INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

Université d'Ottawa · University of Ottawa

The Behaviour of Prices Under Changing Monetary Regimes: The United States and Great Britain

by

© Christopher Kuchciak

#485266

A thesis presented to the

Department of Economics of the University of Ottawa

in partial fulfillment of the requirements of the M.A. Degree

Supervisor: Professor Serge Coulombe

ECO 7999

Ottawa, Ontario

JUNE, 1997

Abstract

This paper is an empirical investigation of the behaviour of prices in the United States (U.S.) and Great Britain (U.K.) over the last two and a half centuries. The objective is to determine if price stability was attained during the classical gold standard regime, Bretton Woods system and a flexible exchange rate regime using unit root testing procedures. This paper explores some of the theory and techniques involved in unit root testing. These tests are then utilized to determine if the price level was stationary during and after the gold standard period.

Contents

Tables and Charts

Tables

Charts

I Introduction

The issue of price stability has attracted a good deal of interest in the field of monetary economics in recent years. Central banks throughout the world are embracing price stability as a primary long-term goal for monetary policy. In Canada, the pursuit of price stability has been the principal objective of monetary policy since 1988. Current Bank of Canada Governor Gordon Thiesson reinforced the Bank's policy in a speech given at *The World in 1996 Conference*, 19 January 1996.

> *The focus of Canadian monetary policy is on price stability. However, the Bank of Canada does not pursue price stability for its own sake but rather as a means of contributing to a well-functioning, productive economy, capable of providing Canadians with a rising standard of living.*-- Gordon Thiesson.

As countries and their central banks are accepting price stability as a primary goal, how will central bankers know when they have achieved price stability? There is considerable debate as to the operational definition of price stability. Some people argue that the long-run goal of monetary policy should be to target the inflation rate. Currently, there are several countries that have adopted explicit inflation targets (e.g. Canada, New Zealand, United Kingdom). However, the literal meaning of price stability is stability of the average price level not low inflation. For the average price level to remain constant in the long-run, variations in the inflation rate are required to reverse past shocks. In this paper, the latter definition of price stability is accepted.

Has price stability ever been achieved? For many years, some economists have argued that price stability would be accomplished by maintaining a commodity money standard, such as the gold standard. Subsequent statistical studies of the gold standard have been conducted to evaluate this theory. Due to the lack of reliable tests, most results have been largely inconclusive. In recent years, new techniques in econometric analysis (the so called unit root tests) have allowed researchers to explore the statistical properties of

time-series data more thoroughly. A series that contains a unit root can be characterized by a random walk process. A series with a mean-reverting tendency is said to be stationary. If the price level was constant during the gold standard, then the series would be characterized by a stationary process.

The objective of this paper is to produce an empirical examination of the behaviour of prices during and after the classical gold standard period. This paper explores some of the theory and techniques involved in unit root testing. These tests are then utilized to determine if price stability was attained during and after the gold standard period.[1]

The principals

England is one of the principals chosen for this examination and there are several reasons for this choice. England is a country for which data are available over unusually long spans of time. She represents an economy with constant political boundaries for many centuries (whereas Germany, Italy and France underwent shifts in boundaries until modern times). England has supported and suffered many wars but has not been invaded by a foreign power since 1066. England has had a remarkably consistent monetary table over time. From the Norman Conquest until the change to decimal coinage in 1971, English money has consisted of pounds, shillings, and pence. Most significant of all, England represents an economy that has been at the heart of economic development and global transactions for many generations.[2]

The United States was an English colony until the late eighteenth century. Their settlers felt themselves to be Englishmen. Anglo-Saxon law prevailed and their cultural attitudes toward money and monetary affairs were similar. There was war for independence and a civil war, but by the twentieth century the U.S. became the dominant economic power of the world. The statistical analysis begins from 1792. To start any earlier would be dealing with a sparse economy not yet settled down from the rending of ties with Britain.[3]

---

[1] The results do not preclude alternative explanations of how price stability was or was not achieved during these periods.

[2] Jastram (1977), p.4.

[3] Ibid., p.135.

The period of study

Three distinct periods are postulated. These periods correspond roughly to three different international monetary systems. The first period demarcates the life of the classical gold standard. The second period, following World War II, spans the quarter century in which the Bretton Woods system was in effect. The third period characterizes a flexible exchange rate mechanism.

Table I
Selected Periods

Regime	Great Britain (U.K.)	United States (U.S.)
Classical gold standard	1717-1931	1792-1933
Bretton Woods	1946-1971	1946-1971
Flexible exchange rates	1973-1991	1973-1991

As in all attempts to divide the seamless web of history into tractable bits, this division of international monetary history into periods may obscure as much as it reveals.[4] For example, the United States went on a paper standard during the Civil War (1861) and did not restore the gold standard until 1879. However, the emphasis here is on the change from one regime to another, rather than on continuity within periods.

[4] Dam (1982), p.7.

Outline

This paper is an empirical investigation of the behaviour of prices in the United States (U.S.) and Great Britain (U.K.) over the last two and a half centuries. The objective is to determine if price stability was attained during the classical gold standard regime, Bretton Woods system and flexible exchange rate regime using unit root testing procedures. Section two presents the theoretical underpinnings of the three monetary regimes. Section three explores the issue of unit roots in time-series data and examines the various tests used for detecting a unit root. These tests are implemented in sections four through six. Section four tests for stationarity in the price level during the gold standard. Section five analyzes the Bretton Woods system and section six tests the stationarity of the price level under a flexible exchange rate regime.

II The Gold Standard in Action

The purpose of section two is to provide a theoretical and historical overview of the monetary regimes under examination. Section 2.1 explores the price adjustment mechanism of the gold standard and the evolution of the classical gold standard regimes in Britain and the United States. When these countries abandoned the classical gold standard regime during the interwar years, it provided the impetus to define a new monetary framework. Section 2.4 summarizes the main features of the Bretton Woods arrangement that prevailed for several decades after World War II. With the collapse of the Bretton Woods system in the early 1970's, a new monetary regime of flexible exchange rates emerged. The ensuing inflation of the 1970's and 1980's shifted the focus of central bank policy towards price stability. Today, there is considerable debate among policy-makers as to what is meant by price stability and how can central banks achieve it. Section 2.5 gives a definition of price stability; distinguishing from a price-level targeting regime versus an inflation targeting regime. A preliminary analysis of inflation rates in the U.K. and U.S. under the changing monetary environment is provided in sections 2.6 and 2.7. The analysis is from a historical perspective, highlighting some of the major economic events that affected inflation rates over the last three centuries.

2.1. The "Automatic" Adjustment of Prices

The appeal of the gold standard can be traced to the belief that it provided price and exchange-rate stability. Since at least Ricardo (1816) it has been argued that the obligation to maintain convertibility provided a check on inflationary finance. By limiting the discretion of monetary authorities, gold standard discipline minimized the danger that the value of financial assets would be eroded by inflation. Even those, such as Viner (1937), who remained sceptical that the gold standard would produce long-run price stability predicted that a system of inconvertible currencies would yield

considerably worse results. They advanced this argument even while recognizing that the authorities retained a significant measure of discretion under a gold standard regime.[5]

The three basic features of a gold standard regime are (i) convertibility between domestic money and gold at a fixed official price, (ii) freedom to import and export gold, and (iii) an institutional framework relating the quantity of money in circulation in a country to that country's gold stock. An international gold standard exists when a number of countries adhere to these principles. With each country willing to convert its domestic currency into a fixed weight of gold and with the price of gold set on world markets subject only to the margins covering shipping and insurance costs, an international gold standard establishes fixed exchange rates between national currencies. Balance of payments settlements are effected through international transfers of gold, and balance of payments equilibrium is obtained through the impact of gold flows on internal conditions.[6]

Since the central bank supports the nominal price of gold, the determination of the absolute price level amounts to the determination of the relative price of gold. The gold standard possesses an important nominal anchor in the fixed price of gold and it is asserted that the absolute price level becomes a determinate quantity.[7] The following is a brief review of the domestic and international adjustment process under a gold standard regime.

2.1.1 The balance of payments mechanism

The classic model of gold standard adjustment is the price-specie-flow mechanism of David Hume (1752). The price-specie-flow mechanism was the means by which arbitrage in gold between nations and regions served to keep overall national and regional price levels in line and to maintain balance of payments equilibrium. A rise in the domestic price level would raise prices of exports relative to prices of imports, leading to a balance of trade deficit, a gold outflow, and eventually a contraction of the money supply. Arbitrage would ensure that the prices of similar traded goods would be the same across countries and across regions within countries, allowing for the influence of tariffs and transportation costs.

---

[5] Eichengreen (1985), p.6-7.
[6] Ibid., p.4.
[7] Barro (1979), p.13.

However, this process was viewed as a long-term adjustment mechanism.

> *Practically, of course, transition periods may be incessant or chronic. It seldom happens that a nation has no balance of trade.*[8]

2.1.2 Credit and the gold standard

Conformity to the gold standard kept credit movements within bounds. The credit cycle occurred because it took years for the restrictive influence of gold to make itself felt. Under the classical gold standard, much scope for discretion on the part of the central bank had been eliminated. The supply of currency was simply the supply of gold. The essence of the classical gold standard was that the price of gold (the value of gold in monetary units) was fixed by law. The central bank was in the gold market as both buyer and seller in unlimited quantities at a fixed price. The central bank could not defend their stock against depletion by raising the price of gold. The power of the central bank over the wealth-value of the monetary unit ultimately depended on the deterrent effect of a high bank rate upon the borrowing and lending operations of banks.[9]

During periods of rising prices, enterprisers noted approvingly that "business is good" and "times are booming." Business men, encouraged by larger profits, expanded their loans. As banks lent freely, prices continued to rise. To stanch the flow of currency and defend its gold reserves, the central bank had to raise the bank rate. In self-defense, the banks were forced to raise interest rates to limit the expansion of loans relative to reserves. As the boom broke down, an extraordinary search arose for liquid assets; the results being a general scramble for gold, a rise in its value, and a fall of the general price level. The typical business man then complains that "business is bad"; there is a "depression of trade."[10]

The gold standard regulated bank lending and put a limit to it. When credit expanded, more currency passed into circulation. However, this flow was very gradual and lagged far behind the expansion of credit that caused it. If the central bank was guided in its action by the adequacy of gold reserves, their intervention was bound to be very tardy.[11]

---

[8] Fisher I, (1922), p.96.
[9] Hawtrey (1927), p.24.
[10] Fisher I,(1922), p.58-68.
[11] Hawtrey (1927), p.29.

2.1.3 The foreign exchange market

The rules governing an international gold standard were quite simple. Each government bought and sold gold in order to keep the value of the country's currency fixed in terms of gold. The implicit exchange rate that held between currencies was the mint exchange rate. For example, prior to World War I, the U.S. dollar value of an ounce of gold was defined as $20.67, while the British pound sterling price of an ounce of gold was defined as £4.24. These commitments defined a mint exchange rate of $4.87 per pound. Arbitrage activities ensured that the mint exchange rate held the market exchange rate at similar levels. Arbitrage couldn't keep the two rates identical at all times because of the transaction costs involved in shipping gold. However, it would keep the market rate within a band around the mint rate, where the width of the band was determined by the costs of gold shipments.[12]

With the gold standard, either an expansion or a contraction of credit had to be checked before it proceeded beyond a certain limit, or the loss or gain of gold would become excessive. This was only so on the assumption that an expansion or contraction of credit did not occur in other gold standard countries. If there were a general and simultaneous expansion of credit in all other gold standard countries, then a country that did not participate in the movement, but kept credit steady, would receive gold from them, just as if it had instituted a contraction of credit on its own account. When a gold standard country found one of its neighbours absorbing gold, the gold it was compelled to export had to come from the reserves of the central bank. Therefore, the central bank's task was to keep the value of the monetary unit in the foreign exchange market as near as possible to par with other gold standard currencies. Any considerable failure in accomplishing this purpose would involve it in a gain or loss of gold.[13]

A general credit expansion would eventually involve an increase in the circulation of currency in all the countries that experienced it. This increase in circulation would mean a demand for gold. However, this process took place very tardily. Consequently, the increased demand for currency failed to check an international credit expansion at an early stage. Under the conditions of the nineteenth century, the expansion would always be allowed to go too far. It eventually had to be reversed, resulting in an international credit contraction, in which all gold standard countries had to keep pace.[14]

---

[12] Yarbrough (1988), p.587.
[13] Hawtrey (1927), p.43.
[14] Ibid., p.44.

2.2. Evolution of the Gold Standard

2.2.1 The gold standard in Britain

Before the close of the seventeenth century, silver was the effective basis for English coinage and hence for the common flow of everyday transactions. Gold coins first strayed into England in the course of international trade. As the export trade in tin, hides, and wool grew after the Conquest, the gold coins of Byzantium (known as "besants" and widely circulated in Europe) entered England in large quantities. In 1257 Henry III minted the first English gold penny of 45 troy grains, which he proclaimed current for 20 pence. This gold penny failed because there was little use for it in the England of that time. In large transactions it failed because at 20 pence it was undervalued in terms of silver. In small transactions it was too high a denomination for convenience. Starting with the gold penny of 1257, fourteen different English gold coins were issued by 1717. Gold coinage was no stranger to early England, but it never caught on with the public until the eighteenth century was well under way.[15]

Because of its high value in relation to the income of most people, gold could not handle the common business of the communities as well as silver. However, as time went on, the nature of dealings and the size of individual transactions were gradually moving toward magnitudes that made gold coins convenient and, therefore, acceptable. Wages still could not be paid in gold, but an increasing proportion of production was passing into the control of capitalists who could use gold in their typical size of transactions with merchants and the larger agriculturalists. One major factor that began to accelerate the proportionate substitution of gold for silver was the rising volume of trade with the East, thanks largely to the activity of the East India Company. Much to the chagrin of the English wool industry, the people of India simply were not interested in exchanging their merchandise for the good, warm cloth of England; but they loved silver. In one year alone, 1717, the East India Company exported three million ounces of silver, much of which came from melting down English silver coins.[16]

Along with this outflow of silver was an influx of gold, for quite a different reason. The resumption of peace with France in 1713 increased tremendously England's trade with that nation, and the French settled their trade balances in gold. Therefore, what was occurring in England was a major shift in the internal stocks of gold and silver. Gold was flowing in as silver was flowing out. Gold was no longer undervalued in terms of silver,

---

[15] Jastram (1977), p.10-11.
[16] Ibid., p.11.

and this was reflected in the narrowing ratio of gold to silver prices. In addition, silver coins were melted down and disappearing, and gold coinage was taking their place. During the three years following peace in 1713, over four million pounds' worth of gold was minted. England, without plan, conscious motivation, or perhaps general realization, was rapidly moving toward a de facto gold standard.[17]

Important to the understanding of the gold standard is the history of guinea coins, so called because the tiny imprint of an elephant showed that the gold came from Africa. The warrant for the issue of this gold coin was dated Christmas Eve 1663. Its nominal face value was 20 shillings. The guinea never did go for exactly 20 shillings. As early as January 1665 the guinea went for 21 shillings 4 pence in actual circulation and it appeared to have always circulated well above 21 shillings. Since the gold guinea was passing in the streets at higher than its face value in terms of the silver shilling, clearly the ratio of the face value of the two coins was out of line with the price ratio existing in the bullion markets. The government tried to solve this economic impasse by edict. A proclamation was issued on December 22, 1717, forbidding any person to give or receive guineas at a higher price than 21 shillings (and reducing any other gold coins in due proportion). This proclamation brought the golden guinea down to 21 shillings. If guineas (by the ordinary working of supply and demand) had then come down to less than 21 shillings and shilling pieces (the silver coin) continued to pass for 12 pence, the currency would still have been based on a silver standard. If guineas remained at 21 shillings and the shilling pieces went to a premium, then ipso facto England had changed over to a gold standard. The guinea stood fast. The value of 21 shillings in money was tied to the value of gold in a guinea and not to the value of silver in 21 shilling pieces. It seems, therefore, that England did not establish the gold standard by any design or deliberate act.[18]

The gold standard remained in effect for over two centuries with brief interruptions during the Napoleonic Wars and World War I. After World War I, the British fully expected the gold standard to be reestablished and London to remain its center. No reason appeared to change the legal form of the gold standard in Britain, and the necessary accommodations to the monetary realities imposed by the war were made without altering the formal interconvertibility of currency and gold on the same terms that governed before 1914. However, a widespread view immediately after the war was that the principal difficulty in returning to the gold standard would be a shortage of gold.

---

[17] Ibid., p12.
[18] Ibid., p.13.

This view was quite popular since the amount of British currency in circulation roughly doubled during the war. The Cunliffe committee, reporting in 1918, made a number of recommendations designed to increase the holdings of gold by the Bank of England and to decrease the public's demand for gold. The most important was that gold coin should not circulate as money and that paper currency should replace it. This was already the de facto situation, inherited from the wartime period when Treasury-issued currency notes had displaced the sovereign. Such a monetary system, under which only gold bullion could be withdrawn from the Bank of England in redemption of notes and in which gold coin would not circulate, was generally known as a "gold bullion" standard. With a gold bullion standard and with adoption of a further Cunliffe committee recommendation that banks should transfer their gold holdings to the Bank of England, all gold in England would be effectively concentrated in the Bank of England and therefore available in support of sterling in foreign exchange markets. Under this system, the essence of the gold standard would be preserved, in the committee's view, because gold would still be withdrawable in large-quantity transactions from the Bank of England for export.[19]

The Cunliffe committee's recommendations became British government policy, and the gold bullion standard was formally adopted on the occasion of the return to gold in 1925. The Gold Standard Act of 1925 provided that notes would be redeemable only in transactions larger than 400 ounces of fine gold. Meanwhile, the virtual discontinuance of the minting of gold sovereigns in 1917 precluded a resurgence of gold coin circulation after the war. The buying and selling price for gold was such, in comparison with the U.S. gold price, that the mint par between Britain and the U.S. was the same as before 1914. The effect was to place Britain back on gold at its prewar parity. In retrospect this rate is considered to have overvalued sterling. By 1931, a drop in U.S. capital exports (coupled with the growth of French reserves as they returned to the gold standard), put strong pressure on the pound. British gold reserves were even less ample than before World War I and now he was suffering from an overvalued currency. In July alone the Bank of England lost nearly £32 million of gold. On September 21, 1931, the British government suspended payments of gold against legal tender currency, and Britain thereby left the classical gold standard.[20]

---

[19] Dam (1982), p.55.
[20] Ibid., p.56.

2.2.2 The gold standard in the United States

When President George Washington took office, he appointed his military aide-de-camp, Alexander Hamilton, as Secretary of the Treasury. Hamilton considered carefully the merits of a gold versus silver basis for the currency and finally recommended a bimetallic standard. The Coinage Act of April 2, 1792, created a bimetallic system. Gold and silver were linked together and were accorded identical standing under law. The system worked reasonably well until the Civil War, although there was constant haggling in and out of Congress about the proper gold-to-silver ratio.[21]

In the cataclysm of the Civil War, all banks suspended specie payment by December 30, 1861, and the U.S. Treasury soon followed. The government created legal-tender note issues, and the country went on a paper-money standard on which it remained until January 1, 1879. While on the paper standard, Congress carried out in 1873 a revision and codification of the Mint and coinage laws. Few silver coins of any denomination were in circulation, and nearly all silver dollars had long before been exported to the Orient in connection with foreign trade or had otherwise disappeared. Consequently, the public was not familiar with the American silver dollar, of which they had seen few. Thus, when Congress in its codification of 1873 omitted the silver dollar in its listing of future coins, no public attention was aroused by the omission. The legal effect was that the right of free coinage of silver at the Mint had been discontinued. Therefore legal bimetallism, which had been established by the Mint Act of 1792, no longer existed. When the United States returned to a specie basis on January 1, 1879, it discovered it was de facto on a monometallic gold standard as gold was the only metal accorded the privilege of free coinage in the codification of 1873.[22] The gold standard was formally recognized by the Gold Standard Act of 1900, which provided a definitive legal recognition of what had been in operation since 1879.[23]

From the time of the Coinage Act of 1792 until March 10, 1933, the United States was on some form of gold standard whether jointly with silver or functioning alone. The official price of gold was established by the various Acts of Congress. Market prices were congruent with those so long as bank notes were redeemable in gold, and this was true except for the suspension of specie payments between 1861 and 1879. By 1933, the incoming Roosevelt administration, though enjoying undiminished gold reserves, elected to engineer a depreciation of the dollar in the foreign exchange markets. The goal was to

---

[21] Jastram (1977), p.139.
[22] See appendix A for a review of the free silver movement as told in the Wizard of Oz.
[23] Jastram (1977), p.139.

force up depreciating domestic prices, especially for internationally traded agricultural commodities. On March 10, 1933, President Roosevelt, prohibited by executive order the export of gold and gold certificates as well as payments in gold by banks. The United States was then off the classical gold standard.[24]

2.3. The Interwar Years: Evolution of Bretton Woods

The period between the two world wars can be viewed as a bridge between the era of the classical gold standard and that of the Bretton Woods system. The fundamental principles of the Bretton Woods agreement (no floating rates, no competitive devaluations, exchange rate changes to be a matter of international rather than solely domestic concern, and exchange rate crises to be overcome when possible through the lending of international reserves rather than through contractionary domestic policies) were prescriptions for avoiding the perceived evils of the interwar period.[25]

2.3.1 The interwar experience in Britain

The effect of the suspension of gold payments in 1931 was a sharp depreciation of sterling against all gold standard currencies. A number of countries, chiefly those in the British Commonwealth and those that held reserves primarily in sterling, elected to allow their currencies to depreciate with the pound. Thus was born the sterling area. The September 1931 decision was in essence a devaluation of sterling, but the means was to let sterling float. The British authorities decided in 1932 to create an Exchange Equalisation Account, which would permit intervention in the foreign exchange markets.[26] Thus, Britain operated a managed float until World War II.

