in italic under the estimated coefficients are the t-ratios, respectively.

Again, there is no Gibson correlation in the United Kingdom for the time period being analyzed. The correlation between interest rate and price level is insignificantly negative and the inflation rate as well.

Figures 7 and 8 show the comparative stationary time series data.

FIGURE 5

Second Difference of CPI and First Difference of Interest rate for the United Kingdom



4. Interpretations

The empirical study in section three shows clearly that there is no Gibson correlation in all of the three countries for the periods being studied. Then, indeed, which one of the three explanations is true, or to be exact, more close to the actual facts?

4.1 Interpretation of Tooke's Cost-push Explanation

Generally speaking, Tooke and his followers state that interest rate is a component part of the costs of production. When firms set prices, they apply a markup to the costs of production. So there ought to be a positive correlation between the price level and interest rate. If the actual fact is as simple as Tooke's original explanation, then, in the empirical test I conducted in section 3 above, we should have found a significant positive correlation between the second difference of price level and first difference of interest rate for the whole period being tested, which was unfortunately not found to be so.

Admittedly, interest is a part of cost of running an enterprise. Then why can we not find a positive correlation between the price level and interest rate? One possible explanation is that, when interest rate goes up, other component parts of cost go down. Hence, after firms apply a markup, the total price may not rise concomitantly with interest costs. Also, remember that there are countless different economic sectors in the whole economy, and we were testing data covering a very long period[9]. When aggregate demand falls suddenly, such as during the Great Depression, some of the monopolistic sectors could be able to maintain their markup or reduce it only a little to sustain their profit. But for other sectors of production, in order to sell their stocks, possibly they would have to reduce their prices greatly even though the interest rate is rising. Consequently, a negative correlation between the price level and interest rate is certainly possible as outcome for the overall sectors. In this case, it is not at all surprising that we could not find a significant positive correlation between the price level and interest rate.

4.2 Interpretation of Fisher's Inflationary Expectation Explanation

In short, the core of Fisher's inflationary expectation explanation is that lenders will raise the interest rate to protect their capital values from inflation; and borrowers would be able to afford the higher interest since they can still make profits in an inflation environment. So there ought to be a positive correlation between the inflation rate and interest rate.

However, from the empirical test carried out in section 3, we can see that there is no significant positive correlation between the inflation rate and interest rate over a very long period. From this result, we can conclude that, at least for the countries and the time periods we have been looking at, the empirical evidence is inconsistent with the Fisher hypothesis.

4.3 Interpretation of Wicksell's Central Bank Reaction Function Explanation

We have seen that the empirical evidence supports neither Tooke's story nor the Fisher hypothesis. Then how about the Wicksellian one? Is the empirical finding in conflict with the Wicksellian hypothesis?

I believe that the answer should be no. Remember that the Wicksellian hypothesis suggests that if the central bank is concerned about inflation and the monetary authorities adopt a Wicksellian reaction function, then that will result in the Gibson correlation. However we analyzed a very long period for the each of the three countries under examination, and it is very possible that inflation was not a significant argument in the reaction functions of the central banks for such a long period. Actually, we know that central banks also could have been concerned with the exchange rate, unemployment rate, economic growth, etc. Inflation became one of the main concerns of central banks only by the late 1970s for most of countries in the world.

Hence an investigation of the correlation between the inflation rate and interest rate for the sub-period when central banks are more concerned about inflation as key objective of monetary policy could provide empirical evidence in support of the Wicksellian hypothesis.

In order to get the proper time series data, we have to choose the time periods for which the three countries under consideration became concerned with the inflation rate when their central banks implemented monetary policies. After a survey, the author found that the proper dates during which there occurred a significant shift in monetary policy in favor of combating inflation for these three countries are: the United States which started in 1979, Canada in 1975, and the United Kingdom in 1992[10].

I tested the Gibson correlation for these three countries for the selected sub-periods and obtained the following results:

Table 4: Regression Results using the annual data: Gibson Correlation for US: 1979-2005; Canada: 1975-2005; UK: 1992-2004

Country	Time Period	Dependent Variable	Constant Term	DI	P value of DI	R^2 adjusted
USA	1979-2005	DINF	-0.000765 *-0.250575*	0.006126* *2.023242*	0.0539	0.10633 0
Canada	1975-2005	DINF	-0.002150 *-0.854402*	0.003361*** *3.018905*	0.0052	0.21288 3
UK	1992-2004	DINF	0.000883 *0.3348172*	0.007173*** *3.687053*	0.0036	0.51208 3

Numbers in italic under the estimated coefficients are the t-ratios, respectively.