---

[24] Ibid., p.141.
[25] Ibid., p.41.
[26] Ibid., p.46.

2.3.2 The interwar experience in the United States

The United States had placed an embargo on the exportation of gold coin and bullion during World War I. However, the lifting of the embargo in 1919 placed it in the unusual position of being the only one of the belligerents firmly on the gold standard. In 1933, the Roosevelt Administration signaled its intention to manage the foreign exchange value of the dollar by imposing exchange controls and a gold export embargo, thereby taking the dollar off the gold standard. In order to pursue the Roosevelt administration's forced depreciation policy, the U.S. began a gold-buying program. The gold value of the dollar declined from the pre-1933 parity of $20.67 per ounce to more than $34 in mid-January 1934. The dollar depreciated commensurately against gold standard currencies and even against the floating pound sterling.[27]

After achieving exchange market goals, the president acted in late January 1934 to peg the gold price at $35 per ounce. To maintain the dollar at the new price, the United States stood ready not merely to buy gold freely and to sell it freely to foreign central banks at $35 per ounce, but also to enter into foreign exchange transactions. To facilitate the latter transactions, an Exchange Stabilization fund was created out of a portion of the profits of the devaluation of the dollar in terms of gold. The Fund bore an obvious resemblance to the British Exchange Equalisation Account. However, in view of the $35 gold commitment, the role of the U.S. Fund was less crucial to the stabilization of the dollar.[28]

By 1936, when France and the other countries of the Gold Bloc had suspended convertibility, only the U.S. maintained a link between domestic currency and gold. But with international gold flows restricted, American monetary arrangements embodied none of the basic elements of the classical gold standard.[29]

2.4. The Bretton Woods System

The legal and institutional framework for the international monetary system throughout several decades after World War II was provided by the Bretton Woods agreement. Unlike earlier changes in the international monetary system, which had been dictated by events, this change was dictated by men- the wartime planners of the postwar world. The war was, at most, an impetus for the key international monetary policy decision of the

---

[27] Ibid., p.47.
[28] Ibid., p.48.
[29] Eichengreen, p.25.

century- namely, the decision of nearly all of the countries outside the emerging communist bloc to regulate the international monetary system through a comprehensive treaty with a potentially powerful central organ, the International Monetary Fund (IMF).[30]

The dominant role of the United States and Britain in postwar economic planning affected the Bretton Woods system in important ways. The anticipated economic position of the two countries at the end of the war put bounds on the proposals that received serious consideration. Since the U.S. influence was stronger than the British, the style of the drafting of the Articles of Agreement of the Fund, together with positions adopted on the role of the Fund staff, reflected U.S. executive branch views of that time. U.S. economic strength had been growing relative to the strength of other major countries, including Britain, since the nineteenth century. The physical devastation of continental countries and the economic stress placed on Britain by extensive borrowing and wartime dislocations accelerated the culmination of these trends in postwar U.S. economic ascendancy. Consequently, the United States self-confidently set out to impress on the postwar international monetary system its particular view of the desirable that corresponded to U.S. perceived self-interest.[31]

The system rested on a series of basic principles and behaviour characteristics that determined its mode of operation. These were derived from law, from international agreements, from the policy aims of central banks and governments, and from technical necessity.

2.4.1 Fixed exchange rates

Fundamental to the system was the aim of monetary authorities to adhere to fixed rates of exchange. Maintenance of the rate had a high priority with all countries and other objectives were often sacrificed to it. Under the IMF Articles, a country could declare its par value in terms of either gold or dollars. However, the operative standard for most countries was the dollar. In practice, central banks intervened in the market when necessary by buying and selling dollars against their own currencies to keep the dollar exchange rate within agreed limits. There were exceptions, such as the countries of the sterling area, which pegged their currencies to sterling and relied on the Bank of England to maintain the fixed rate between sterling and the dollar. The exception in the system

---

[30] Dam (1982), p.71.
[31] Ibid., p.72.

itself was the dollar which, by law, was fixed in terms of gold at $35 an ounce. The U.S. was not obliged to intervene in the exchange market but it had to be prepared to buy and sell gold at $35. It could leave the intervention to other central banks to maintain fixed rates to the dollar.[32]

2.4.2 Reserves

To maintain fixed rates the monetary authorities held reserves so that they could smooth out fluctuations in supply and demand in the foreign exchange market. Reserve assets were almost entirely confined to gold and to foreign exchange assets in dollars (or sterling).[33] Each central bank was free to determine the composition of its reserves as between gold and dollars. Its policy in this respect was in its own hands because it could sell or buy gold against dollars at the U.S. Treasury. Dollars were held almost entirely in money-market instruments and time deposits that earned interest. Gold, on the other hand, produced no revenue. If the U.S. did not permit central banks to invest dollars at interest, their reserves would have been almost entirely in gold.[34]

While other countries were free to hold their reserves in any combination of gold and dollars, the United States was required to hold its reserves essentially in gold. No other currency besides the dollar could be used for general intervention in the exchange market. As a result, any foreign currencies held by the U.S. could not be used for general support of the dollar in the way that other countries used the dollar as a general support for their currencies. The U.S. could generally use foreign exchange holdings only for bilateral settlements.

Since the United States was the only country obliged to hold its reserves in gold, the function of gold as a discipline against excessive money creation was primarily applicable to the U.S. Other countries were subject to balance of payments discipline but this discipline relied on the loss of any reserves- whether dollars or gold. Even so, if other countries entirely stopped acquiring gold, the discipline of gold on the U.S. would become rather theoretical; increases in its liabilities to foreign official institutions would exert little discipline on the United States.[35]

---

[32] Eichengreen (1985), p.230.

[33] While sterling was important to the international economy as a trading currency, it was active as a reserve currency only in settlements between the United Kingdom and sterling-area countries.

[34] Eichengreen (1985), p.232.

[35] Ibid., p.233.

2.4.3 Credit facilities

Besides reserves, IMF facilities were available in the system to assist countries that encountered balance of payments difficulties. The amount any country could draw was originally fixed by its quota, which broadly reflected its size and economic strength. In establishing its quota, each country as a rule paid 25 percent to the IMF in gold and 75 percent in its own currency and agreed that its currency might be drawn upon in case of need to finance other countries' drawings. The right of a country to draw on its gold subscription was practically automatic; so also was its right to draw on any credit balance it may have built up by having had its own currency drawn upon.[36]

In addition to the IMF, short-term central bank credit facilities had been arranged among a number of countries. These could be used on an ad hoc basis and were designed to help meet reversible movements of private funds and to relieve pressure on the reserves from a demand for foreign exchange. Foreign commercial bank credit and other private liquid funds could also be used to relieve strains on the exchange market.

2.4.4 The adjustment process

A country with a balance of payments deficit could for a time hold its exchange rate by drawing on reserves and available borrowing facilities. As these reserves were limited, sooner or later, the authorities were required to take action to get out of deficit. Among the policy actions available to eliminate a deficit were: fiscal and monetary restraint on total domestic demand so as to limit imports, a rise in interest rates relative to rates abroad so as to improve the net external balance on short and long-term capital, direct controls on imports and/or direct controls on capital exports.[37]

The primary responsibility and the active role in the adjustment process, fell on deficit countries because it was their exchange rates that were in jeopardy. When a country was in surplus, the central bank was free to concentrate on domestic objectives. Therefore, there was a natural bias toward being in surplus since this was the surest way to avoid any risks to the exchange rate. When a country was in a moderate surplus, it would not take deliberate action to reduce the surplus.[38]

---

[36] Ibid., p.236.
[37] Ibid., p.238.
[38] Ibid., p.243.

2.4.5 The close of the gold window

The Bretton Woods arrangement operated for merely a quarter of a century. In the mid-1950's the dominance of the U.S. dollar was clear; however, in the 1960's, the dollar began a slow but steady retreat as the world's principal currency. By the late 1960's, economic trends threatened America's commitment to sell gold at $35 per ounce. Resulting from a steady leakage of gold from the U.S. Treasury, U.S. gold stocks had fallen from $22.9 billion in 1957 to less than $11 billion early in 1968. The United States attempted to stem the tide by making it clear that requests to convert dollars into gold at the Federal Reserve, though legally possible, would be viewed as an unfriendly act. This diplomatic stance kept U.S. gold holdings largely intact but could not relieve the ever growing negative balance in the U.S. international reserve position. It was later observed, "the fiction of dollar convertibility had been stretched beyond the limits of credibility."[39]

On August 12, 1971, the British sought to cover a portion of their dollar holdings by requesting the Federal Reserve to make a swap drawing on the Bank of England. To the top U.S. decision-makers, the British request was the beginning of a run on the U.S. gold bank. The British move led directly to the decision on August 15, 1971, to close the U.S. gold window.

2.5. A Flexible Exchange Rate Regime

With the gold window closed, the gold-exchange system of the postwar period drew to an end, and the international economy was perched on the edge of a new era of generalized floating. The U.K. floated the pound sterling in June 1972, which promptly depreciated by about six percent. In early 1973, the U.S. dollar weakened seriously in the exchange markets. In February 1973, foreign intervention in support of the dollar approached $10 billion. After a short respite, sales of dollars were so great that exchange markets were closed in major European countries and Japan for a two-week period. The United States announced its intent to refrain from supporting the value of the dollar in exchange markets. The European Economic Community Council of Finance Ministers in turn announced the intention of the Community's member countries to float jointly against the dollar.[40]

---

[39] Dam (1982), p.187.
[40] Ibid., p.193.

Economists had long pointed out that under a floating system, international reserves would not be needed. This proposition assumed an absolutely free float by each country independent of every other country. This was not the pattern that emerged. Many countries actively managed their exchange rate through market intervention and all countries intervened at least occasionally.[41]

2.5.1 Inflation and the desire for price stability

The fundamental change in the world oil market, which burst upon the public consciousness with a fourfold increase in oil prices in the winter of 1973-74, had a number of consequences for the international monetary system. The first was that the principal oil exporters would enjoy (for a time at least) large payments surpluses and most of the rest of the world would have to live with payments deficits. The second consequence was that the spectacular increases in liquidity that accompanied the collapse of the Bretton Woods system continued through much of the 1970's. New liquidity increasingly took the form of commercial bank lending to deficit countries.[42]

The rise of inflation in the late 1960's and 1970's (sometimes called the Great Inflation) was ended in the early 1980's as central banks embraced "price stability" as a primary long-term goal for monetary policy.[43] Today, there is considerable discussion among central bankers as to what is meant by "price stability" and what policies and operating procedures should be implemented to maintain price stability.

2.5.2 A price level targeting regime versus an inflation targeting regime

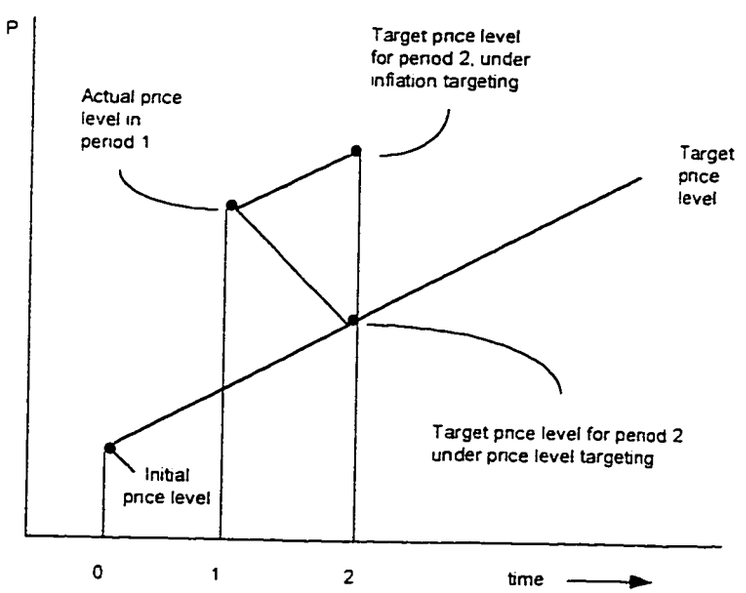
The literal meaning of price stability is stability of the average price level, not low inflation. An inflation targeting regime is distinguished from a price level targeting regime in figure 2.5.1.[44] With a price level target, the central bank is always aiming to return to the original (target) path, so that above average inflation would, on average, be followed by below average inflation. With inflation targeting, past failures to hit the inflation target are treated as bygones, and the price level is likely to deviate increasingly

---

[41] Ibid., p.196.
[42] Ibid., p.292.
[43] Taylor (1996), p.182.
[44] Fischer (1996), p.21.

from the path it was initially expected to take. Price level targeting provides greater certainty about the level of prices in the distant future, and thus encourages long-term nominal targeting. However, it puts greater strain on monetary policy, requiring variations in the inflation rate to reverse the effects of previous shocks. In the real world, there are currently several monetary policy regimes with explicit or implicit inflation targeting, but there are no regimes with explicit or implicit price level targeting.[45]

Figure 2.5.1
Inflation Versus Price Level Targeting

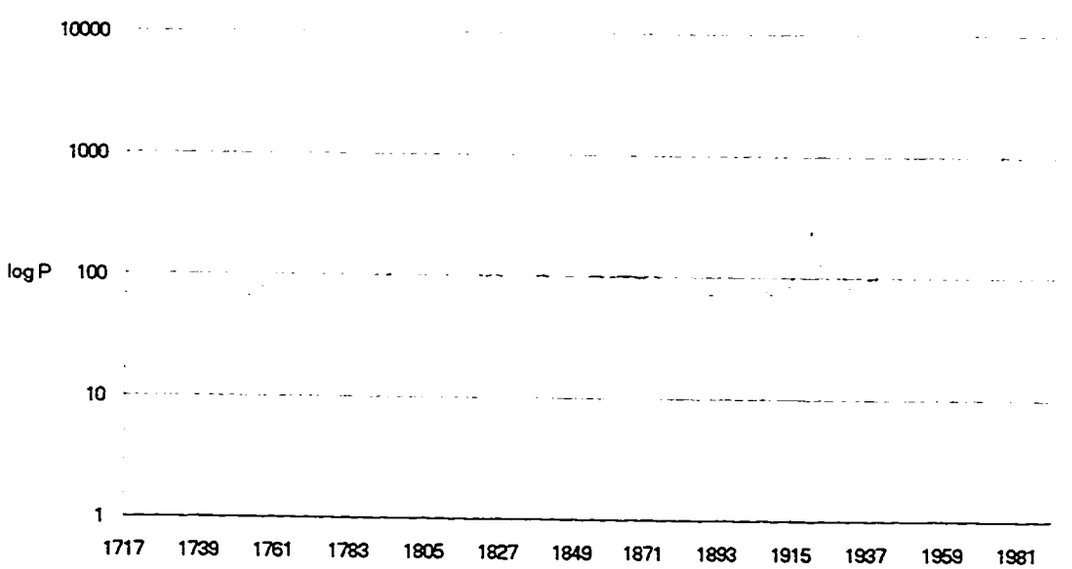


[45] Ibid. p.22.

2.6. Significant Events Affecting Inflation Rates in Britain

This section highlights the major economic events affecting inflation rates in Britain. The statistical analysis begins in 1717 when Britain established a *de facto* gold standard. Up to this time, both silver and gold circulated side-by side. However when Sir Isaac Newton, then Master of the Mint, set too high a silver price for the gold guinea, silver coins were quickly driven from circulation. The Peel's Act in 1819 and amendment in 1821 established a full legal gold standard in England.[46] Figure 2.6.1 displays British wholesale commodity prices from 1717 to 1991.[47]

Figure 2.6.1
British Wholesale Commodity Prices, 1717-1991

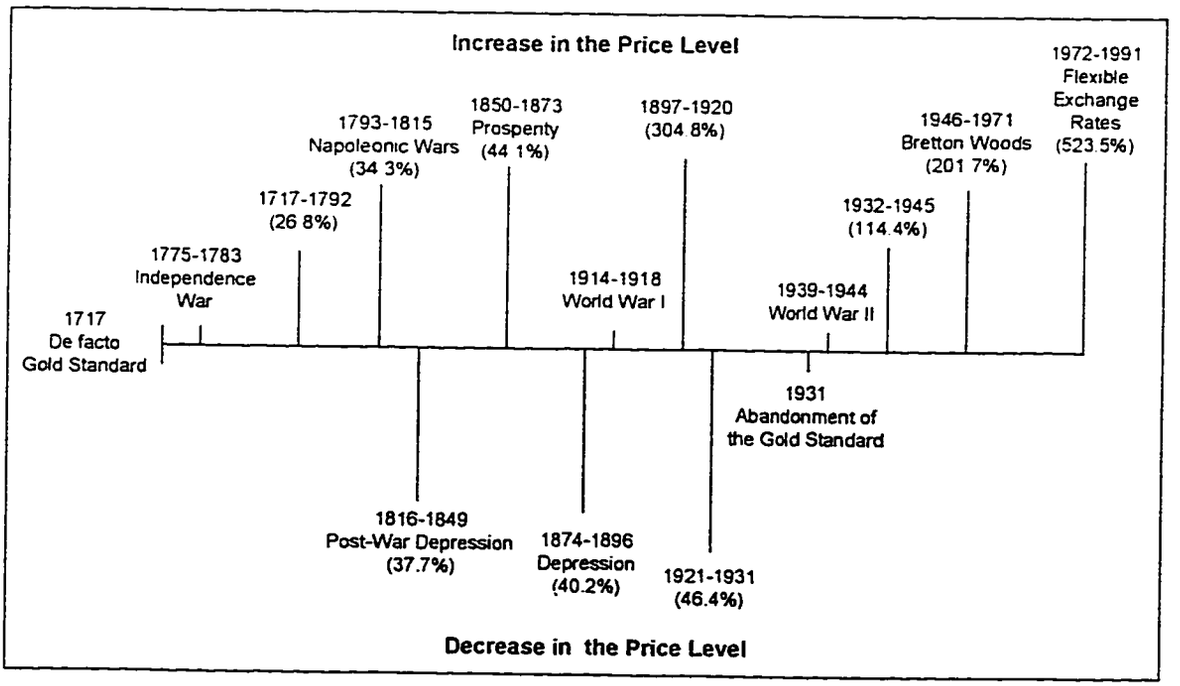


[46] Eichengreen (1985), p.4.
[47] See appendix C for information about the price series.

2.6.1 A historical overview of inflation rates in Britain[48]

The eighteenth century was a century of growing economic and political strength at home and abroad. Constitutional parliamentary government and a limited monarchy were gradually accepted. The nineteenth century was one of rapid economic growth and hard money. The Industrial Revolution ran its full course as railroads and factories transformed the economy. By the twentieth century England lost much of its reputation for financial stability and leadership. The financial consequences of the two world wars played a role in this. Although victorious in both wars, England lost its position as the dominant political and financial power in the world. What follows is an overview of key economic and political events in Britain and their effects on prices over the last three centuries.

Figure 2.6.2
Periods of Rising and Falling Prices in Britain



[48] The historical events highlighted in section 2.6.1 are obtained from Homer (1991), p. 147-436.

1717-1792

In 1717, gold was given the status of legal tender along with silver. There was war with Spain in 1717-1720 and 1729-1748, the War of the Austrian Succession in 1740-1748, the Seven Years' War in 1755-1763. By 1763, England was for the time being at the summit of her power. She had acquired Canada, Florida, Gibraltar, and many other foreign possessions as well as establishing a position in India. There followed a period of crises and disaster: the loss of the American colonies in the War for Independence, 1775-1783, the shock of the French Revolution, 1789, and the wars with France. From 1717-1792, the commodity price level rose a mere 26.8% at a rate of 0.3% per year.[49]

1793-1815

Wars had been fought for thousands of years but never a conflagration like the Napoleonic Wars. All Europe was involved and, through Russia, the Asiatic Dominions. Even Africa was not spared. In 1815, Napoleon's defeat at Waterloo touched off a speculative boon that ended in credit collapse and failures. Commodity prices declined, money tightened, and many country banks failed. Over the 23 year period, the price level increased 34.3% at an average rate of 1.3% per year.

1816-1849

After Waterloo in 1815, a century of relative peace followed. In 1816, a severe economic depression began that brought falling commodity prices, falling interest rates, and unemployment. There was stagnation of industry and trade generally. The iron and coal industries were paralyzed. There was a failure of the wheat crops and below-average harvests in barley and oats. It was a long period of depression and distress, only occasionally punctuated by brighter times of short duration. Altogether, the price level fell 37.7% at an annual rate of 1.4%.

1850-1873

In 1849 a period of heavy gold imports to London began, which arose from new discoveries in California and Australia. Large sums were loaned abroad. Britain financed

---

[49] The average rate of inflation is the compound annual growth rate.

railways in Europe and North America and stock speculation became widespread. The period, 1867-1873, marked a turning point in nineteenth century political and economic history. The U.S. was united and on its way to becoming a great power. Germany emerged from the Franco-Prussian War of 1870-1871 as a great power. The opening of the Suez Canal in 1869 signalized the vital concern of England in the affairs of the entire globe. The prosperity produced an average increase in commodity prices of 1.5% per year. As a result, the price level rose 44.1% during this period.

1874-1896

Recession hit in 1873 with a stringent money market and very poor wheat harvests. A long depression followed; however, there were no major financial crises. Commodity prices declined for over 20 years at an average annual rate of 2.2%. For the period as a whole, the price level dropped 40.2%.

1896-1920

The years 1894-1896 were remarkable for the fact that interest rates reached their lowest point of the century. Prosperity returned and the pound sterling was "as good as gold," a true international currency. The accumulation of English capital and the difficulty of finding profitable outlets for it in England led to increased foreign investment. World War I, 1914-1918, took the world's markets by surprise and created a wave of liquidation. In time it became a contest between the resources of the Central Powers blockaded in Europe and those of most of the rest of the world. Specie payments were suspended during the war and commodity prices surged. The commodity price level jumped 304.8% at a rate of 6% per year.

1921-1931

World War I was followed by a sharp depression in 1920. In 1925, England returned to the gold standard at the prewar parity. The crash of the American stock market in 1929 brought large declines on the London Exchange and started a wave of credit liquidation throughout the world. American capital, which had financed an important part of world trade in the 1920's, was no longer available. Liquidation and deep depression led many countries to abandon their recently restored gold standards, and this put pressure on the

London money market. In 1931, England abandoned the gold standard. Commodity prices contracted at an annual rate of 5.8% and the price level dropped 46.4%.

1932-1945

Immediately after England abandoned the gold standard, English monetary policy was reversed. Interest rates were quickly pushed down, and every effort was made to encourage production and consumption. The outbreak of World War II in 1939 did not come as a surprise. The markets had long been prepared for it and were very liquid. There was no financial panic such as had occurred in 1914. Detailed plans had been made in England for economic mobilization. It was fully realized that economic resources would play a large part in determining the outcome of the war. Consumers were rationed, prices were controlled, exports and imports were regulated for national purposes, and the foreign assets of nationals were mobilized. England drew heavily on her foreign assets to finance essential imports and She also lost an important part of her export markets. Consequently, England came out of the war a net debtor. The commodity price level rose 114.4% at a rate of 5.6% per year.

1946-1971

In 1946, England, along with nearly all of the countries outside the emerging communist bloc, adopted the gold-exchange standard as outlined in the Bretton Woods Agreement. During the years after 1949, the pound was held at a reduced value. After 1965 a world-wide inflation got under way, and it soon became worse in England than in other industrial nations. Commodity prices increased at an average annual rate of 4.3%; with the price level rising 201.7% for the period.

1972-1991

In the 1970's, Britain saw an oil embargo, escalating money supply, and large government borrowing abroad. After a general suffering of inflation, steps were announced to reduce consumption and encourage production. In the 1980's the conservative Thatcher government pursued policies similar to those of the Reagan administration in the United States. In total, the price level ballooned 523.5% at a rate of 9.5% per year.

2.6.2 The variability of inflation rates in Britain

The appeal of the gold standard is the belief that it provides price level stability. In order to stabilize the price level, periods of inflation must be succeeded by periods of deflation. As shown in figure 2.6.3, periods of rising prices were usually followed by periods of falling prices during the classical gold standard (1717-1931). Conversely after 1946, there has been a persistent increase in the price level.

Figure 2.6.3
Inflation Rates in Britain, 1718-1991

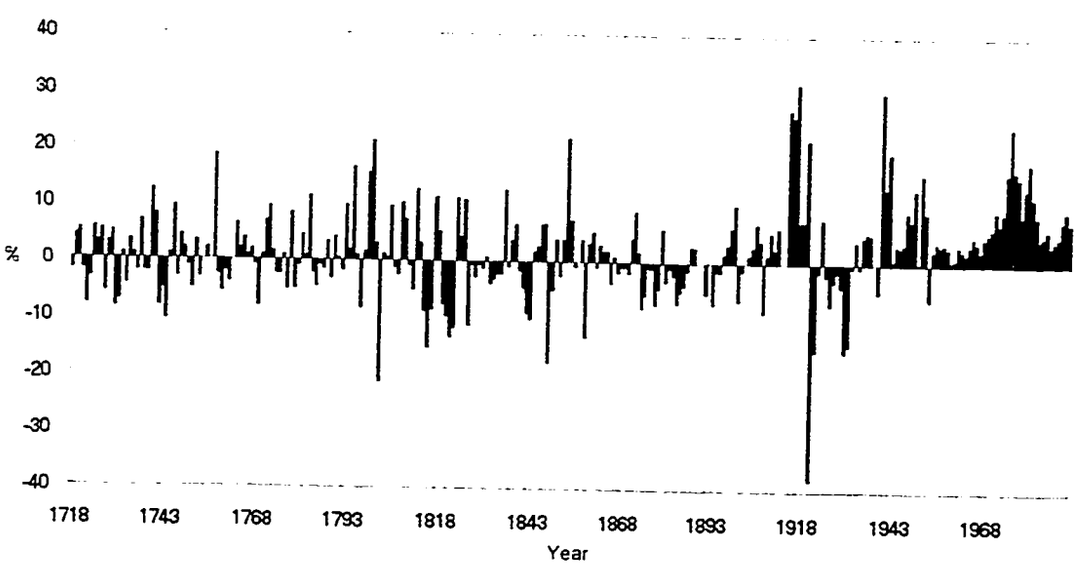


Table 2.6.1 shows a comparison of the standard deviation of the year-over-year rate of change in prices during and after the classical gold standard. It appears that inflation was more variable under the classical gold standard regime.

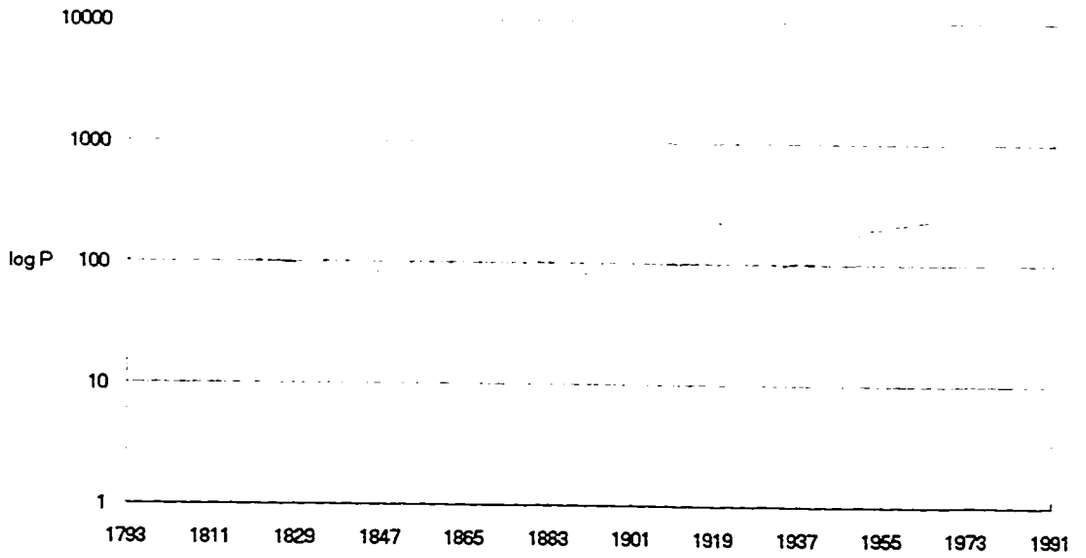
Table 2.6.1
Standard Deviation of Inflation Rates in Britain

Regime	Period	σ_π
Classical gold standard	1717-1931	8.00
Bretton Woods	1946-1971	4.36
Flexible Exchange Rates	1973-1991	5.56

2.7. Significant Events Affecting Inflation Rates in the United States

This section reviews some of the significant economic events in the United States and their repercussions for inflation rates. The statistical analysis begins from 1793 after the United States established a commodity money regime. Until the 1880's, the United States was officially on a bimetallic standard; offering to convert its currency into specified amounts of either gold or silver. Figure 2.7.1 charts wholesale commodity prices in the United States from 1793 to 1991.[50]

Figure 2.7.1
U.S. Wholesale Commodity Prices, 1793-1991

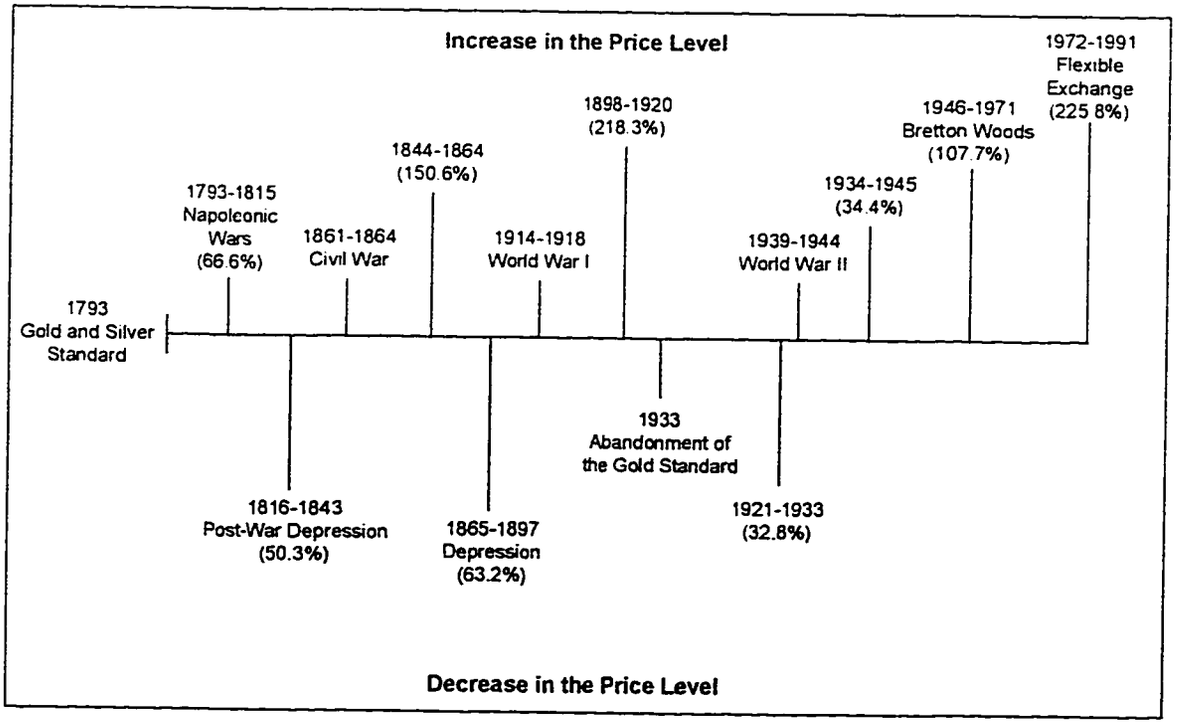


[50] See appendix C for information about the price series.

2.7.1 A historical overview of inflation rates in the U.S.[51]

From 1789 to 1815 the new United States of America was deeply involved in a succession of European wars and crises that began with the French Revolution and ended with Waterloo. Caught between English and French ambitions, and with its sympathy and interest divided between these two world powers, the United States was finally involved on the losing side in the War of 1812. During these first 26 years, foreign political affairs exerted a dominant influence on American finance. During the succeeding 100 years, the political events that influenced American finance were usually domestic. The dominating domestic political event of the nineteenth century was the Civil War. By the twentieth century, the United States was preeminent among nations. What follows is a brief review of the key economic and political events that affected inflation rates in the U.S over the last 200 years.

Figure 2.7.2
Periods of Rising and Falling Prices in the U.S.



[51] The historical events highlighted in section 2.7.1 are obtained from Homer (1991), p. 275-549.

1793-1815

During the European wars (1792-1815), American farm prices rose rapidly and remained abnormally high. There were temporary dips in 1802-1803 and during the embargoes of 1808-1809, but general prosperity was the rule. The War of 1812-1814 created financial stress and prices rose continuously until peace was declared. The commodity price level increased 66.6% from 1793 to 1815 at an average annual rate of 2.2%.

1815-1843

After the European wars, money became very tight in financial centers, and failures in the speculation of land added to the financial chaos. Unemployment in 1816 was severe and credit contractions caused widespread financial difficulties by 1818. By 1823, conditions stabilized. Business fluctuations were thereafter moderate for a decade, with minor pressures in 1825, 1828, and 1831. In 1833 a brief expansion began. The states pledged their credit to finance various infrastructure projects, there was speculation in Western lands and foreign capital poured in freely. A crisis occurred in 1837. Its immediate causes were financial trouble in England, crop failures in 1835 and 1837, and a fall in the price of cotton. From 1815 to 1843, commodity prices contracted at a rate of 1.8% per year and the price level fell 50.3%.

1844-1864

Prosperity gradually swelled and became general again by 1845. The Mexican War of 1846 created no serious pressures. The European financial disturbances of 1847-1848 led to only a brief setback. Following the California gold strike of 1848, there was a period of great prosperity. Banking expanded and prices rose. Active railroad construction was under way, and foreign trade was booming. The Civil War (1861-1864) brought the usual economic stimulations and dislocations of a great conflict. War finance led to a suspension of specie payments and a huge emission of short-term government securities and legal tender notes. Over the 20 year period, the commodity price level jumped 150.6% at a rate of 4.4% per year.

1865-1897

Lee surrendered in April of 1865. Lincoln was assassinated in the same month and the Civil War was formally ended in August. The South was in economic chaos, with a complete collapse of currency and government finance. In 1879, heavy gold imports into the U.S. led to an abatement of financial pressures and to the beginning of a business recovery. The government assured convertibility of its paper money at par and re-established the gold standard. The panic of 1893 was marked by a collapse of the stock market and 600 bank failures. There were serious labour troubles, an agricultural depression, and agitation for free silver. Railroad bankruptcies again became common. Commodity prices declined at an average annual rate of 3.1% during the period. Overall, the price level dropped 63.2%.

1898-1920

The era of industrial combinations began. In 1899 immigration surged, carrying all the implications that were to follow for the supply of labour and the demands for industrial output. The achievement of large-scale industry was epitomized by the U.S Steel Corporation, formed in 1901. By 1915, war industries manufacturing and exports increased enormously. Altogether, the commodity price level increased 218.3% at a rate of 5.1% per year

1920-1933

From 1920 to 1921, prices dropped steadily but then held steady until 1929. In October of 1929, stock prices collapsed on the New York Stock Exchange. The domestic economy was running poorly and unemployment was growing. In the latter part of 1931, European countries were no longer able to meet their debts. The various gold standards were abandoned and national currencies were disarranged. In 1933, the U.S. went off the classical gold standard. Commodity prices declined at a rate of 3.1% per year and the price level decreased 32.8% for the period.

1934-1945

By 1936, business recovered substantially and a large volume of gold was flowing in from Europe. The outbreak of World War II brought a brief decline in the bond market, but no noticeable repercussion in the money market. Pearl Harbor (1941) brought America into the war. Commodity prices rose at a rate of 2.5% per year and the price level increased 34.4% during the period.

1946-1971

From the war's end through the mid-1960's, the United States maintained a gold exchange standard that was essentially a gold-dollar standard. The American economy experienced stable economic growth with minimal inflation, aided the recovery of war-torn Europe, and led the Western alliance in keeping a lid on the Cold War. Talk of "the American Century" was common. During the later 1960's the American century began to unravel. Inflation and loss of gold reserves forced the United States to abandon the Bretton Woods Arrangement. The Bretton Woods system came to an end in 1971 when the United States officially "closed the gold window." The price level rose 107.7% at a rate of 2.8% per year.

1972-1991

The period would be one of an unpopular war in Asia, a more stagnant and unstable economy and a protracted inflation of prices. The term "stagflation" came into general use as a result of the experiences of 1973-1975 and 1980-1982. At the end of 1982, there began a sustained economic expansion that carried through the 1980's. Overall, the price level jumped 225.8% at an average annual rate of 6.1%.

2.7.2 The variability of inflation rates in the U.S.

The Coinage Act of 1792 created a bimetallic system. This system worked reasonably well until convertibility was suspended with the outbreak of the Civil War. In 1879 the U.S. returned to a monometallic gold standard. The United States was on some form of gold standard whether jointly with silver or functioning alone until 1933. As shown in figure 2.7.3, periods of rising prices were accompanied by periods of falling prices during the classical gold standard (1793-1933). Conversely after the wars, there has been a persistent increase in the price level.

Figure 2.7.3
Inflation Rates in the United States, 1794-1991

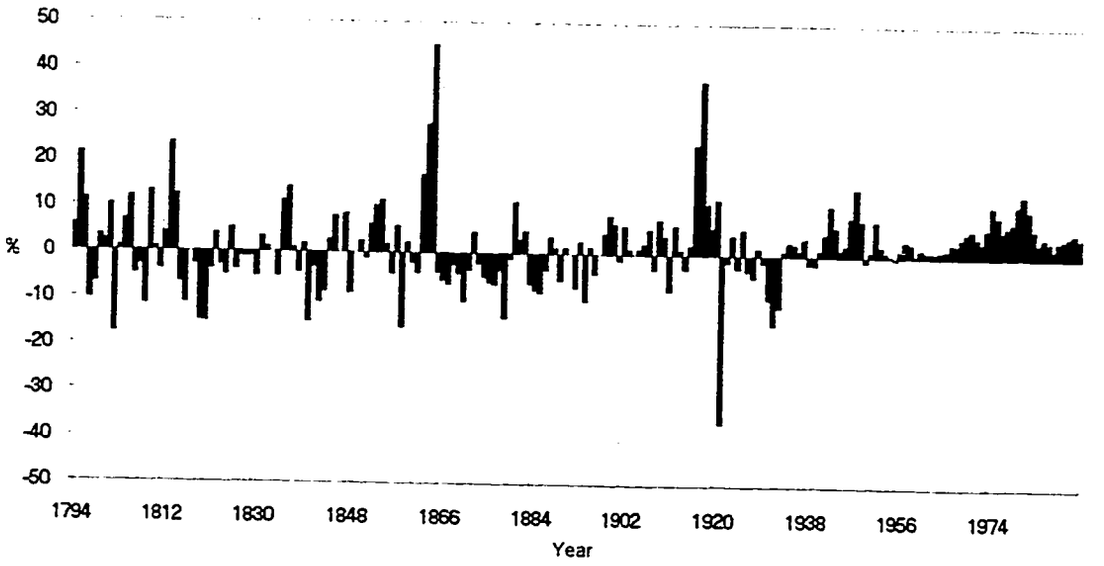


Table 2.7.1 shows a comparison of the standard deviation of the year-over-year rate of change in prices during and after the classical gold standard. As in the British case, inflation was more variable under the classical gold standard regime.

Table 2.7.1
Standard Deviation of Inflation Rates in the U.S.

Regime	Period	σ_π
Classical gold standard	1793-1933	9.93
Bretton Woods	1946-1971	3.42
Flexible Exchange Rates	1973-1991	3.19

III Unit Root Tests: Issues and Practice

A significant re-evaluation of the statistical basis of econometric modelling took place during the 1980's. Its analytical basis expanded from the assumption of stationarity to include integrated processes. A series is said to be integrated if it accumulates past effects. An integrated series is nonstationary because its future path depends upon all past influences, and is not tied to some mean to which it must eventually return. Consequently, this has led to the interest in testing for the order of integration in time series variables or the so called unit root tests. The presence of a unit root implies a stochastic nonstationarity instead of a deterministic one.[52]

It has long been thought that the classical gold standard induced stability of the price level. Gold served as an "anchor" for commodity prices. Periods of rising prices would be followed by periods of declining prices so that the average price level would remain constant. If this were so, then it would imply that the price level was stationary during the gold standard period. With the advent of unit root tests, the order of integration of the commodity price level in the U.K. and the U.S. can be explored. Sections 3.2 and 3.3 present the various methods that have been developed to test for unit roots in time series variables. The power and limitations of these tests are examined in section 3.4 and a testing strategy is proposed in section 3.5. The seminal paper of Nelson and Plosser (1982) tested for unit roots in 14 individual U.S. historical time series. Their results were subsequently re-examined by Perron (1988, 1989), DeJong and Whiteman (1991) and Kwiatkowski et. al. (1992). The empirical results are compared and contrasted in section 3.6. In the following section (major section four) the unit root tests illustrated in this section are used to determine the stationarity of the price level during the classical gold standard regime, Bretton Woods system, and flexible exchange rate regime.