One, two, three asterisks indicate statistical significance at the 10%, 5%, and 1% confidence levels, respectively.

We can see that for all of the three countries under examination, for the sub-periods when they were primarily concerned with inflation, there is a significant positive correlation between interest rate and the inflation rate, thereby supporting the Gibson Paradox. The finding of the Gibson correlation in these countries for the time series being tested is consistent with the Wicksellian hypothesis.

However, one may notice that the sample sizes of the sub-periods series are not as large as was the case for the whole period under examination in section 3. To avoid a problem of insufficient sample size, I ran the regression again using the monthly data for all of the three countries and obtained the following results:

Table 5: Regression Results using the monthly data: Gibson Correlation for US: 1979-2005; Canada: 1975-2005; UK: 1992-2004

Country	Time Period	Dependent Variable	Constant Term	DI (+1)	P value of DI	R^2 adjusted
USA	197901-200512	DINF	-4.36E-05 *-0.267693*	0.001437** *2.535762*	0.0117	0.016686
Canada	197501-200512	DINF	-1.70E-05 *-0.072290*	0.000720*** *1.816004*	0.0702	0.061893
UK	199201-200412	DINF	2.32E-05 *0.7213481*	0.000735** *2.585370*	0.0216	0.569082

Numbers in italic under the estimated coefficients are the t-ratios, respectively. One, two, three asterisks indicate statistical significance at the 10%, 5%, and 1% confidence levels, respectively.

It is very clear that there is significant positive correlation between the inflation rate and interest rate for each of these countries being tested, for the sub-periods when their central banks became primarily concerned with fighting inflation. One may notice that there is a lag of one month between the interest rate and inflation rate. However, that is very understandable. It takes time for the central banks to collect the information of inflation changes in the economy, and undertake their corresponding reactions to adjust the bank rate or discount rate. According to our regression results, the central banks in these three countries under examination took about one month to react to the inflation rate. Such a delay did not appear in the regression results when I used the annual data, because I obtained them by averaging the monthly data.

Therefore, the finding of the Gibson correlation in the three countries for the time series being tested seems to be consistent with the Wicksellian hypothesis.

5. Summary and Conclusion.

There are essentially three major explanations of the Gibson Paradox that have been put forth historically: Tooke's cost-push explanation, Fisher's inflationary expectation hypothesis, and Wicksell's central bank reaction function explanation. All of them suggest that there is a positive correlation between the price level or the inflation rate and interest rate. And all of them offer a reasonable theoretical explanation.

This paper explored these three explanations, and used some simple econometric techniques to find supporting empirical evidence for these three explanations. First I examined the whole sample period, 1919-2005 for the United States, 1935-2005 for Canada, and 1948-2004 for the United Kingdom, and I found significant positive correlation neither between the price level and interest rate, nor between the inflation rate and interest rate. However, when the data are divided according to whether the central banks are concerned with inflation, we do find convincing evidence for the presence of the Gibson Paradox in the period in which the central banks identified inflation as their main concern.

The rejection of the Gibson Paradox in the whole sample periods in selected countries under consideration suggest that at least for the time series we have been looking at, the evidence is consistent with neither Tooke's nor Fisher's explanation. The convincing Gibson correlation found in the sub-periods in these countries provides the best evidence for the Wicksellian hypothesis, which states that the Gibson correlation could be nothing but the empirical outcome of the central banks' application of a Wicksellian reaction function.

Notes:

1. In the explanations of the Gibson Paradox, there are two correlations: some economists, such as Thomas Tooke, explained that there is a positive correlation between the price level and interest rate, while some others, such as Irving Fisher and Knut Wicksell, provided their explanations of the Gibson Paradox by identifying a positive correlation between the inflation rate and interest rate. These two correlations are different but highly related. Both of them can be viewed as a Gibson correlation from the author's point of view.

2. It was first developed by Anyadike-Danes, Coutts, and Godley in 1988.

3. According to Seccareccia (1992, p.182), this natural rate of interest was also called the "previous", the "uncontrolled", the "neutral", the "natural real" and the "natural capital" rate in the Wicksellian frame.

4. According to Seccareccia (1992, p.182), the bank rate of interest was also known as the "market", the "lending", the "contractual", the "loan", and the "money" rate of interest in the Wicksellian frame.

5. In time series analysis, it is better to keep as many data as possible. Therefore, I did not follow the usual practice of suppressing the observations for wartime in this empirical study.

6. According to Elliott, Rothenberg, and Stock (1996), the Augmented Dickey-Fuller (ADF) test is no longer considered the best unit root test available. Nor is the Schwarz Info Criterion (SIC) considered the best criterion to use to choose the lag length according to Ng and Perron (2001). So following these econometric authorities, I use Dickey-Fuller GLS (ERS) test and the modified Akaike Info Criterion (MAIC). The results of unit root tests can be very sensitive to the choice of which deterministic terms to add to the equation. Here I choose to include an intercept but no trend in the ERS test. Since from the graph of DLP, the series shows little trend but the mean of the sample, at least the latter part seems to be positive.

7. In this paper, the author chose 5% significance value for all of the empirical tests.

8. According to Ng and Perron (2001), it might be desirable to do the PP test using AR Spectral - GLS detrended as the spectral estimation method and the MAIC to select the truncation lag in this case.

9. US 87 years, Canada 71 years, and UK 57 years.

10. Following Timberlake (1993), I choose 1979, the year in which Paul Volcker was nominated the chairman of the Federal Reserve Board, as the starting year of the

United States' concern with inflation. Hence, in 1979, the United States shifted its main concern of monetary policy from the unemployment rate to inflation.

1975 is chosen to be the break point for Canada according to Courchene's influential works: Money, Inflation and the Bank of Canada (Vol. I, 1976, and Vol. II, 1981). Courchene stated that in 1975, spurred on by large civil service pay demands, the existing policy environment of Canada could not contain the inflationary tide. The Anti-Inflation Board (AIB) was inaugurated in Canada. (Courchene, 1981, pp. 10-11) "...in 1975 Canadian policies shifted towards combating inflation."(Courchene, 1981, p. 319)

According to Bean, Chief Economist and member of the Monetary Policy Committee of the Bank of England, the break point for the UK should be 1992. According to Bean (2003) and Cobham (2002), in the first part of the post-war period, monetary policy was assigned only a marginal role in the UK. Fiscal policy was seen as the primary tool of macroeconomic stabilization during that period. After the Bretton Woods system broke down in the 1970s, monetary policy became more important. In 1977, Labour Chancellor, Healey first adopted Monetary targets, which was abandoned in 1986. Through the second half of the 1980s, an informal exchange rate peg was pursued, which evolved into a formal exchange rate target when sterling entered the ERM in 1990. On 16 September 1992 sterling was suspended from the ERM. "In the aftermath of the exit from the

ERM, the UK authorities "(introduced) an inflation target in the aftermath of sterling's exit from the Exchange Rate Mechanism (ERM) in September 1992." (Bean, 2003, p. 479). Therefore, 1992 was chosen as the break point for the United Kingdom.

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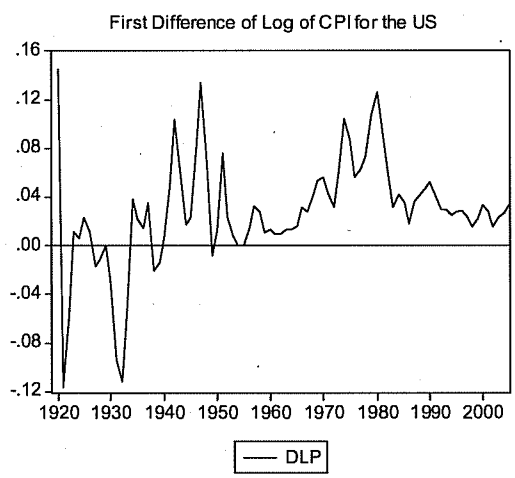
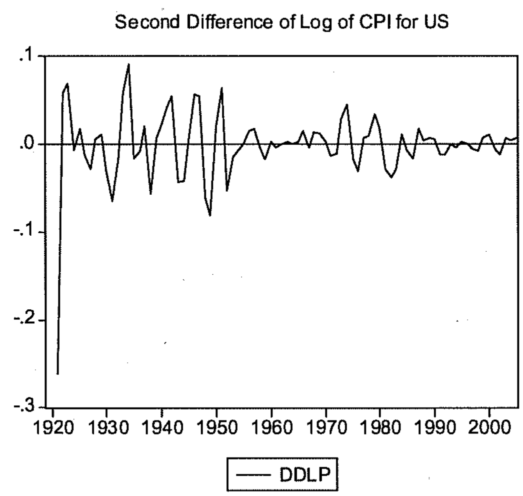
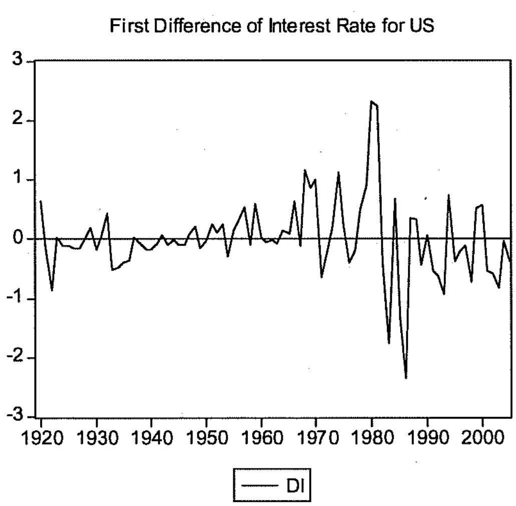
Appendix