[52] P. Perron (1988), p.297-298.

3.1. Unit Roots in Macroeconomic Time Series

Much conventional asymptotic theory for least-squares estimation (e.g., the standard proofs of consistency and asymptotic normality of OLS estimators) assumes stationarity of the explanatory variables, possibly around a deterministic trend. In an integrated series, random shocks have an enduring effect on future values of the variable, while in a stationary series, they have a vanishing effect. While an integrated series cannot be stationary, the changes in that series might be. A series is said to be integrated of order one I(1) if, although it is itself nonstationary, the changes in the series form a stationary series. In general, if the series must be differenced exactly k times to achieve stationarity, then the series is integrated of order k, I(k). A stationary series is integrated of order zero I(0).[53]

One potential solution suggested for dealing with integrated series was to assume that the source of nonstationarity could be captured by (or approximated by) a deterministic function of time. If this were so, it would be possible to break up an integrated series into a deterministic (and therefore completely predictable) component, and a stationary series of deviations from this trend. Methods for analyzing stationary series could be applied to the deviations, and the whole series thereby modelled. Unfortunately, subsequent evidence from Monte Carlo and analytical studies (e.g., Phillips, 1986) showed that inference in models that contained time trends could not be carried out in the straightforward way that practitioners had hoped. Time trends would appear to be statistically significant in models where they should not be, much more often than conventional test sizes would suggest. Therefore, analytical techniques have been developed to test for unit roots in time series.

---

[53] Ibid. p. 136.

3.2 Standard Unit Root Tests

The simplest data-generating processes (DGP) for which unit root tests can be conducted are:

(3.21) $y_t = \rho_n y_{t-1} + u_t$

(3.22) $y_t = \mu_c + \rho_c y_{t-1} + u_t$

(3.23) $y_t = \mu_{ct} + \gamma_{ct} t + \rho_{ct} y_{t-1} + u_t$

where $\phi(L) u_t = \theta(L) \varepsilon_t$, and $\varepsilon_t \sim i.i.d.(0, \sigma_\varepsilon^2)$.

First assume that u_t is equal to ε_t so that it is white-noise under some specific values of the parameters. These processes can be characterized in the following manners:[54]

- For equation (3.21):
  - if $\rho_n < 1$, then the DGP is a stationary zero-mean first-order autoregressive process;
  - if $\rho_n = 1$, then the DGP is a pure (driftless) random walk.
- For equation (3.22):
  - if $\rho_c < 1$, then the DGP is a level-stationary first-order autoregressive process;
  - if $\rho_c = 1$, then the DGP is a random walk.
- For equation (3.23):
  - if $\rho_{ct} < 1$, then the DGP is a trend-stationary first-order autoregressive process;
  - if $\rho_{ct} = 1$, then the DGP is a random walk with a drift changing over time.

3.2.1. Simple Dickey-Fuller tests

Since an I(1) series becomes stationary upon being differenced once, it must contain one unit root. The Dickey-Fuller procedure involves estimating the following models:

- For equation (3.21):

(3.24) $\Delta y_t = (\rho_n - 1) y_{t-1} + u_t$

---

[54] Dickey and Fuller (1979), p.428.

- For equation (3.22):

(3.25) $\Delta y_t = \beta_{0c} + (\rho_c - 1) y_{t-1} + u_t$

- For equation (3.23):

(3.26) $\Delta y_t = \beta_{0\tau} + \beta_{1\tau} t + (\rho_\tau - 1) y_{t-1} + u_t$

In their seminal papers, Dickey and Fuller (1979, 1981) had originally developed unit root test statistics for regressions (3.24) to (3.26), for the case of a DGP with $\rho = 1$, under the maintained assumptions that $y_0 = 0$ and that $u_t = \varepsilon_t \sim i.i.d.(0, \sigma_\varepsilon^2)$. In contrast to the usual t-statistics, under the null hypothesis of nonstationarity, the Dickey-Fuller test statistic does not follow the Student t-distribution even asymptotically. Rather, it follows a non-standard Dickey-Fuller distribution that is skewed to the left compared with the normal distribution. Dickey and Fuller (1981) tabulated the critical values of these test statistics from Monte Carlo simulations. Since the asymptotic and finite distributions of the Dickey-Fuller statistic are dependent upon the set of exogenous or deterministic regressors (such as an intercept or a time trend) being included in the regression, different critical values have been tabulated for regression models (3.24) to (3.26). The null and alternative hypotheses to be tested are:

- For equation (3.24):

H_0: pure random walk with initial condition $y_0 = 0$.
H_1: zero-mean AR(1) process.

- For equation (3.25):

H_0: pure random walk with initial condition $y_0 = 0$.
H_1: non-zero-mean AR(1) process.

- For equation (3.26):

H_0: random walk with drift.
H_1: linear trend-stationary AR(1) process.

3.2.2. Augmented Dickey-Fuller tests

The simple Dickey-Fuller test was the first form of unit root test to have been developed. Its main potential disadvantage lies in the fact that it is based upon the assumption that the DGP holds precisely under the null. Many series will be integrated of order one but will not have this form. In practice, it is not uncommon to encounter data whose innovations exhibit all sorts of dynamics best represented by some ARMA process.[55] Said and Dickey (1984) have shown that to account for the time-dependence in the innovation, one can augment the basic regression models with lags of Δy_t.

(3.27) $\Delta y_t = (\rho_n - 1) y_{t-1} + \sum_{i=1}^{\ell} \alpha_i \Delta y_{t-i} + v_t$.

(3.28) $\Delta y_t = \beta_{\kappa} + (\rho_c - 1) y_{t-1} + \sum_{i=1}^{\ell} \alpha_i \Delta y_{t-i} + v_t$.

(3.29) $\Delta y_t = \beta_{\delta\tau} + \beta_{t\tau} t + (\rho_\tau - 1) y_{t-1} + \sum_{i=1}^{\ell} \alpha_i \Delta y_{t-i} + v_t$.

These procedures are called "augmented" Dickey-Fuller (ADF) tests. The test statistic follows the same asymptotic distribution as that when u_t is white noise. The aim of these modifications to the simpler form of the Dickey-Fuller test is to use lagged changes in the dependent variable to capture autocorrelated omitted variables that would otherwise, by default, appear in the (necessarily autocorrelated) error term. Campbell and Perron (1991) suggested that one use a data-dependent procedure to select the value of ℓ. Begin with some upper bound on ℓ, say ℓ_{max}, chosen a priori. Estimate an autoregression of order ℓ_{max}. If the last included lag is significant (using the standard normal distribution), select $\ell = \ell_{max}$. If not, reduce the order of the estimated autoregression by one until the coefficient on the last included lag is significant. If none is significant, select $\ell = 0$.

3.2.3. Phillips-Perron tests

In extending the simple Dickey-Fuller tests to allow for higher-order autocorrelation, extra terms were added to the regression model to account for the autocorrelation in the residuals that would otherwise be present. Phillips (1987) and Phillips and Perron (1988) have proposed another way to remove the dependency of the asymptotic distribution on the autocorrelation of the innovations. Rather than taking account of extra elements in

---

[55] Banerjee et al. (1993), p.104.

the data-generating process by adding them to the regression model, Phillips suggests accounting for the autocorrelation through a nonparametric correction to the standard statistics. While the Dickey-Fuller procedure aims to retain the validity of tests based on white noise errors in the regression model by ensuring that those errors are indeed white noise, the Phillips procedure acts instead to modify the statistics after estimation in order to take into account the effect that autocorrelated errors will have on the results.

As with the Dickey-Fuller tests, the Phillips-Perron tests are based upon one of three different regression models, differing only in one case from those used earlier, by centering the trend term:[56]

(3.2a) $y_t = \rho_\alpha y_{t-1} + u_t$.

(3.2b) $y_t = \mu_\alpha + \rho_\alpha y_{t-1} + u_t$.

(3.2c) $y_t = \mu_\alpha + \gamma_\alpha (t - T/2) + \rho_\alpha y_{t-1} + u_t$.

The error term is *not* assumed to follow a white-noise process. The Phillips-Perron approach is first to calculate the unit root test statistics and then to adjust them to reflect autocorrelation in the error term. Essentially, the correction uses a nonparametric estimate of the variance-covariance matrix so that it is free from the influence of autocorrelation and of some time-dependent heteroskedasticity.[57]

The Newey and West (1987) method is used to construct an estimate of the error variance from the estimated residuals:

$$S_{\ell}^2 = \frac{1}{N}\sum_{t=1}^{N} \varepsilon_t^2 + \frac{2}{N}\sum_{s=1}^{\ell} \omega(s,\ell) \sum_{t=s+1}^{N} \varepsilon_t \varepsilon_{t-s},$$

where the estimator is indexed by the lag truncation parameter ℓ.[58] The unit root hypothesis tests are carried out in the same manner as the Dickey-Fuller tests and the critical values are the same as those used in those tests.

---

[56] Phillips and Perron (1988), p.337-338.

[57] Banerjee et al. (1993), p.109.

[58] Since the test statistics are sensitive to the choice of lag truncation parameter, Campbell and Perron (1991) suggest computing the statistics with different lag lengths.

3.3. Testing the Null Hypothesis of Stationarity

It has been established empirically that standard unit root tests (DF, ADF, PP tests) fail to reject the null hypothesis of a unit root for many economic time series. This was first argued systematically in the influential article of Nelson and Plosser (1982) and subsequent others.[59] These results are not changed by allowing for error autocorrelation using the augmented Dickey-Fuller tests or the Phillips-Perron tests. Similar results are obtained for many other macroeconomic time series.

One conclusion that can be drawn from this empirical evidence is that many or most aggregate economic time series contain a unit root. However, it is important to note that in this empirical work the unit root is the null hypothesis to be tested, and the way in which classical hypothesis testing is carried out ensures that the null hypothesis is accepted unless there is strong evidence against it. Therefore, an alternative explanation for the common failure to reject a unit root is simply that most economic time series are not very informative about whether or not there is a unit root, or equivalently, that standard unit root tests are not very powerful against relevant alternatives.[60]

These studies suggest that, in trying to decide by classical methods whether economic data are stationary or integrated, it would be useful to perform tests of the null hypothesis of stationarity as well as tests of the null hypothesis of a unit root. Kwiatkowski, Phillips and Schmidt (1992) propose tests of the null of stationarity against the alternative of a unit root, thereby reversing the usual burden of proof.

3.3.1. Kwiatkowski, Phillips and Schmidt (KPS) test

Kwiatkowski, Phillips and Schmidt (1992) use a parameterization that provides a plausible representation of both stationary and nonstationary variables and that leads naturally to a test of the hypothesis of stationarity. The time series under study is decomposed into the sum of a deterministic trend, a random walk, and a stationary error:

(3.31) $y_t = \xi t + r_t + \varepsilon_t$.

---

[59] Similar results are obtained for many other macroeconomic time series. A partial listing of empirical studies yielding these findings can be found in DeJong et al. (1992).

[60] Kwiatkowski et al. (1992), p.160.

Here r_t is a random walk:

(3.32) $r_t = r_{t-1} + u_t$.

where the u_t are i.i.d $(0,\sigma_u^2)$. The initial value r_0 is treated as fixed and serves the role of an intercept. The stationary hypothesis is simply $\sigma_u^2 = 0$. Since ε_t is assumed to be stationary, under the null hypothesis, y_t is trend stationary. In the case where $\xi = 0$, under the null hypothesis y_t is stationary around a level (r_0) rather than around a trend.

The key insight of KPS is that this is simply a special case of the random coefficients model:

(3.33) $y_t = x_t\beta_t + \varepsilon_t$.

(3.34) $\beta_t = \beta_{t-1} + u_t$.

where imposing $x_t = 1$ and $\beta_t = r_t$ reduces (3.33) to (3.31). This means testing the null of stationarity against the alternative of a unit root is equivalent to testing the null of a constant coefficient model against the alternative of a random coefficient model.[61]

Under the assumptions that the random walk is normal and that the stationary error is white noise, the test statistic is a one-sided Lagrange Multiplier (LM) statistic. However, proceeding in the spirit of Phillips and Perron (1988), KPS derive the asymptotic distribution of the statistics under general conditions on the stationary error. KPS propose a modified version of the LM statistic that is valid asymptotically under these general conditions.[62]

The appropriate Lagrange Multiplier test statistic works out to be:

(3.35) $$LM = \frac{\sum_{t=1}^{T} S_t^2}{\sigma_\varepsilon^2}$$

(3.36) where $S_t = \sum_{t=1}^{t} e_t$

[61] Amano and van Norden (1992), p.3-4.

[62] The asymptotic distribution is nonstandard, involving higher-order Brownian bridges.

e_t is the residual from the regression of y_t on a constant (and trend), σ_ε^2 is the usual estimate of the residual variance from this regression, and T is the sample size. This derivation depends on the strong assumption that ε_t is *i.i.d.* normal with mean zero. KPS extend this test to the case where ε_t is autocorrelated and may be heteroscedastic. The key difference is that the denominator of (3.35) is replaced with the Newey and West (1987) estimate of the long-run variance of ε_t, denoted $s^2(k)$, giving the KPS test statistic:

$$\eta = \frac{T^{-2} \cdot \sum_{t=1}^{T} S_t^2}{s^2(k)} \qquad (3.37)$$

where (k) is equal to the lag truncation parameter and an additional factor of T^{-2} is used to normalize the numerator. KPS suggest computing values of the test statistic for lag truncation values from one to eight. The KPS test statistic is used to conduct a one-sided test of the null hypothesis of stationarity. Critical values that are valid asymptotically are supplied by Kwiatkowski et al (1992).

3.4. Power and Limitations of Unit Root Tests

Testing for unit roots can create opportunities as well as problems for applied work. Taken together, unit root tests offer a way of discriminating between stationary and nonstationary processes in reasonably general circumstances, albeit with some limitations. Simulation results suggest that unit root tests are sensitive to the specification of the underlying data generating process. Considerable work remains to be done in improving the power of unit root tests.[63]

3.4.1 Near unit root processes

In practice, it is not very easy to distinguish between a unit root process (with $\rho = 1$) and a near unit root process (with $\rho = 0.95, 0.98, 0.99$). With a near unit root process, the series y_t eventually returns to its mean even though it may take quite some time. Campbell and Perron (1991) provide results of Monte Carlo experiments of the ADF and PP test statistics. When the true DGP has a unit root but is close to being stationary, the standard

[63] Campbell and Perron (1991), p.141.

unit root tests have severe size distortions; they reject the true null hypothesis too often. When the true DGP is stationary but has a root close to unity, then the standard unit root tests have very little power.

Amano and van Norden (1992) present Monte Carlo results for the KPS test. As is the case with conventional unit root tests, the KPS test appears to suffer from size distortion and loss of power for certain data generating processes. Specifically, the test rejects the null hypothesis too often when the root is close to unity.

3.4.2. Negative moving average component in the innovation

Another important complication arises when performing unit root tests on time series whose first-difference exhibits negative moving average autocorrelation. Schwert's (1989) Monte Carlo simulations show that the Phillips and Perron tests will reject too often the unit root hypothesis and are too liberal to be useful for $\theta = -0.5, -0.8$. The results of this experiment indicate that the distribution of the Phillips-Perron test is not close to the Dickey-Fuller distribution. The poor behaviour of the Phillips-Perron tests where negative MA terms are present persists in regressions that incorporate a time trend.

Likewise, Monte Carlo simulations of the KPS test show that it suffers from size distortions. However, the KPS test is too conservative and rejects too seldom the null hypothesis. Therefore, it would be safest to avoid these non-parametric tests if there is any evidence of the kind of MA component to the errors that causes size distortions. The critical values of the augmented Dickey-Fuller test statistics are much more robust to the presence of moving average terms in the errors of the random-walk process than are the corresponding non-parametrically adjusted statistics.[64]

3.4.3 Sensitivity of lag truncation parameter

There are two approaches for dealing with autocorrelation in the noise component of the data generating process. The ADF test attempts to adjust parametrically whereas the Phillips-Perron and KPS tests use the Newey and West variance estimate to adjust nonparametrically. These tests require the selection of the number of lags to include in the model. In practice, the choice of the truncation lag parameter is an issue. This

[64] Schwert (1989), p.158.

problem is of importance because it is often the case that the outcome of the test depends on the particular choice of this truncation lag parameter. Campbell and Perron (1991) point to several factors that may explain such a sensitivity. First, too few lags may adversely affect the size of the test. Second, the introduction of too many lags may reduce power (because of more parameters being estimated and a reduced number of effective observations, given the need for additional initial conditions). Finally, as ℓ changes, the initial conditions change. These factors point to the importance of choosing the truncation lag parameter judiciously. The choice of a fixed ℓ independent of the data is likely to be inappropriate.[65]

3.4.4. Frequency of observation

Applied researchers are often faced with choices among different types of data sets for a given time series. This can occur when data are available at different sampling frequencies for different lengths of time. It is common to have quarterly observations for the period after World War II, while monthly observations may be available starting in the early 1960s. On the other hand, data covering longer horizons are often available only at an annual frequency. An annual data set might typically contain around 100 observations, while a quarterly data set might contain more than 160 and a monthly one over 300. It is then natural to ask which data set would allow the greatest discriminating power.[66]

For tests of the unit root hypothesis versus stationary alternatives, the power depends very little on the number of observations but is rather influenced in an important way by the span of the data. Shiller and Perron (1985) show that, for a given number of observations, the power of the test is largest when the span of data is longest. For a given span, additional observations obtained using data sampled more frequently lead only to a marginal increase in power. Hence, one would not generally gain more power in unit root tests by working with 288 monthly observations rather than 24 annual observations. Whenever possible, tests of the unit root hypothesis should be performed using annual data over a long time period.

---

[65] In practice, a sensitivity check of the results to different values of the lag truncation parameter should be incorporated in the testing procedures.

[66] Campbell and Perron (1991), p.152.

3.4.5. Structural breaks

While a long span of data improves the power of unit root tests, it also increases the probability that the series of interest is affected by a major structural change in the process characterizing either the trend function or the noise component. The presence of such a structural change would bias the test in favour of the unit root hypothesis. Perron (1989) showed how a break in a deterministic trend at a particular date (say at the start of the Great Depression or at the outset of the first OPEC oil shock) may bias the integration tests to support statistically the unit root hypothesis in real output.

> *If one allows a single change in the intercept of the trend function after the Great Crash of 1929 and a single change in the slope of the trend function after the oil price shock of 1973, then the conclusion is that most macroeconomic time series are not characterized by the presence of a unit root. Fluctuations are stationary around a deterministic trend function. The only "shocks" that have had persistent effects are the 1929 crash and the 1973 oil price "shock".*[67]

3.4.6 A Bayesian critique

The difficulties associated with classical testing methods have led some researchers to use Bayesian methods to make inferences about the presence of unit roots in economic time-series. Modern proponents of Bayesian techniques often start with the likelihood principle and derive Bayesian inference as a logical consequence. The Bayesian treats the data as fixed (they have already been observed), the parameters as random (they are unknown and subject to varying "degrees of belief") and asks what the data have to say about the parameters. Conversely, the Classicist treats the parameters as fixed, the data as random and asks whether the results of an analysis are unusual, given the properties of the procedure being employed (the sampling distribution and the null hypothesis).[68]

Intellectual acceptance of Bayesian methods has not been universal. Scepticism of the field and criticism of its methodology still persist.[69] However, there is one point that is

---

[67] P. Perron (1989), p.1361.
[68] DeJong and Whiteman (1991), p.227.
[69] Phillips (1991), p.334.

generally agreed upon between Bayesians and Classicists. According to the Bayesians, a large σ_ρ in a large sample is evidence against $\rho = 1$ even if the t-statistic for $\rho = 1$ is fairly small.[70] Here, $\sigma_\rho = \sigma\{\Sigma y_{t-1}^2\}^{-1/2}$ is a "standard error" for ρ. Its asymptotic behaviour depends on the value of ρ. When $|\rho| < 1$ we have $\sigma_\rho = O_p(T^{-1/2})$ and when $\rho = 1$ we have $\sigma_\rho = O_p(T^{-1})$, leading one to expect smaller "standard errors" for ρ in large samples in models with a unit root.[71]

3.5. Strategy for Unit Root Testing

Kwiatkowski, Phillips and Schmidt (1992) suggest that tests of the null of stationarity can be used to complement standard unit root tests. Utilizing unit root tests in conjunction with a stationarity test yields four possible outcomes. If the stationarity test rejects the stationary null and the unit root test accepts the unit root null, we would logically conclude that unit roots are present. If the stationarity test accepts the null of stationarity and the unit root test rejects the presence of unit roots, we would logically conclude that the data are stationary. If neither test rejects its null, we could conclude that the data are simply not sufficiently informative to distinguish between stationarity and a unit root. Finally, if both tests reject their nulls, we may suspect some kind of misspecification, since at least one of the tests must be suffering from Type I error. The latter two situations would not allow us to draw conclusions about the presence of unit roots.[72]

To determine the value of using a joint test as opposed to a single traditional unit root test, one must weigh the likelihood of producing conflicting and therefore inconclusive results against the reduced probability of an incorrect conclusion. Amano and van Norden (1992) use a Monte Carlo framework to examine the consequences of using the KPS test in conjunction with the standard unit root tests. For unit root DGPs with non-negative MA parameters, both the single and the joint testing procedures produce few incorrect conclusions of stationarity, with the joint test always more conservative than the single test. However, for negative MA parameters, the joint procedure greatly reduces the number of incorrect conclusions produced by the single test. For stationary DGPs, the results once again differ depending on whether there are negative or non-negative values of the MA parameter. For negative values, the single and joint testing procedures produce

---

[70] Sims (1988), p.471.
[71] Phillips (1991), p.341.
[72] Amano and van Norden (1992), p.8.

nearly identical results. For non-negative MA parameters, the single and joint tests give very similar numbers of incorrect conclusions in larger samples while for small samples and large truncation lengths, the joint test produces far fewer incorrect conclusions than the single test.