Appendix One: Figures of the time series for the United States, Canada, and the United Kingdom.

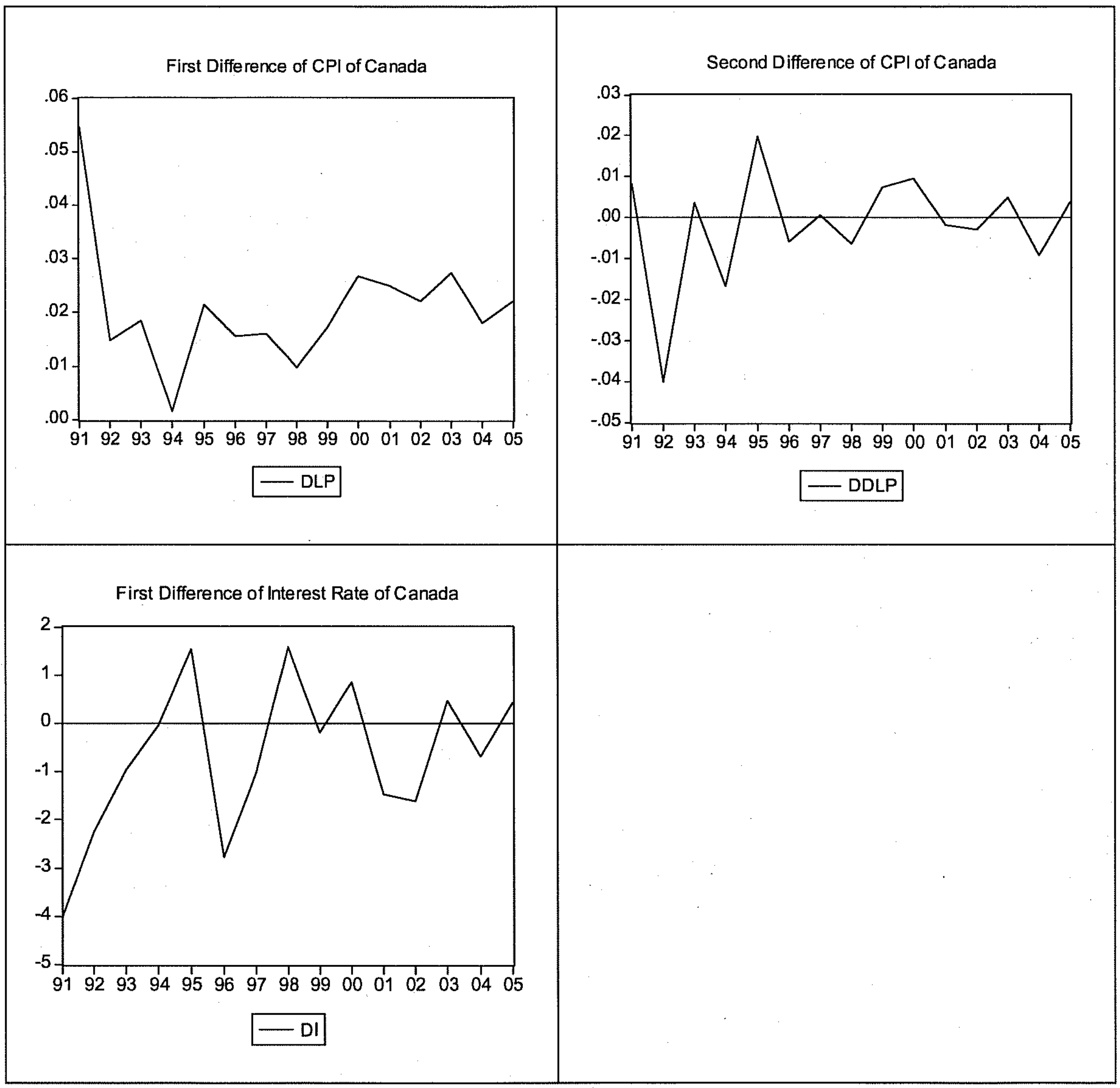
1. The United States





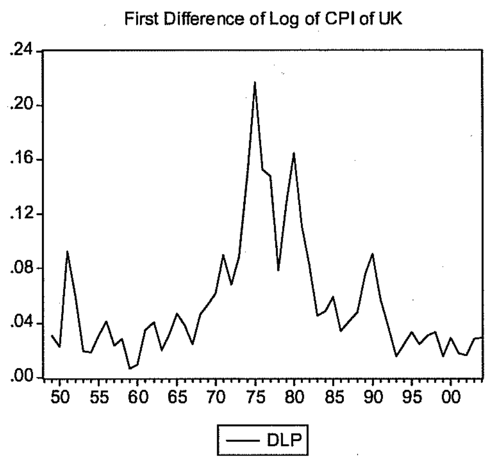


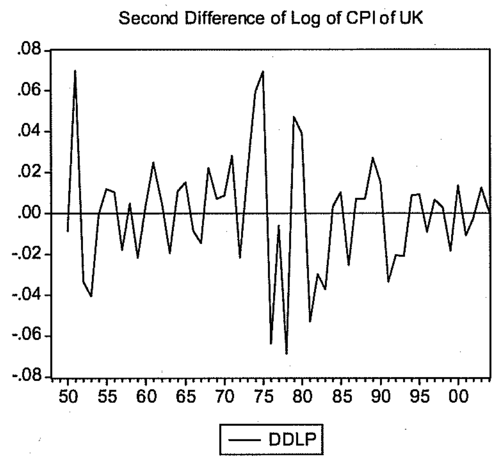
2. Canada

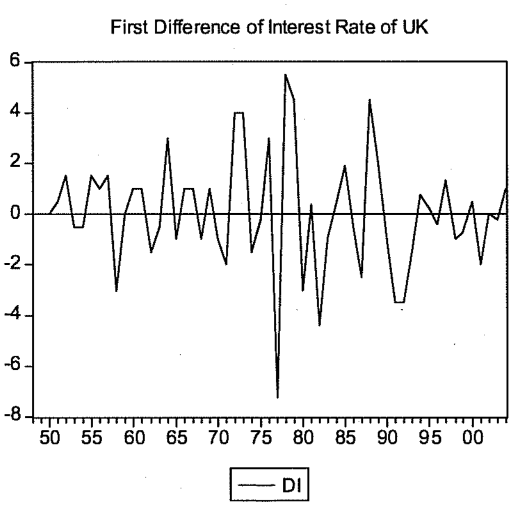


First Difference of CPI of Canada
.06
.05
.04
.03
.02
.01
.00
91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
DLP
Second Difference of CPI of Canada
.03
.02
.01
.00
-.01
-.02
-.03
-.04
-.05
91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
DDLP
First Difference of Interest Rate of Canada
2
1
0
-1
-2
-3
-4
-5
91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
DI

3. The United Kingdom







Appendix Two: Unite root tests:

1. USA

(1) ERS Test with MAIC on DLP

Null Hypothesis: DLP has a unit root

Exogenous: Constant

Lag Length: 4 (Automatic based on Modified AIC, MAXLAG=11)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-1.072048
Test critical values:	1% level	-2.593824
	5% level	-1.944862
	10% level	-1.614145

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals

Dependent Variable: D(GLSRESID)