Whether the single or joint testing approach is superior in any well-defined sense will depend on the specific application and the relative importance the researcher places on Type I and Type II errors.

> *These results suggest that the joint testing procedure improves our confidence in our results most when it indicates our series are stationary, or when it indicates our series have a unit root for small samples and large truncation length. However, we should expect the joint test to produce frequently inconclusive results.*[73]

3.6. Some Empirical Evidence

The seminal paper of Nelson and Plosser (1982) carried out simple Dickey-Fuller tests for unit roots in 14 individual U.S. historical time series and found that all of the series, except the unemployment rate, were characterized by stochastic nonstationarity. Perron (1988) used the Phillips-Perron test to analyze the Nelson-Plosser data and his findings confirmed their results. Most macroeconomic variables were found to be nonstationary. However, Perron (1989) re-examined the Nelson-Plosser data with the hypothesis that the 1929 Great Crash and the 1973 oil price shock caused a major change in the trend function.[74] After adjusting for structural breaks, Perron (1989) concluded that most macroeconomic time series were *not* characterized by the presence of a unit root.

DeJong and Whiteman (1991) examined the Nelson-Plosser series for unit roots following explicitly Bayesian techniques. They inferred that real, nominal and per capita real GNP, industrial production, employment, the GNP deflator, nominal and real wages, the money supply, and the common stock price index were most likely trend stationary processes. Furthermore, they inferred that the unemployment rate was stationary, while consumer prices, bond yields and velocity appeared nonstationary.

---

[73] Ibid., p.10.

[74] Analysis of the unemployment rate series is omitted since it is assumed to be stationary.

Kwiatkowski, Phillips, and Schmidt (1992) applied the KPS test to the Nelson-Plosser data. For all series except the unemployment rate and the interest rate, the hypothesis of level stationarity could be rejected. Furthermore, the trend stationary hypothesis could be rejected for five series: industrial production, consumer prices, real wages, velocity, and stock prices. However, the trend stationary hypothesis could not be rejected at usual critical levels for six series: real per capita GNP, employment, unemployment rate, GNP deflator, wages, and money.

Table 3.6.1 provides a summary of these empirical results.

Table 3.6.1
Empirical Results

Series	Period	Nelson Plosser (1982)	Perron (1988)	Perron (1989)	DeJong Whiteman (1991)	KPS (1992)
Real GNP	1909-1970	N	N	TS	TS	TS
Nominal GNP	1909-1970	N	N	TS	TS	TS
Real per capita GNP	1909-1970	N	N	TS	TS	TS
Industrial production	1860-1970	N	N	TS	TS	N
Employment	1890-1970	N	N	TS	TS	TS
Unemployment	1890-1970	S	S	S	S	LS
GNP deflator	1889-1970	N	N	TS	TS	TS
Consumer prices	1860-1970	N	N	TS	N	N
Wages	1900-1970	N	N	TS	TS	TS
Real wages	1900-1970	N	N	TS	TS	N
Money stock	1889-1970	N	N	TS	TS	TS
Velocity	1869-1970	N	N	TS	N	N
Interest rate	1900-1970	N	N	N	N	LS
Common stock prices	1871-1970	N	N	TS	TS	N

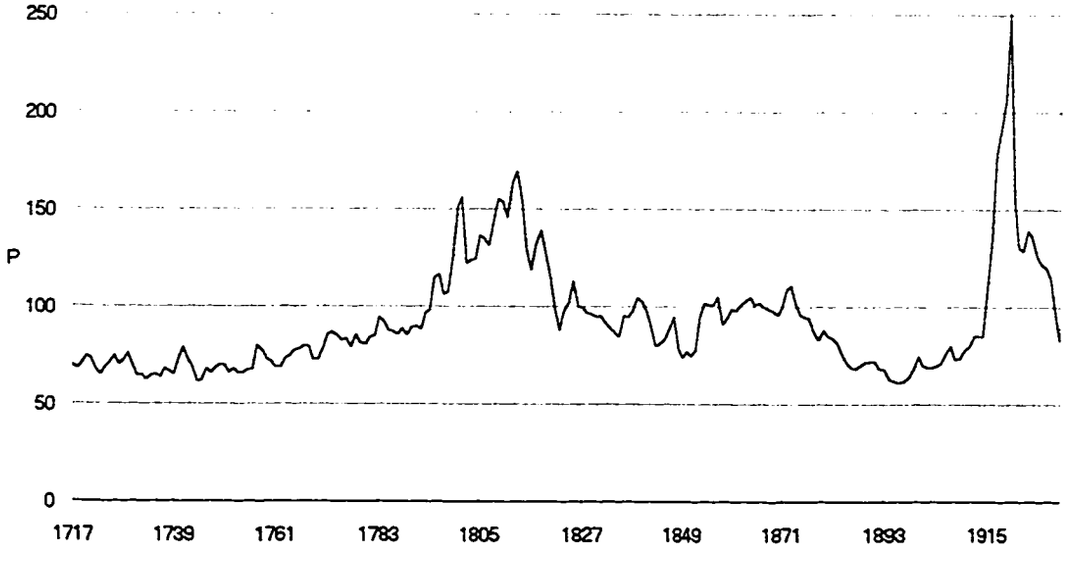
- N- nonstationary
- S- stationary
- TS- trend stationary
- LS- level stationary

IV Was the Price Level Stationary During the Classical Gold Standard?

4.1. Commodity Prices in Britain During the Gold Standard

Figure 4.1.1 illustrates British wholesale commodity prices during the classical gold standard period (1717-1931). The price level in 1914 was at the level it had been 90 years earlier: leading one to believe that the gold standard achieved price stability.

Figure 4.1.1
Wholesale Commodity Prices in the U.K., 1717-1931



4.2. Testing for Stationarity in the U.K. Price Level

Unit root tests are conducted to determine if U.K. commodity prices were stationary under the classical gold standard regime (1717-1931).

4.2.1 Standard unit root tests

Tests of the null hypothesis of a unit root are applied to the U.K. wholesale price index in levels. The augmented Dickey-Fuller and Phillips-Perron models are tested with a constant and without a time trend.[75] The five percent and ten percent critical values for these models are -2.86 and -2.57 respectively.

Table 4.2.1
Augmented Dickey-Fuller and Phillips-Perron Tests

	t-ratio	Lags
ADF (μ)	-2.86	0
PP(Z_α)	-3.06	1

Rejection of the null hypothesis of a unit root is implied by values smaller than the critical value. The Phillips-Perron test rejects the null hypothesis at both the ten and five percent levels. The ADF test rejects the null at the ten percent level; however, the t-ratio is equal to the critical value at the five percent level.

[75] Statistics for all models are found in appendix B.

4.2.2 Testing the null of stationarity, Kwiatkowski, Phillips, Schmidt (KPS) test

The level stationary model is used to analyze the U.K. price level under the classical gold standard. The KPS test assumes the null hypothesis of stationarity. The test statistic is computed for values of the lag truncation parameter from zero to eight. The five percent critical value for the level stationary model is 0.463.

Table 4.2.2
KPS Test For Level Stationarity

Lag	0	1	2	3	4	5	6	7	8
KPS $\eta\mu$	2.96	1.54	1.04	0.78	0.63	0.53	0.45	0.40	0.35

Rejection of the null hypothesis of stationarity is implied if all values exceed the critical value. The null hypothesis cannot be rejected at the five percent level.

4.3. Diagnostic Tests

4.3.1 Autocorrelation

The least squares residuals from the ADF regression model (equation 3.28) are plotted over time in figure 4.3.1. The sample autocorrelation function is illustrated in figure 4.3.2 while the partial autocorrelation function is graphed in figure 4.3.3. Although stationary, the price series exhibits significant lags in the adjustment process.

Figure 4.3.1
Plot of the OLS Residuals

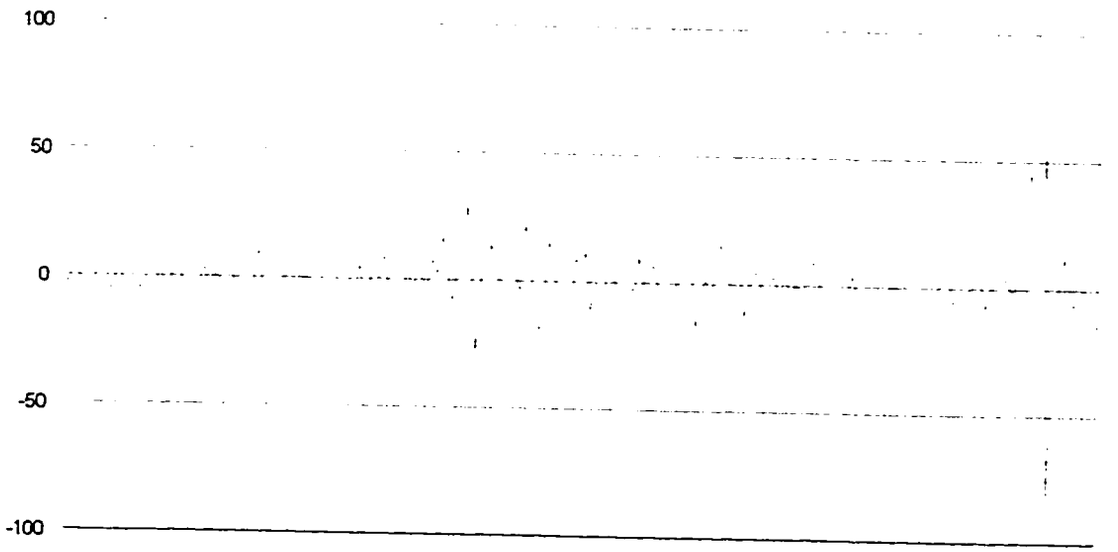


Figure 4.3.2
Sample Autocorrelation Function in Levels

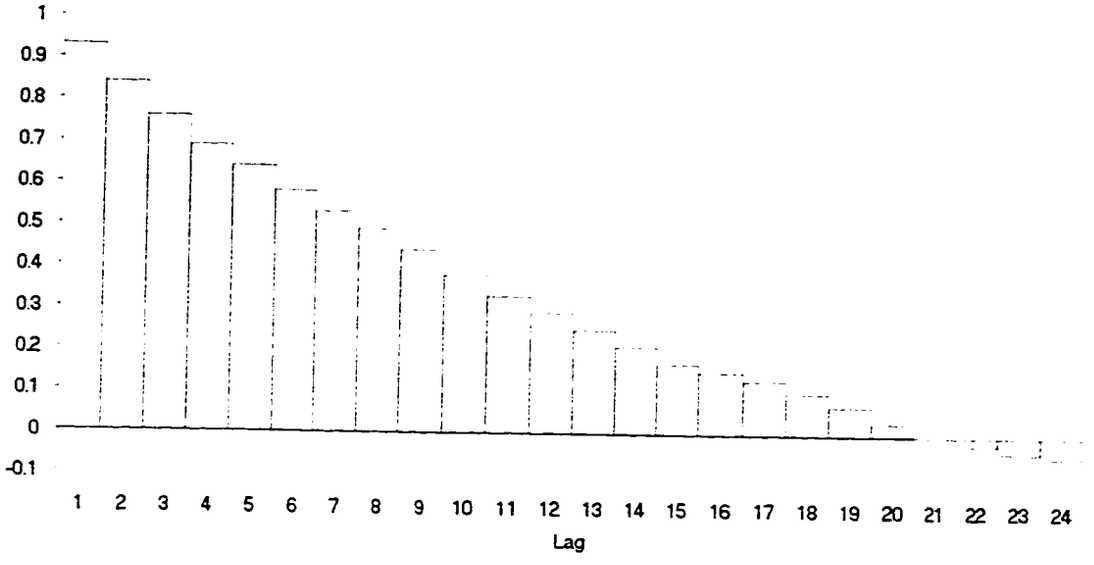
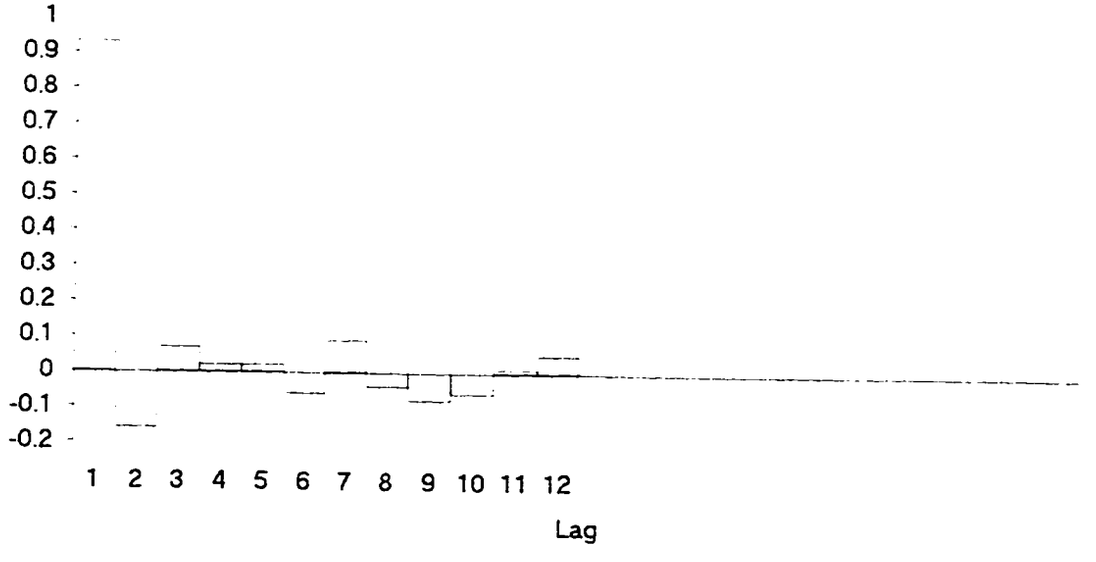


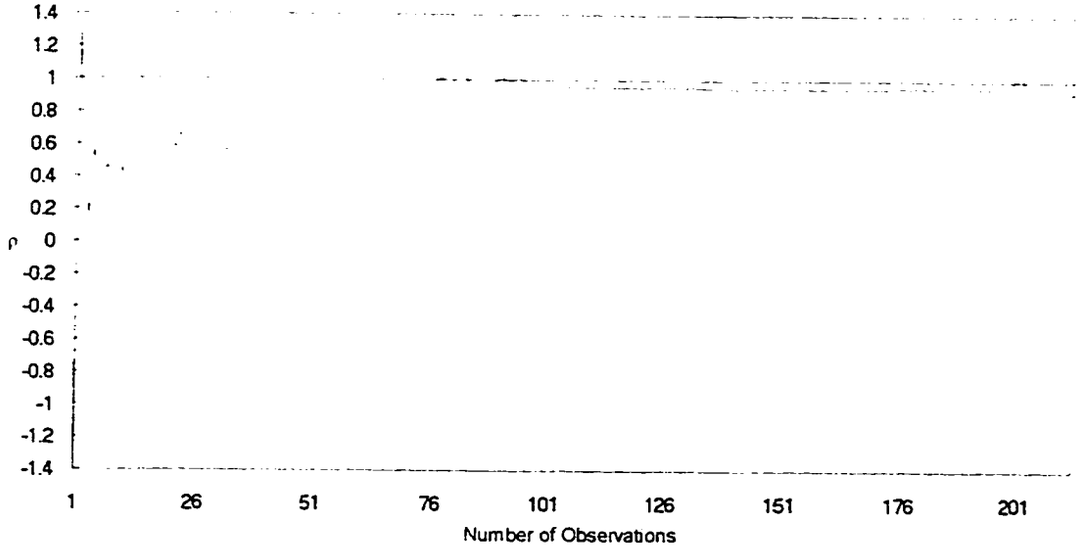
Figure 4.3.3
Partial Autocorrelation Function in Levels



4.3.2 A Bayesian perspective

According to the Bayesian literature, if $\rho = 1$ is true, σ_ρ should shrink much faster with sample size than if $\rho \neq 1$. One way to analyze σ_ρ is to obtain recursive estimates of ρ. Recursive estimation is performed by running a series of regressions adding one observation per regression. Recursive estimates of ρ (from equation 3.28) are illustrated in figure 4.3.4. As the sample size increases, ρ displays high variability and eventually stabilizes after 100 observations, thus providing evidence against the presence of a unit root in the price level.

Figure 4.3.4
Recursive Estimates of ρ



4.4 Joint Test Results

Since the unit root hypothesis can be rejected for the standard unit root tests and the level stationary hypothesis cannot be rejected for the KPS test, the evolution of commodity prices in Britain could be represented as a stationary process under the classical gold standard regime.

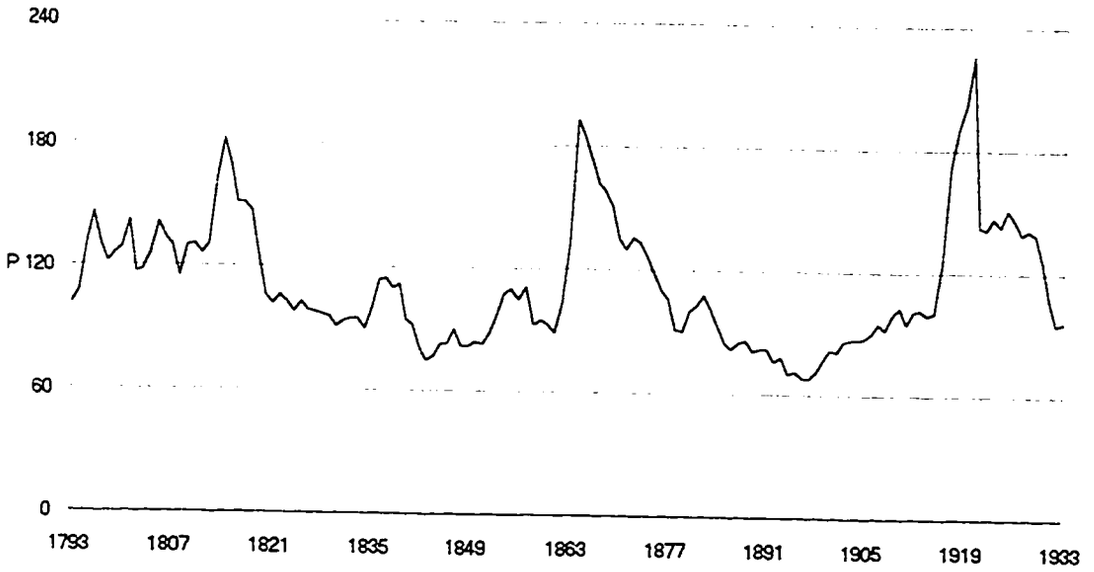
Table 4.4.1
Joint Results of Stationarity Tests
U.K. Prices Under the Classical Gold Standard (1717-1931)

KPS test \ ADF-PP tests	Reject H_o	Do Not Reject H_o
Do Not Reject H_o	**Stationary**	No Decision
Reject H_o	Misspecification Error	Nonstationary

4.5. Commodity Prices in the U.S. During the Gold Standard

Figure 4.5.1 illustrates U.S. wholesale commodity prices during the classical gold standard period (1793-1933). Periods of rising prices were usually accompanied by falling prices under the gold standard regime.

Figure 4.5.1
Wholesale Commodity Prices in the U.S., 1793-1933



4.6. Testing for Stationarity in the U.S. Price Level

Unit root tests are conducted to determine if U.S. commodity prices were stationary under the classical gold standard regime.

4.6.1 Standard unit root tests

Tests of the null hypothesis of a unit root are applied to the U.S. wholesale price index in levels. The augmented Dickey-Fuller and Phillips-Perron models are tested with a constant and without a time trend.[76] The five percent and ten percent critical values for these models are -2.86 and -2.57 respectively.

Table 4.6.1
Augmented Dickey-Fuller and Phillips-Perron Tests

	t-ratio	Lags
ADF (μ)	-3.32	1
PP(Z_α)	-2.92	1

Rejection of the null hypothesis of a unit root is implied by values smaller than the critical value. The augmented Dickey-Fuller and the Phillips-Perron tests reject the null hypothesis of a unit root at both the ten and five percent levels.

[76] See appendix B for the statistical results for all models

4.6.2 Testing the null of stationarity, Kwiatkowski, Phillips, Schmidt (KPS) test

The level stationary model is used to analyze the U.S. price level under the classical gold standard. The KPS test assumes the null hypothesis of stationarity. The five percent critical value for the level stationary model is 0.463.

Table 4.6.2
KPS Test For Level Stationarity

Lag	0	1	2	3	4	5	6	7	8
KPS $\eta\mu$	0.77	0.41	0.28	0.21	0.17	0.14	0.12	0.11	0.10

Rejection of the null hypothesis of stationarity is implied if all values exceed the critical value. The null hypothesis of level stationarity cannot be rejected at the five percent level.

4.7. Diagnostic Tests

4.7.1 Autocorrelation

The least squares residuals from the ADF regression model (equation 3.28) are plotted over time in figure 4.7.1. The sample autocorrelation function is illustrated in figure 4.7.2 while the partial autocorrelation function is graphed in figure 4.7.3. Although stationary, the U.S. price series exhibits significant lags in the adjustment process.

Figure 4.7.1
Plot of the OLS Residuals

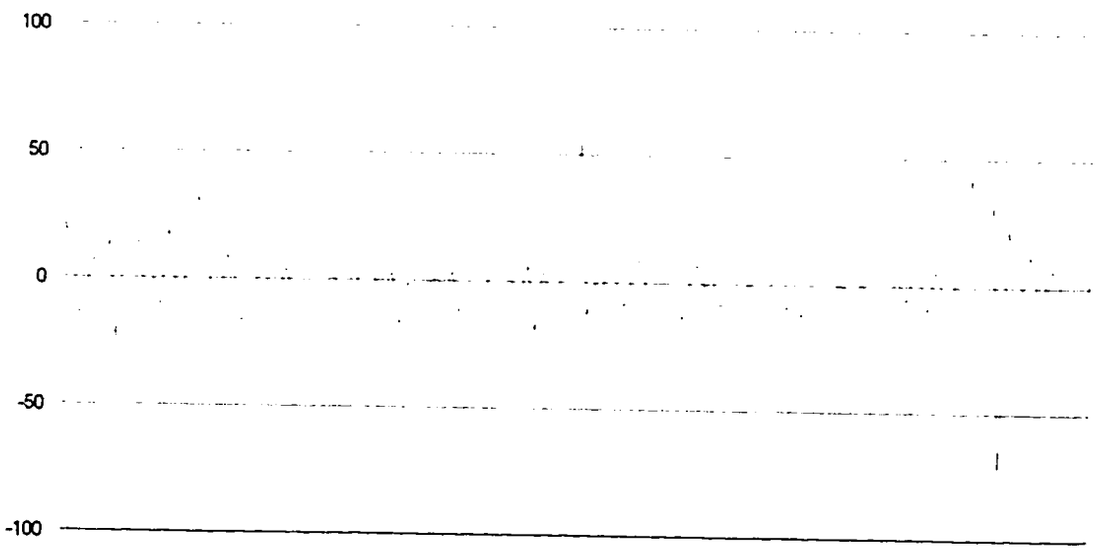


Figure 4.7.2
Sample Autocorrelation Function in Levels

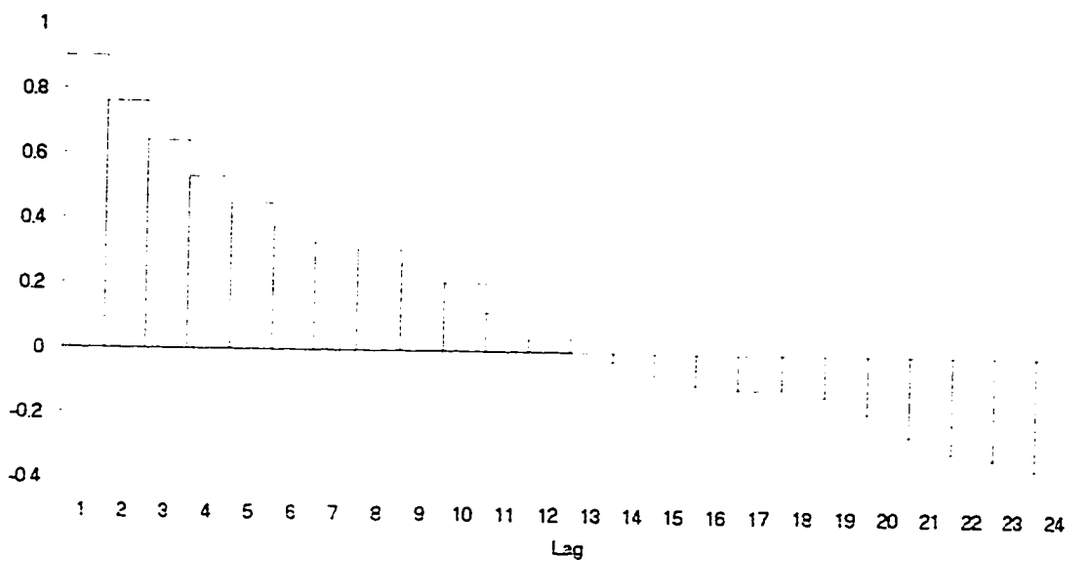
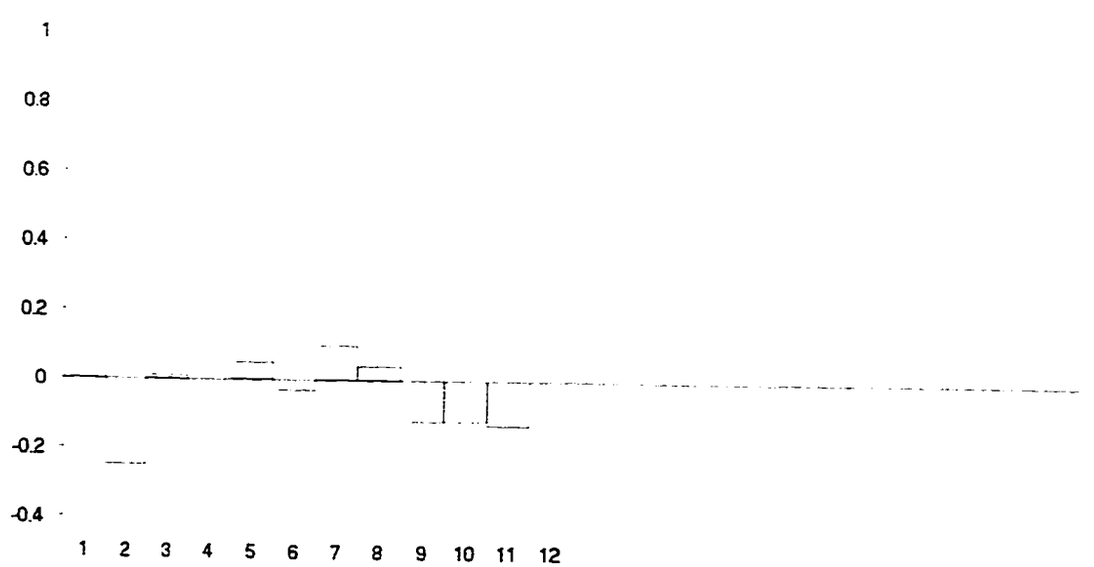


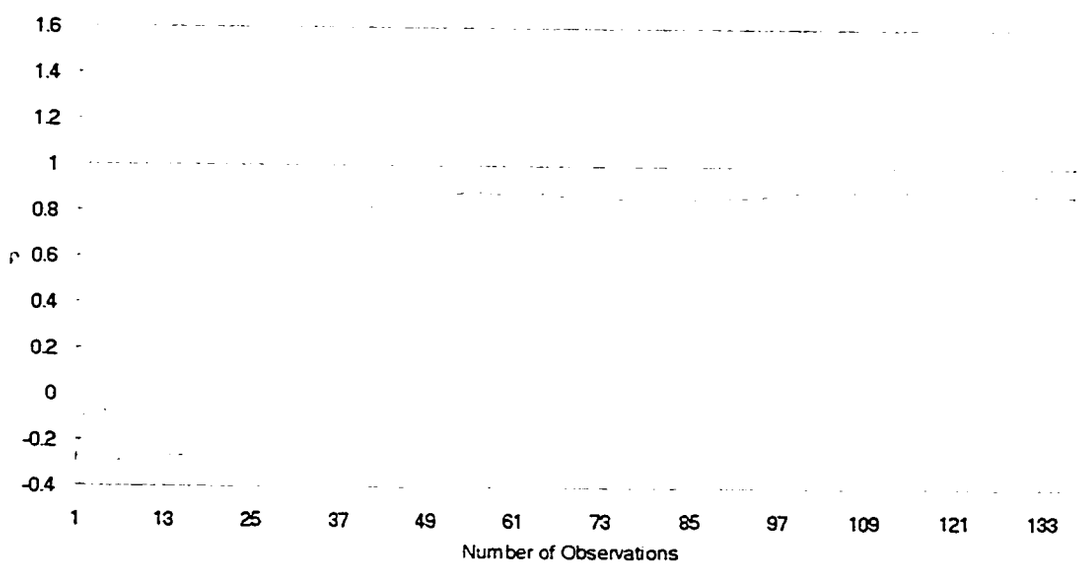
Figure 4.7.3
Partial Autocorrelation Function in Levels



4.7.2 A Bayesian perspective

Recursive estimates of ρ are illustrated in figure 4.7.4. As the sample size increases, ρ exhibits instability and eventually stabilizes after 50 observations, thus providing evidence against the presence of a unit root in the price level.

Figure 4.7.4
Recursive Estimates of ρ



4.8 Joint Test Results

Since the unit root hypothesis can be rejected for the standard unit root tests and the level stationary hypothesis cannot be rejected for the KPS test, the evolution of commodity prices in the United States could be represented as a stationary process under the classical gold standard regime.

Table 4.8.1
Joint Results of Stationarity Tests
U.S. Prices Under the Classical Gold Standard (1793-1933)

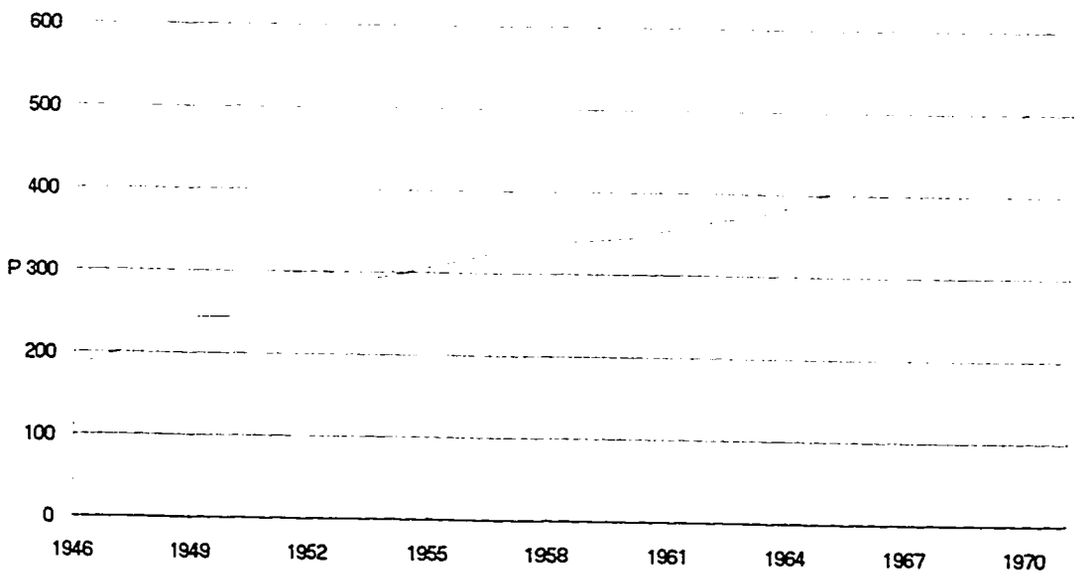
		ADF-PP tests: Reject H_o	ADF-PP tests: Do Not Reject H_o
KPS test	Do Not Reject H_o	**Stationary**	No Decision
	Reject H_o	Misspecification Error	Nonstationary

V *Was the Price Level Stationary Under the Bretton Woods System?*

5.1. Commodity Prices in Britain Under the Bretton Woods System

Figure 5.1.1 illustrates British wholesale commodity prices under the Bretton Woods system (1946-1971). There was a persistent rise in the price level during this period.

Figure 5.1.1
Wholesale Commodity Prices in the U.K., 1946-1971



5.2. Testing for Stationarity in the U.K. Price Level

Unit root tests are conducted to determine if U.K. commodity prices were trend stationary under the Bretton Woods gold-exchange regime (1946-1971).

5.2.1 Standard unit root tests

Tests of the null hypothesis of a unit root are applied to the U.K. wholesale price index in levels. The augmented Dickey-Fuller and Phillips-Perron models are tested with a constant and a time trend. The five percent and ten percent critical values are -3.41 and -3.13 respectively.

Table 5.2.1
Augmented Dickey-Fuller and Phillips-Perron Tests

	t-ratio	Lags
ADF (μ)	0.04	0
PP(Z_α)	-0.22	1

Rejection of the null hypothesis of a unit root is implied by values smaller than the critical value. Both the augmented Dickey-Fuller and Phillips-Perron tests fail to reject the null hypothesis of a unit root at the five and ten percent levels.

5.2.2 Testing the null of stationarity, Kwiatkowski, Phillips, Schmidt (KPS) test

The trend stationary model is used to analyze the U.K. price level under the Bretton Woods system (1946-1971). Due to the short time span of the Bretton Woods system, the KPS test is applied to the entire post-war period (1946-1991). The results of the entire post-war period are then compared to the shorter sub-period. The KPS test assumes the null hypothesis of stationarity. The five percent critical value for the trend stationary model is 0.146.

Table 5.2.2
KPS Test For Trend Stationarity

	Lag								
Period	0	1	2	3	4	5	6	7	8
KPS η_τ (1946-1991)	1.11	0.58	0.39	0.30	0.24	0.20	0.17	0.16	0.15
KPS η_τ (1946-1971)	0.28	0.18	0.13	0.11	0.09	0.07	0.06	0.05	0.04

Rejection of the null hypothesis of stationarity is implied if all values exceed the critical value. The null hypothesis of trend stationarity can be rejected at the five percent level for the post-war period (1946-1991). However, there is insufficient information to reject the null hypothesis for the sub-period (1946-1971).

5.3 Diagnostic Tests

5.3.1 Autocorrelation

The least squares residuals from the ADF regression model (equation 3.29) are plotted over time in figure 5.3.1. The sample autocorrelation function is illustrated in figure 5.3.2 while the partial autocorrelation function is graphed in figure 5.3.3. The series exhibits a degree of persistence although with relatively short lags in the adjustment process.

Figure 5.3.1
Plot of the OLS Residuals

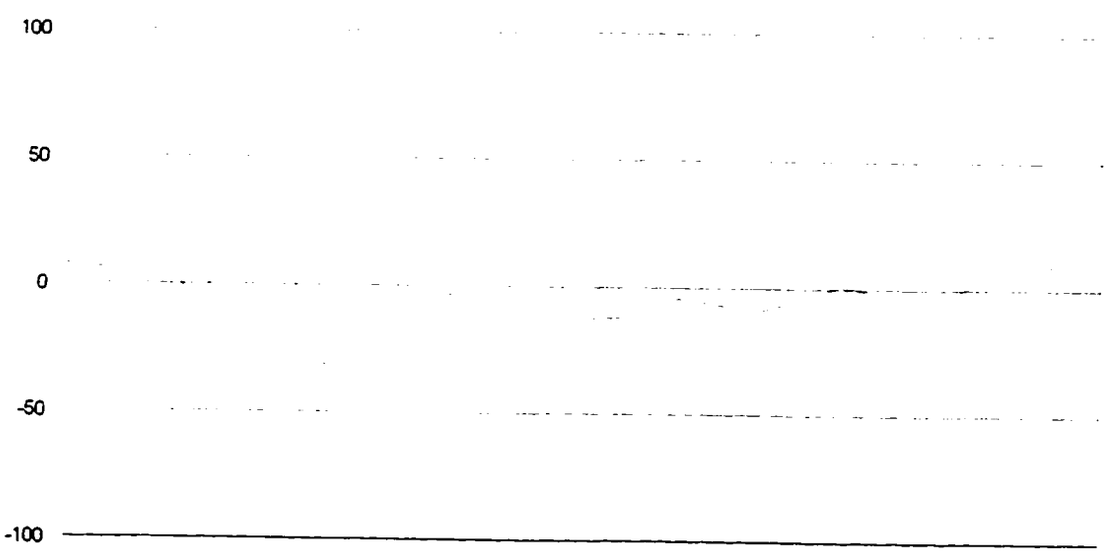


Figure 5.3.2
Sample Autocorrelation Function in Levels

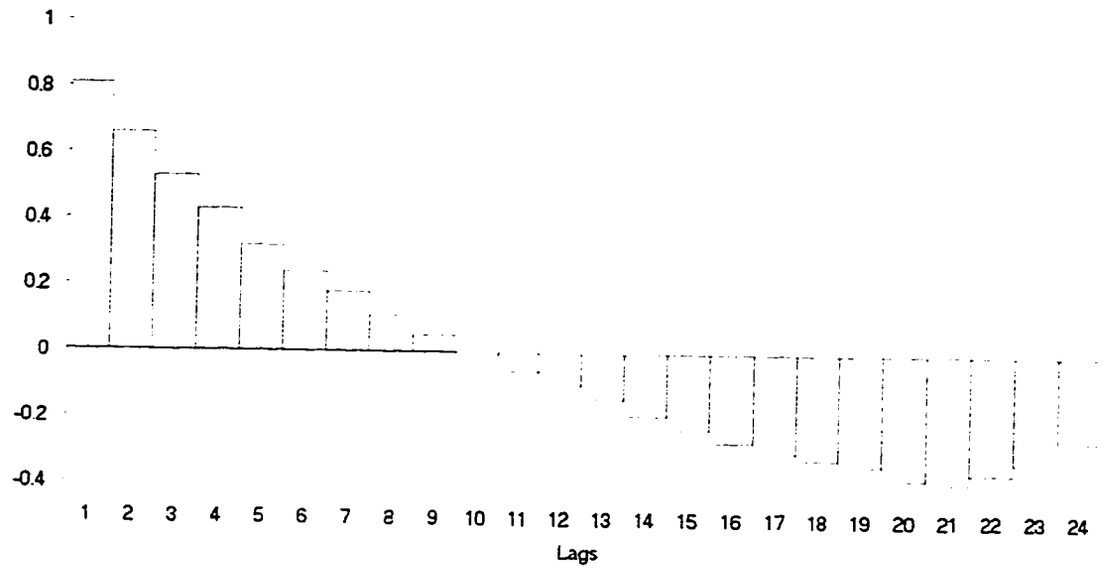
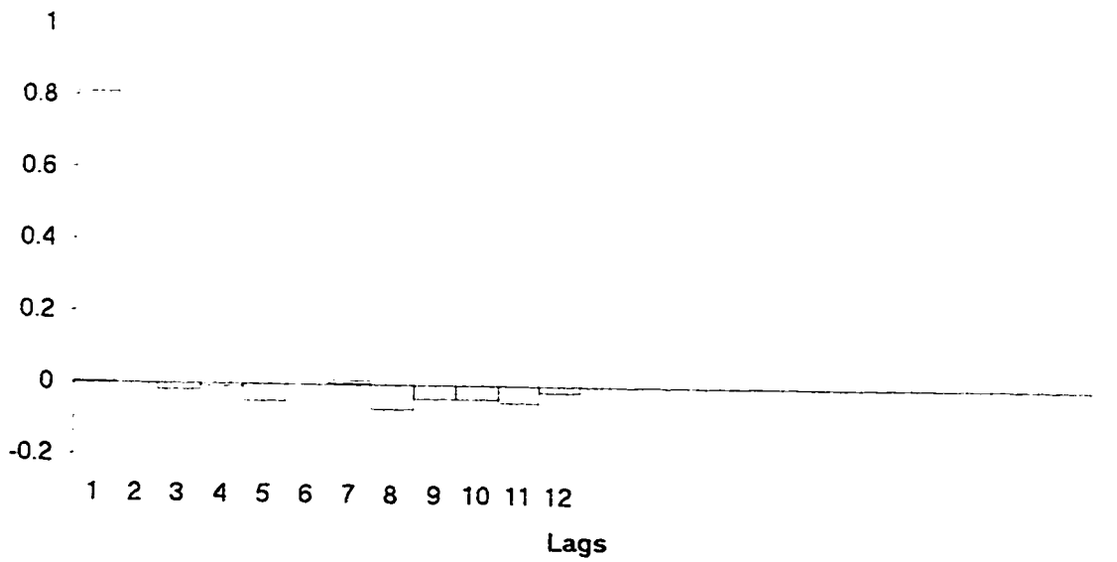


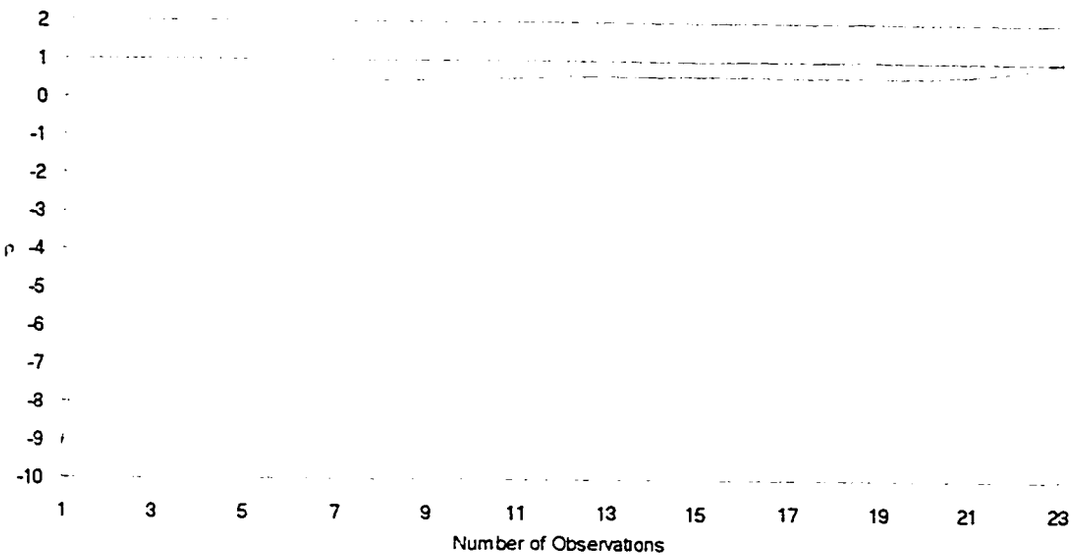
Figure 5.3.3
Partial Autocorrelation Function in Levels



5.3.2 A Bayesian perspective

Recursive estimates of ρ are illustrated in figure 5.3.4. As the sample size increases, the variability of ρ diminishes rapidly and eventually stabilizes after six observations, thus providing evidence of a unit root in the price level.