Method: Least Squares

Date: 03/23/06 Time: 01:20

Sample (adjusted): 1925 2005

Included observations: 81 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.036859	0.034382	-1.072048	0.2871
D(GLSRESID(-1))	0.205843	0.108111	1.903997	0.0607
D(GLSRESID(-2))	-0.629994	0.108343	-5.814810	0.0000
D(GLSRESID(-3))	-0.062180	0.101591	-0.612057	0.5423
D(GLSRESID(-4))	-0.222324	0.072563	-3.063882	0.0030

R-squared	0.402807	Mean dependent var	0.000339
Adjusted R-squared	0.371375	S.D. dependent var	0.029107
S.E. of regression	0.023077	Akaike info criterion	-4.640180
Sum squared resid	0.040475	Schwarz criterion	-4.492374
Log likelihood	192.9273	Durbin-Watson stat	1.929778

(2) PP Test with MAIC on DDLP

Null Hypothesis: DDLP has a unit root

Exogenous: None

Lag length: 0 (Spectral GLS-detrended AR based on Modified AIC, MAXLAG=11)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-12.52010	0.0000
Test critical values:	1% level	-2.592782	
	5% level	-1.944713	
	10% level	-1.614233	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.000906
HAC corrected variance (Spectral GLS-detrended AR)	0.000906

Phillips-Perron Test Equation
Dependent Variable: D(DDLP)
Method: Least Squares
Date: 03/29/06 Time: 00:24
Sample (adjusted): 1922 2005
Included observations: 84 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DDLP(-1)	-0.997483	0.079671	-12.52010	0.0000

R-squared	0.652453	Mean dependent var	0.003198
Adjusted R-squared	0.652453	S.D. dependent var	0.051369
S.E. of regression	0.030284	Akaike info criterion	-4.144589
Sum squared resid	0.076119	Schwarz criterion	-4.115651
Log likelihood	175.0728	Durbin-Watson stat	1.541529

(3) PP unit root test for DI
Null Hypothesis: DI has a unit root
Exogenous: None
Lag length: 11 (Spectral GLS-detrended AR based on Modified AIC, MAXLAG=11)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-9.720821	0.0000
Test critical values:	1% level	-2.592452	
	5% level	-1.944666	
	10% level	-1.614261	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.393662
HAC corrected variance (Spectral GLS-detrended AR)	0.034270

Phillips-Perron Test Equation
Dependent Variable: D(DI)
Method: Least Squares
Date: 03/23/06 Time: 22:54
Sample (adjusted): 1921 2005
Included observations: 85 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DI(-1)	-0.719137	0.104336	-6.892505	0.0000

R-squared	0.361100	Mean dependent var	-0.012000
Adjusted R-squared	0.361100	S.D. dependent var	0.789614
S.E. of regression	0.631148	Akaike info criterion	1.929143
Sum squared resid	33.46123	Schwarz criterion	1.957880
Log likelihood	-80.98857	Durbin-Watson stat	1.893314

(4) ERS Test with MAIC on Inflation rate
Null Hypothesis: INF has a unit root
Exogenous: Constant
Lag Length: 4 (Automatic based on Modified AIC, MAXLAG=11)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-1.022716
Test critical values:	1% level	-2.593824
	5% level	-1.944862
	10% level	-1.614145

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/29/06 Time: 00:41
Sample (adjusted): 1925 2005

Included observations: 81 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.034025	0.033269	-1.022716	0.3097
D(GLSRESID(-1))	0.176392	0.108598	1.624263	0.1085
D(GLSRESID(-2))	-0.620639	0.108010	-5.746137	0.0000
D(GLSRESID(-3))	-0.088373	0.102580	-0.861500	0.3917
D(GLSRESID(-4))	-0.216244	0.073670	-2.935326	0.0044

R-squared	0.396893	Mean dependent var	0.000346
Adjusted R-squared	0.365151	S.D. dependent var	0.030108
S.E. of regression	0.023989	Akaike info criterion	-4.562672
Sum squared resid	0.043737	Schwarz criterion	-4.414866
Log likelihood	189.7882	Durbin-Watson stat	1.931358

(5) PP test with MAIC On DINT of US

Null Hypothesis: DINF has a unit root

Exogenous: None

Lag length: 0 (Spectral GLS-detrended AR based on Modified AIC, MAXLAG=11)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-12.40531	0.0000
Test critical values:	1% level	-2.592782	
	5% level	-1.944713	
	10% level	-1.614233	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.000953
HAC corrected variance (Spectral GLS-detrended AR)	0.000953

Phillips-Perron Test Equation

Dependent Variable: D(DINF)

Method: Least Squares

Date: 03/29/06 Time: 00:39

Sample (adjusted): 1922 2005

Included observations: 84 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

DINF(-1)	-0.992199	0.079982	-12.40531	0.0000

R-squared	0.648261	Mean dependent var	0.003254
Adjusted R-squared	0.648261	S.D. dependent var	0.052376
S.E. of regression	0.031063	Akaike info criterion	-4.093751
Sum squared resid	0.080089	Schwarz criterion	-4.064812
Log likelihood	172.9375	Durbin-Watson stat	1.578214

2. Canada

(1) ERS Unit Root Test on DLP

Null Hypothesis: DLP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic based on Modified AIC, MAXLAG=3)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-1.809846
Test critical values:	1% level	-3.770000
	5% level	-3.190000
	10% level	-2.890000

*Elliott-Rothenberg-Stock (1996, Table 1)
Warning: Test critical values calculated for 50 observations
and may not be accurate for a sample size of 15

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/28/06 Time: 23:44
Sample: 1991 2005
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.493845	0.272866	-1.809846	0.0935
D(GLSRESID(-1))	-0.200553	0.257777	-0.778010	0.4505