Figure 5.3.4
Recursive Estimates of ρ



5.4 Joint Test Results

The unit root hypothesis cannot be rejected for the standard unit root tests during the Bretton Woods system (1946-1971). The trend stationary hypothesis can be rejected for the KPS test during the post-war period, although the time span is insufficient to reject the null hypothesis for the sub-period. Nevertheless, it may be inferred that the commodity price level in Britain was not characterized by a stationary process under the Bretton Woods system.

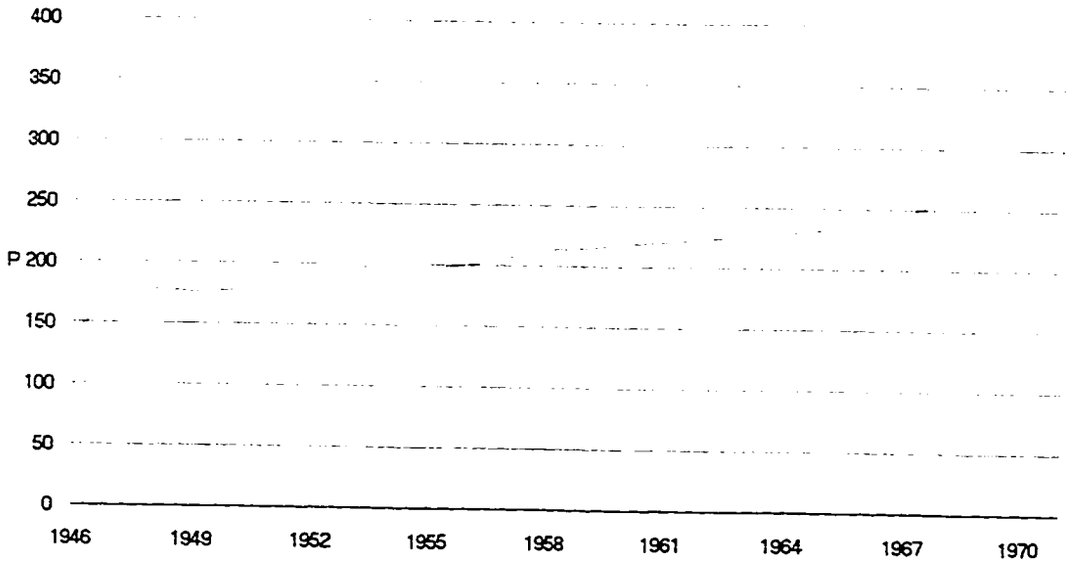
Table 5.4.1
Joint Results of Stationarity Tests
U.K. Prices Under the Bretton Woods System (1946-1971)

KPS test	ADF-PP tests: Reject H_o	ADF-PP tests: Do Not Reject H_o
Do Not Reject H_o	Stationary	No Decision
Reject H_o	Misspecification Error	**Nonstationary**

5.5. Commodity Prices in the U.S. Under the Bretton Woods System

Figure 5.5.1 illustrates U.S. wholesale commodity prices under the Bretton Woods system (1946-1971). An overall rise in the price level is observed during the period.

Figure 5.5.1
Wholesale Commodity Prices in the U.S., 1946-1971



5.6. Testing for Stationarity in the U.S. Price Level

Unit root tests are conducted to determine if U.S commodity prices were trend stationary under the Bretton Woods gold-exchange regime (1946-1971).

5.6.1 Standard unit root tests

Tests of the null hypothesis of a unit root are applied to the U.S. wholesale price index in levels. The augmented Dickey-Fuller and Phillips-Perron models are tested with a constant and a time trend. The five percent and ten percent critical values are -3.41 and -3.13 respectively.

Table 5.6.1
Augmented Dickey-Fuller and Phillips-Perron Tests

	t-ratio	Lags
ADF (μ)	-0.31	1
PP(Z_α)	-1.10	1

Rejection of the null hypothesis of a unit root is implied by values smaller than the critical value. The augmented Dickey-Fuller and the Phillips-Perron tests do not reject the null hypothesis of a unit root at both the ten and five percent levels.

5.6.2 Testing the null of stationarity, Kwiatkowski, Phillips, Schmidt (KPS) test

The trend stationary model is used to analyze the U.S. price level under the Bretton Woods system (1946-1971). The KPS test is applied to both the entire post-war period (1946-1991) and the sub-period (1946-1971) and the results are contrasted. The KPS test assumes the null hypothesis of stationarity. The five percent critical value for the trend stationary model is 0.146.

Table 5.6.2
KPS Test For Trend Stationarity

Period	Lag								
	0	1	2	3	4	5	6	7	8
KPS η_τ (1946-1991)	1.13	0.59	0.40	0.30	0.24	0.20	0.17	0.16	0.15
KPS η_τ (1946-1971)	0.29	0.18	0.13	0.10	0.08	0.07	0.06	0.05	0.04

Rejection of the null hypothesis of trend stationarity is implied if all values exceed the critical value. The null hypothesis of trend stationarity can be rejected at the five percent level for the post-war period (1946-1991). However, there is insufficient information to reject the null hypothesis for the sub-period (1946-1971).

5.7 Diagnostic Tests

5.7.1 Autocorrelation

The least squares residuals from the ADF regression model (equation 3.29) are plotted over time in figure 5.7.1. The sample autocorrelation function is illustrated in figure 5.7.2 while the partial autocorrelation function is graphed in figure 5.7.3. The series displays relatively short lags in the adjustment process.

Figure 5.7.1
Plot of the OLS Residuals

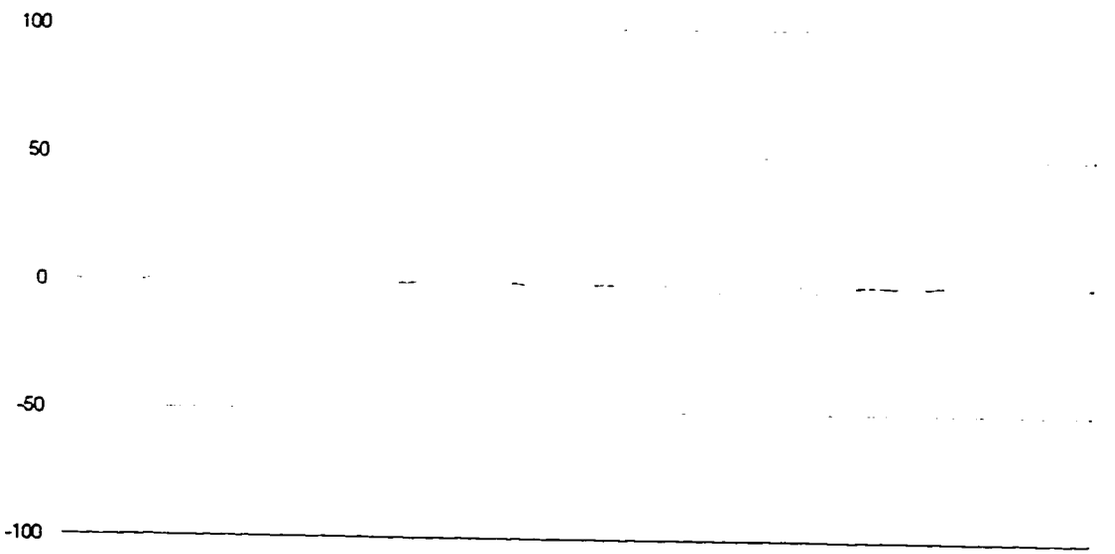


Figure 5.7.2
Sample Autocorrelation Function in Levels

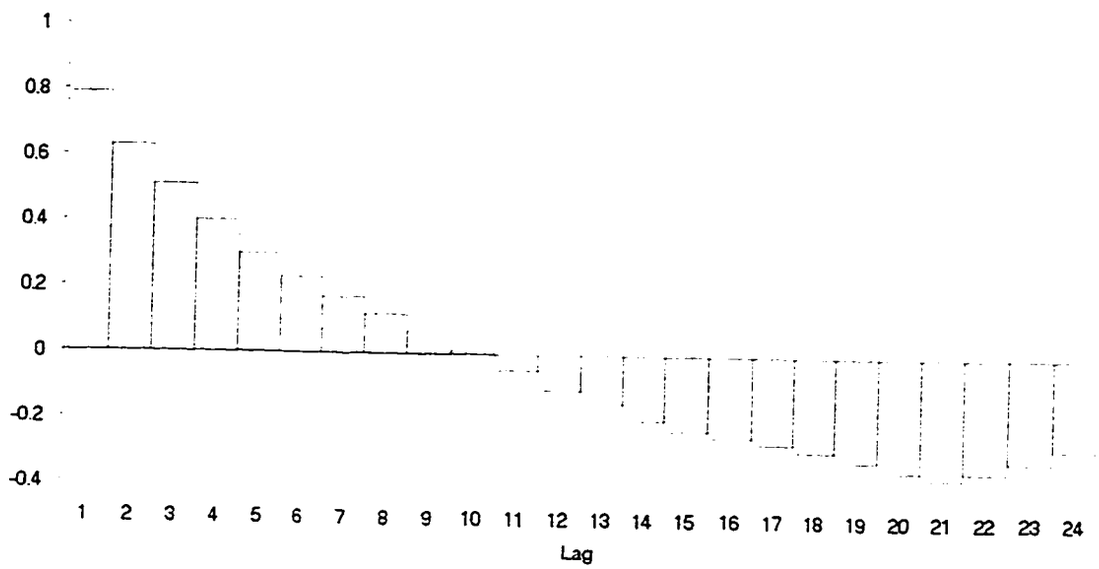
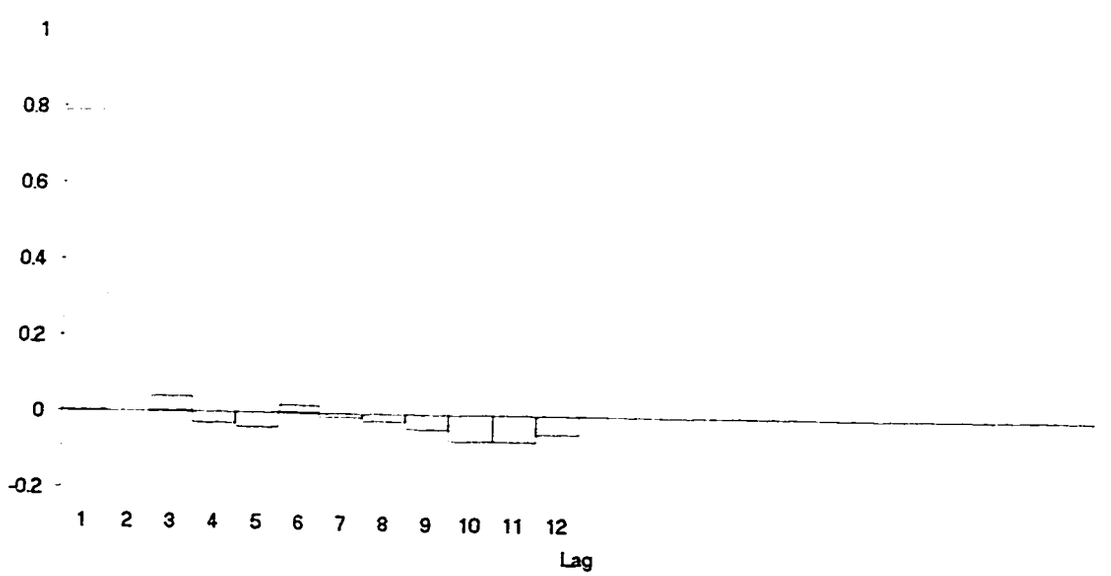


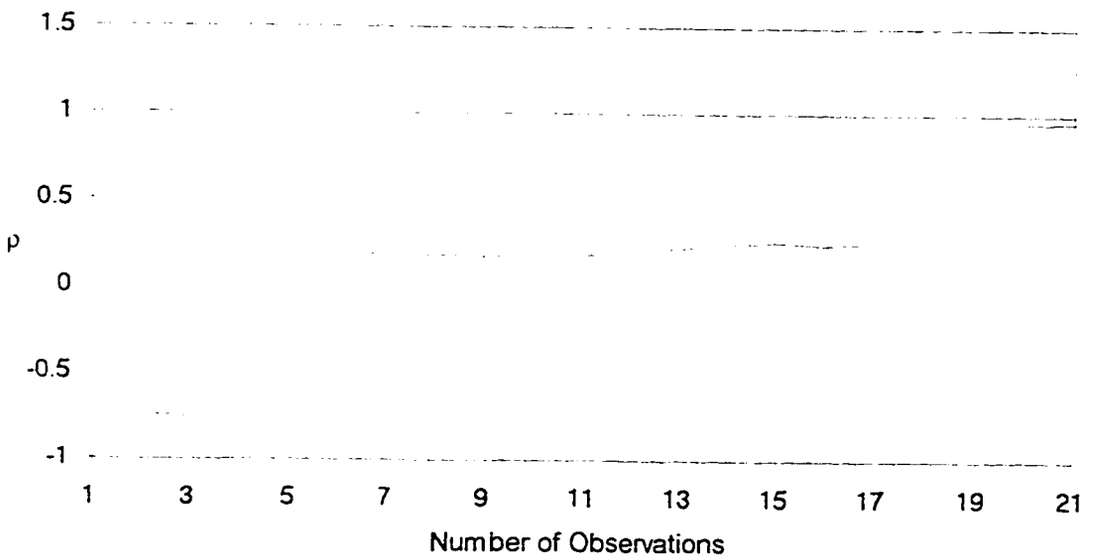
Figure 5.7.3
Partial Autocorrelation Function in Levels



5.7.2 A Bayesian perspective

Recursive estimates of ρ are illustrated in figure 5.7.4. As the sample size increases, ρ exhibits considerable variability, thus providing evidence against the presence of a unit root in the price level.

Figure 5.7.4
Recursive Estimates of ρ



5.8 Joint Test Results

The unit root hypothesis cannot be rejected for the standard unit root tests during the Bretton Woods system (1946-1971). The trend stationary hypothesis can be rejected for the KPS test during the post-war period, although there is insufficient information to reject the null hypothesis for the sub-period. However, the evolution of commodity prices in the United States could be characterized as a nonstationary process under the Bretton Woods system.

Table 5.8.1
Joint Results of Stationarity Tests
U.S. Prices Under the Bretton Woods System (1946-1971)

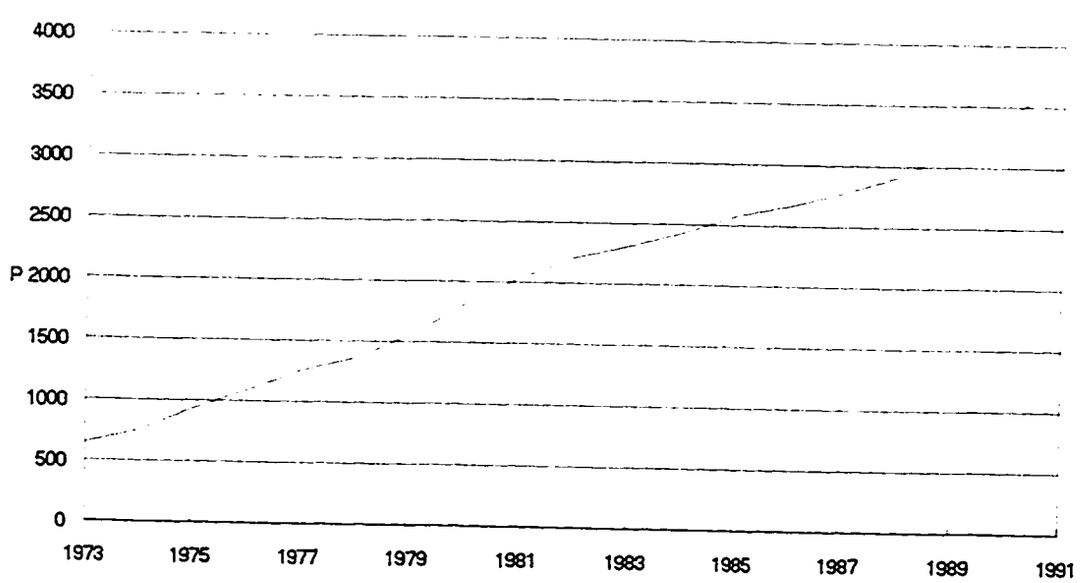
		ADF-PP tests: Reject H_o	ADF-PP tests: Do Not Reject H_o
KPS test	Do Not Reject H_o	Stationary	No Decision
	Reject H_o	Misspecification Error	**Nonstationary**

VI Has the Price Level Been Stationary Under a Flexible Exchange Rate Regime?

6.1. Commodity Prices in Britain Under a Flexible Exchange Rate Regime

Figure 6.1.1 illustrates British wholesale commodity prices after the collapse of the Bretton Woods regime (1973-1991). A rising trend characterizes the price level under a flexible exchange rate regime.

Figure 6.1.1
Wholesale Commodity Prices in the U.K., 1973-1991



6.2. Testing for Stationarity in the U.K. Price Level

Unit root tests are conducted to determine if U.K. commodity prices were trend stationary under a flexible exchange rate regime (1973-1991).

6.2.1 Standard unit root tests

Tests of the null hypothesis of a unit root are applied to the U.K. wholesale price index in levels. The augmented Dickey-Fuller and Phillips-Perron models are tested with a constant and a time trend. The five percent and ten percent critical values are -3.41 and -3.13 respectively.

Table 6.2.1
Augmented Dickey-Fuller and Phillips-Perron Tests

	t-ratio	Lags
ADF (μ)	-3.07	1
PP(Z_α)	-1.52	1

Rejection of the null hypothesis of a unit root is implied by values smaller than the critical value. Both the augmented Dickey-Fuller and Phillips-Perron tests fail to reject the null hypothesis of a unit root at the five and ten percent levels.

6.2.2 Testing the null of stationarity, Kwiatkowski, Phillips, Schmidt (KPS) test

The trend stationary model is used to analyze the U.K. price level for the post-Bretton Woods period (1973-1991). Due to the short time span, the KPS test is applied to the entire post-war period (1946-1991). The results of the entire post-war period are then compared to the shorter sub-period. The KPS test assumes the null hypothesis of stationarity. The five percent critical value for the trend stationary model is 0.146.