R-squared	0.344513	Mean dependent var	-0.000462
Adjusted R-squared	0.294091	S.D. dependent var	0.013781
S.E. of regression	0.011579	Akaike info criterion	-5.955728
Sum squared resid	0.001743	Schwarz criterion	-5.861321
Log likelihood	46.66796	Durbin-Watson stat	1.788623

(2) PP Test with MAIC on DDLP

Null Hypothesis: DDLP has a unit root
Exogenous: None
Lag length: 1 (Spectral GLS-detrended AR based on Modified SIC, MAXLAG=3)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-9.180425	0.0000
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 15

Residual variance (no correction)	0.000151
HAC corrected variance (Spectral GLS-detrended AR)	3.37E-05

Phillips-Perron Test Equation
Dependent Variable: D(DDLP)
Method: Least Squares
Date: 03/30/06 Time: 00:08
Sample: 1991 2005
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DDLP(-1)	-1.402203	0.245275	-5.716871	0.0001

R-squared	0.700004	Mean dependent var	0.000406
Adjusted R-squared	0.700004	S.D. dependent var	0.023218
S.E. of regression	0.012717	Akaike info criterion	-5.827427
Sum squared resid	0.002264	Schwarz criterion	-5.780224
Log likelihood	44.70570	Durbin-Watson stat	1.779786

(3) PP unit root test for DI

Null Hypothesis: DI has a unit root
Exogenous: None
Lag length: 0 (Spectral GLS-detrended AR based on Modified AIC,

MAXLAG=3)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.377636	0.0024
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 15

Residual variance (no correction)	2.773991
HAC corrected variance (Spectral GLS-detrended AR)	1.762359

Phillips-Perron Test Equation
Dependent Variable: D(DI)
Method: Least Squares
Date: 03/28/06 Time: 23:46
Sample: 1991 2005
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DI(-1)	-0.897396	0.264609	-3.391402	0.0044

R-squared	0.450961	Mean dependent var	-0.022334
Adjusted R-squared	0.450961	S.D. dependent var	2.326658
S.E. of regression	1.723988	Akaike info criterion	3.991497
Sum squared resid	41.60986	Schwarz criterion	4.038701
Log likelihood	-28.93623	Durbin-Watson stat	1.423045

(4) ERS test with MAIC On Inflation rate
Null Hypothesis: INF has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic based on Modified AIC, MAXLAG=3)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-1.802235
Test critical values:	1% level	-2.728252

5% level	-1.966270
10% level	-1.605026

*MacKinnon (1996)
Warning: Test critical values calculated for 20 observations
and may not be accurate for a sample size of 15

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/30/06 Time: 00:11
Sample: 1991 2005
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.434103	0.240869	-1.802235	0.0947
D(GLSRESID(-1))	-0.211442	0.250762	-0.843200	0.4144

R-squared	0.317153	Mean dependent var	-0.001691
Adjusted R-squared	0.264626	S.D. dependent var	0.014161
S.E. of regression	0.012143	Akaike info criterion	-5.860501
Sum squared resid	0.001917	Schwarz criterion	-5.766094
Log likelihood	45.95376	Durbin-Watson stat	1.809705

(5) PP test with MAIC On DINT of Canada
Null Hypothesis: DINF has a unit root
Exogenous: None
Lag length: 1 (Spectral GLS-detrended AR based on Modified SIC, MAXLAG=3)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-9.235370	0.0000
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20
observations and may not be accurate for a sample size of 15

Residual variance (no correction)	0.000160

HAC corrected variance (Spectral GLS-detrended AR)	3.48E-05

Phillips-Perron Test Equation
Dependent Variable: D(DINF)
Method: Least Squares
Date: 03/30/06 Time: 00:11
Sample: 1991 2005
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DINF(-1)	-1.400000	0.245509	-5.702430	0.0001

R-squared	0.698940	Mean dependent var	0.000418
Adjusted R-squared	0.698940	S.D. dependent var	0.023842
S.E. of regression	0.013082	Akaike info criterion	-5.770811
Sum squared resid	0.002396	Schwarz criterion	-5.723608
Log likelihood	44.28108	Durbin-Watson stat	1.780712

3. UK

(1) ERS Unit Root Test on DLP
Null Hypothesis: DLP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on Modified AIC, MAXLAG=10)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-2.420596
Test critical values:	1% level	-3.751000
	5% level	-3.174000
	10% level	-2.875000

*Elliott-Rothenberg-Stock (1996, Table 1)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/28/06 Time: 23:52
Sample (adjusted): 1950 2004
Included observations: 55 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

GLSRESID(-1)	-0.197844	0.081733	-2.420596	0.0189

R-squared	0.097836	Mean dependent var	-0.000206
Adjusted R-squared	0.097836	S.D. dependent var	0.028426
S.E. of regression	0.026999	Akaike info criterion	-4.367988
Sum squared resid	0.039364	Schwarz criterion	-4.331491
Log likelihood	121.1197	Durbin-Watson stat	1.895110

(2) PP Unit Root Test with MAIC on DDLP

Null Hypothesis: DDLP has a unit root

Exogenous: None

Lag length: 0 (Spectral GLS-detrended AR based on Modified SIC, MAXLAG=10)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-7.600758	0.0000
Test critical values:	1% level	-2.608490	
	5% level	-1.946996	
	10% level	-1.612934	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.000805
HAC corrected variance (Spectral GLS-detrended AR)	0.000805

Phillips-Perron Test Equation

Dependent Variable: D(DDLP)

Method: Least Squares

Date: 03/30/06 Time: 00:12

Sample (adjusted): 1951 2004

Included observations: 54 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DDLP(-1)	-1.042286	0.137129	-7.600758	0.0000

R-squared	0.521530	Mean dependent var	0.000163
Adjusted R-squared	0.521530	S.D. dependent var	0.041411
S.E. of regression	0.028644	Akaike info criterion	-4.249381
Sum squared resid	0.043486	Schwarz criterion	-4.212548

Log likelihood	115.7333	Durbin-Watson stat	1.880800

(3) PP unit root test for DI
Null Hypothesis: DI has a unit root
Exogenous: None
Lag length: 0 (Spectral GLS-detrended AR based on Modified AIC, MAXLAG=10)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-8.469952	0.0000
Test critical values:	1% level	-2.607686	
	5% level	-1.946878	
	10% level	-1.612999	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	5.133929
HAC corrected variance (Spectral GLS-detrended AR)	5.133929

Phillips-Perron Test Equation
Dependent Variable: D(DI)
Method: Least Squares
Date: 03/28/06 Time: 23:53
Sample (adjusted): 1950 2004
Included observations: 55 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DI(-1)	-1.142824	0.134927	-8.469952	0.0000

R-squared	0.570531	Mean dependent var	0.018182
Adjusted R-squared	0.570531	S.D. dependent var	3.489341
S.E. of regression	2.286701	Akaike info criterion	4.510112
Sum squared resid	282.3661	Schwarz criterion	4.546609
Log likelihood	-123.0281	Durbin-Watson stat	2.074907

(4) ERS test with MAIC On Inflation rate
Null Hypothesis: INF has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic based on Modified AIC, MAXLAG=10)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-1.423967
Test critical values: 1% level	-2.610192
5% level	-1.947248
10% level	-1.612797

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/30/06 Time: 00:15
Sample (adjusted): 1953 2004
Included observations: 52 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.125803	0.088347	-1.423967	0.1609
D(GLSRESID(-1))	0.022375	0.143943	0.155446	0.8771
D(GLSRESID(-2))	-0.166228	0.132265	-1.256782	0.2149
D(GLSRESID(-3))	-0.198521	0.132147	-1.502269	0.1396

R-squared	0.155497	Mean dependent var	-0.000605
Adjusted R-squared	0.102716	S.D. dependent var	0.030385
S.E. of regression	0.028782	Akaike info criterion	-4.184327
Sum squared resid	0.039763	Schwarz criterion	-4.034232
Log likelihood	112.7925	Durbin-Watson stat	2.037145

(5) PP test with MAIC On DINT of the United Kingdom
Null Hypothesis: DINF has a unit root
Exogenous: None
Lag length: 0 (Spectral GLS-detrended AR based on Modified SIC, MAXLAG=10)

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-7.634561	0.0000
Test critical values: 1% level	-2.608490	
5% level	-1.946996	
10% level	-1.612934	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.000996
HAC corrected variance (Spectral GLS-detrended AR)	0.000996

Phillips-Perron Test Equation
Dependent Variable: D(DINF)
Method: Least Squares
Date: 03/30/06 Time: 00:16
Sample (adjusted): 1951 2004
Included observations: 54 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DINF(-1)	-1.046831	0.137117	-7.634561	0.0000

R-squared	0.523745	Mean dependent var	0.000167
Adjusted R-squared	0.523745	S.D. dependent var	0.046154
S.E. of regression	0.031852	Akaike info criterion	-4.037107
Sum squared resid	0.053770	Schwarz criterion	-4.000274
Log likelihood	110.0019	Durbin-Watson stat	1.895452