Table 6.2.2
KPS Test For Trend Stationarity

	Lag								
Period	0	1	2	3	4	5	6	7	8
KPS η_τ (1946-1991)	1.11	0.58	0.39	0.30	0.24	0.20	0.17	0.16	0.15
KPS η_τ (1973-1991)	0.14	0.09	0.06	0.05	0.04	0.03	0.029	0.025	0.023

Rejection of the null hypothesis of stationarity is implied if all values exceed the critical value. The null hypothesis of trend stationarity can be rejected at the five percent level for the post-war period (1946-1991). However, there is insufficient information to reject the null hypothesis for the sub-period (1973-1991).

6.3 Diagnostic Tests

6.3.1 Autocorrelation

The least squares residuals from the ADF regression model (equation 3.29) are plotted over time in figure 6.3.1. The sample autocorrelation function is illustrated in figure 6.3.2 while the partial autocorrelation function is graphed in figure 6.3.3. The price series exhibits positive autocorrelation with relatively short lags in the adjustment process.

Figure 6.3.1
Plot of the OLS Residuals

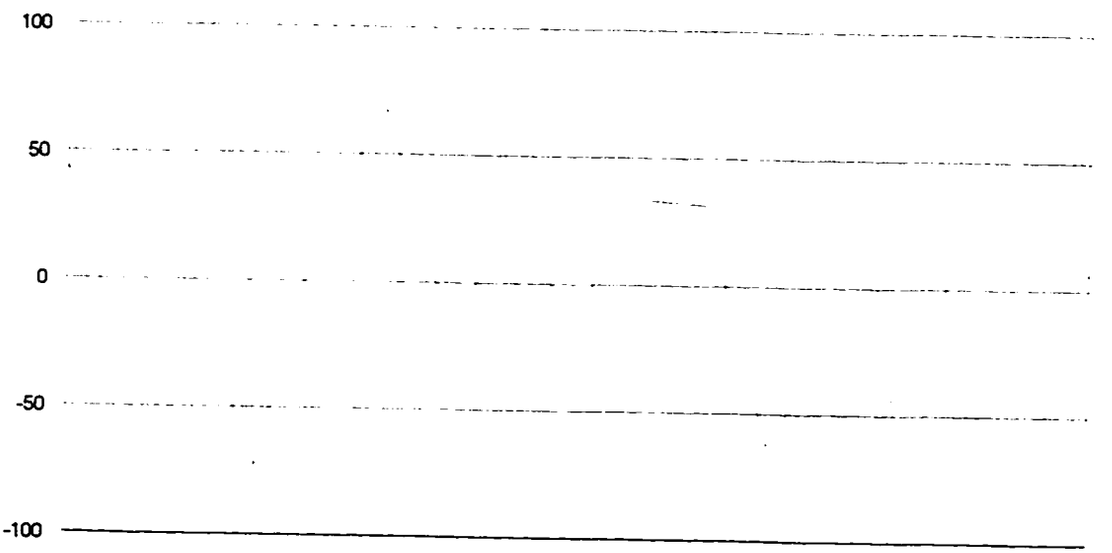


Figure 6.3.2
Sample Autocorrelation Function in Levels

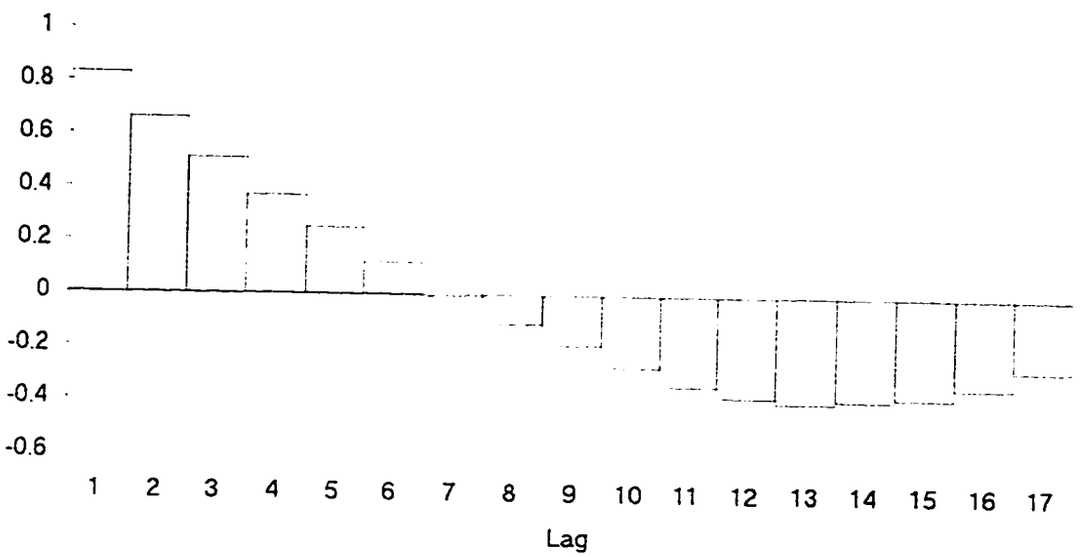
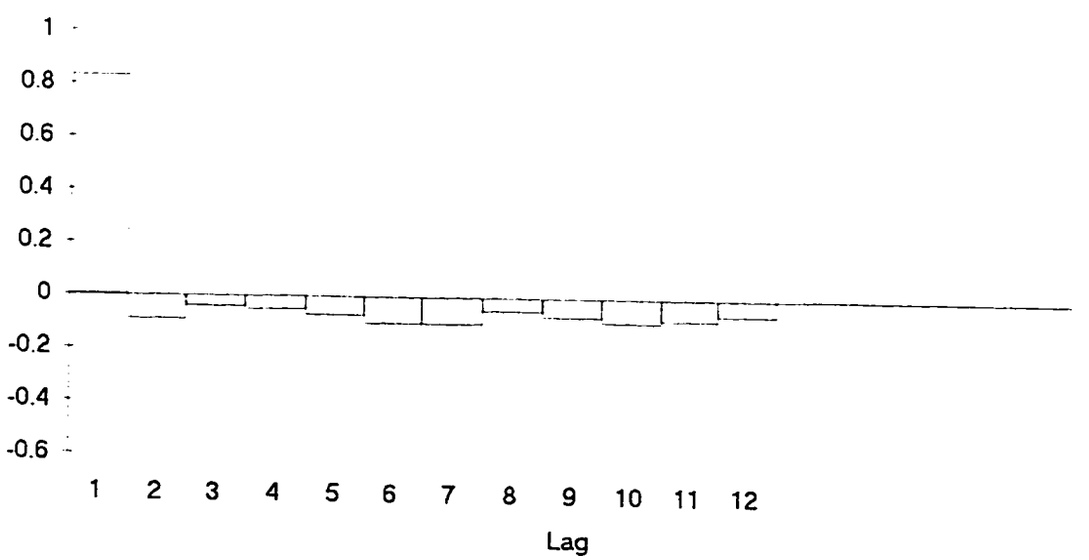


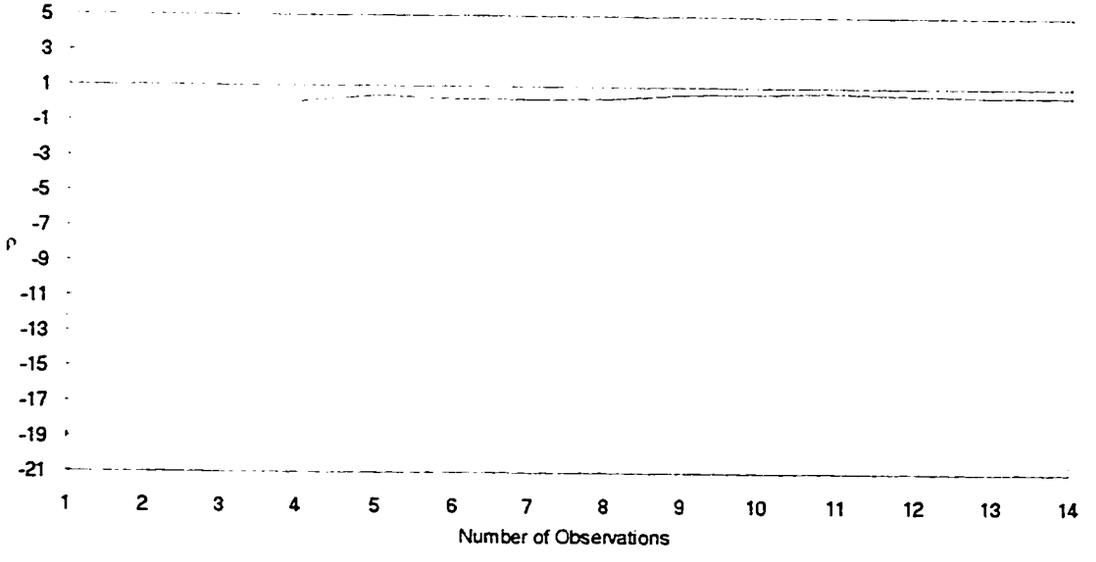
Figure 6.3.3
Partial Autocorrelation Function in Levels



6.3.2 A Bayesian perspective

Recursive estimates of ρ are illustrated in figure 6.3.4. As the sample size increases, the variability of ρ diminishes rapidly and eventually stabilizes after four observations, thus providing evidence of a unit root in the price level.

Figure 6.3.4
Recursive Estimates of ρ



6.4 Joint Test Results

The unit root hypothesis cannot be rejected for the standard unit root tests during the flexible exchange rate regime (1973-1991). The trend stationary hypothesis can be rejected for the KPS test during the post-war period, although the span of data is insufficient to reject the null hypothesis for the sub-period. However, it appears that the commodity price level in Britain was characterized by a nonstationary process under a flexible exchange rate regime.

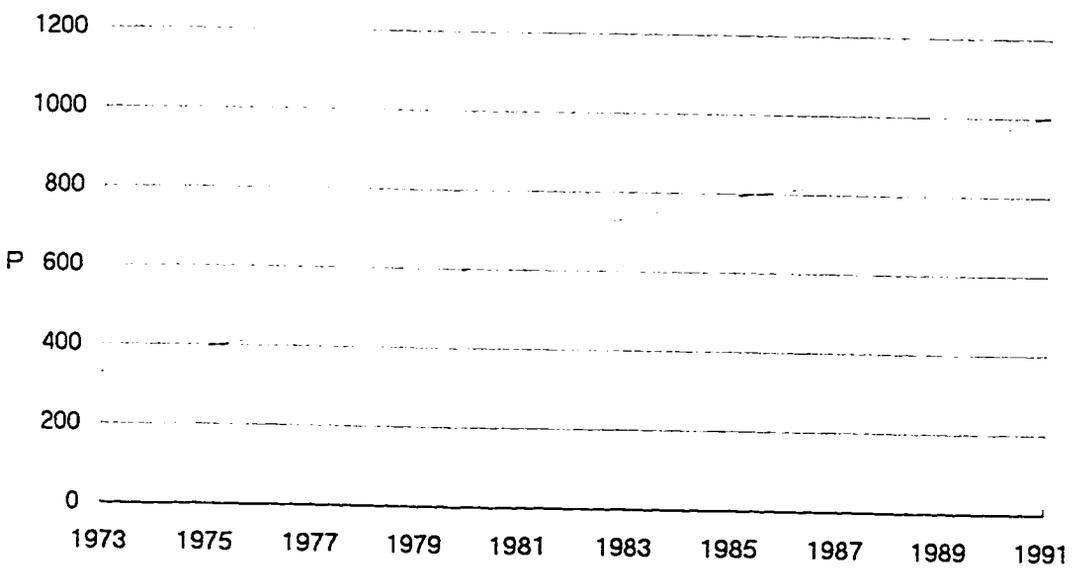
Table 6.4.1
Joint Results of Stationarity Tests
U.K. Prices Under A Flexible Exchange Rate Regime
(1973-1991)

		ADF-PP tests	
		Reject H_o	Do Not Reject H_o
KPS test	Do Not Reject H_o	Stationary	No Decision
	Reject H_o	Misspecification Error	**Nonstationary**

6.5. Commodity Prices in the U.S. Under a Flexible Exchange Rate Regime

Figure 6.5.1 illustrates U.S. wholesale commodity prices after the collapse of the Bretton Woods system (1973-1991). The U.S. price level has risen steadily under a flexible exchange rate regime.

Figure 6.5.1
Wholesale Commodity Prices in the U.S., 1973-1991



6.6. Testing for Stationarity in the U.S. Price Level

Unit root tests are conducted to determine if U.S. commodity prices were trend stationary under a flexible exchange rate regime (1973-1991).

6.6.1 Standard unit root tests

Tests of the null hypothesis of a unit root are applied to the U.S. wholesale price index in levels. The augmented Dickey-Fuller and Phillips-Perron models are tested with a constant and a time trend. The five percent and ten percent critical values are -3.41 and -3.13 respectively.

Table 6.6.1
Augmented Dickey-Fuller and Phillips-Perron Tests

	t-ratio	Lags
ADF (μ)	-1.88	2
PP(Z_α)	-1.74	2

Rejection of the null hypothesis of a unit root is implied by values smaller than the critical value. The augmented Dickey-Fuller and the Phillips-Perron tests do not reject the null hypothesis of a unit root at both the ten and five percent levels.

6.6.2 Testing the null of stationarity, Kwiatkowski, Phillips, Schmidt (KPS) test

The trend stationary model is used to analyze the U.S. price level for the post-Bretton Woods period (1973-1991). These results are contrasted against those for the entire post-war period (1946-1991). The KPS test assumes the null hypothesis of stationarity. The five percent critical value for the trend stationary model is 0.146.

Table 6.6.2
KPS Test For Trend Stationarity

	Lag								
Period	0	1	2	3	4	5	6	7	8
KPS η_τ (1946-1991)	1.13	0.59	0.40	0.30	0.24	0.20	0.17	0.16	0.15
KPS η_τ (1973-1991)	0.25	0.14	0.09	0.07	0.06	0.05	0.04	0.036	0.032

Rejection of the null hypothesis of trend stationarity is implied if all values exceed the critical value. The null hypothesis of trend stationarity can be rejected at the five percent level for the post-war period (1946-1991). However, there is insufficient information to reject the null hypothesis for the sub-period (1973-1991).

6.7. Diagnostic Tests

6.7.1 Autocorrelation

The least squares residuals from the ADF regression model (equation 3.29) are plotted over time in figure 6.7.1. The sample autocorrelation function is illustrated in figure 6.7.2 while the partial autocorrelation function is graphed in figure 6.7.3. The price series exhibits positive autocorrelation with relatively short lags in the adjustment process.

Figure 6.7.1
Plot of the OLS Residuals

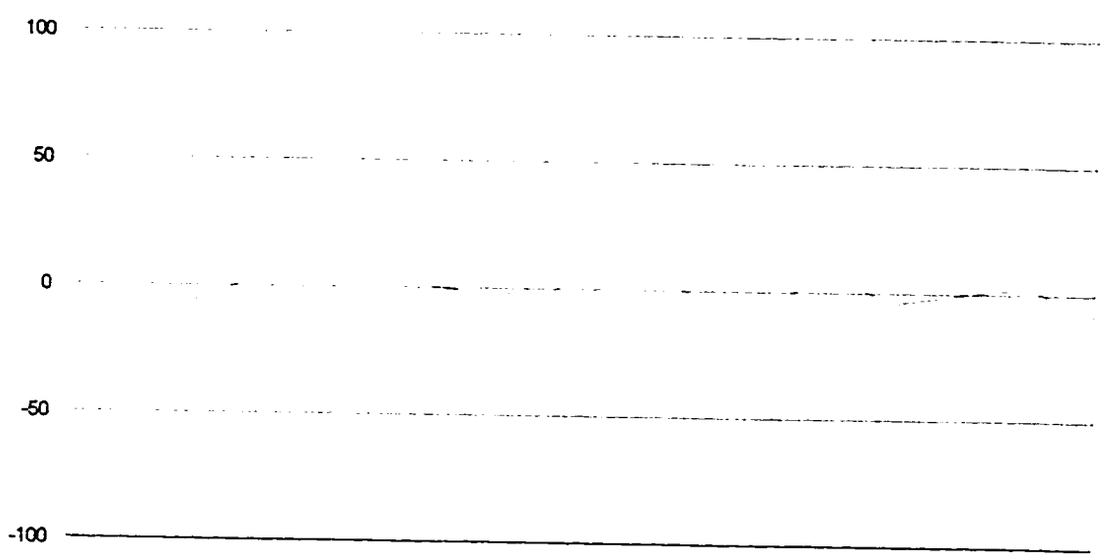


Figure 6.7.2
Sample Autocorrelation Function in Levels

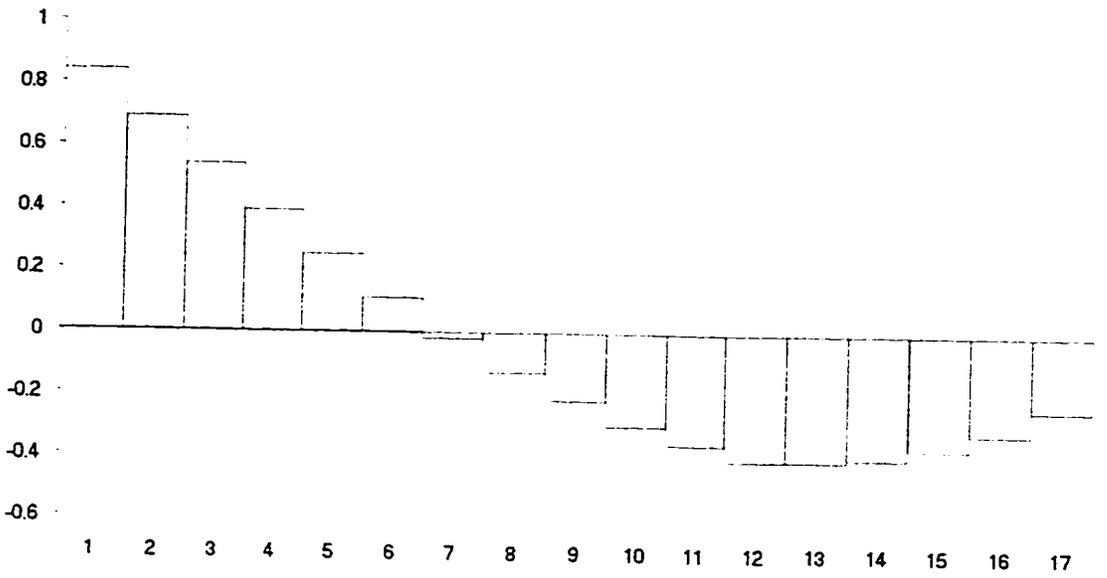
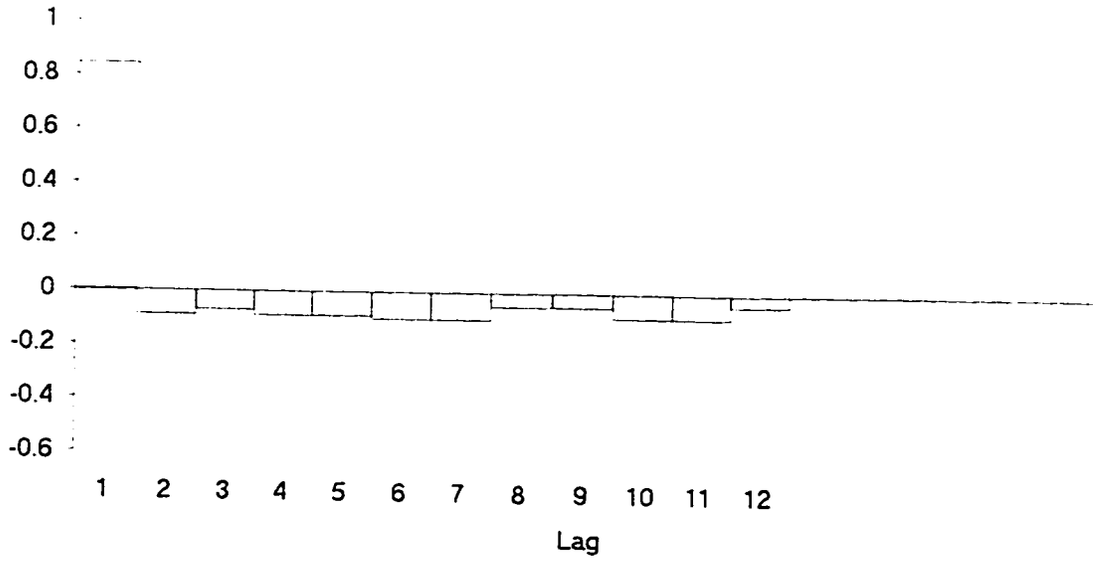


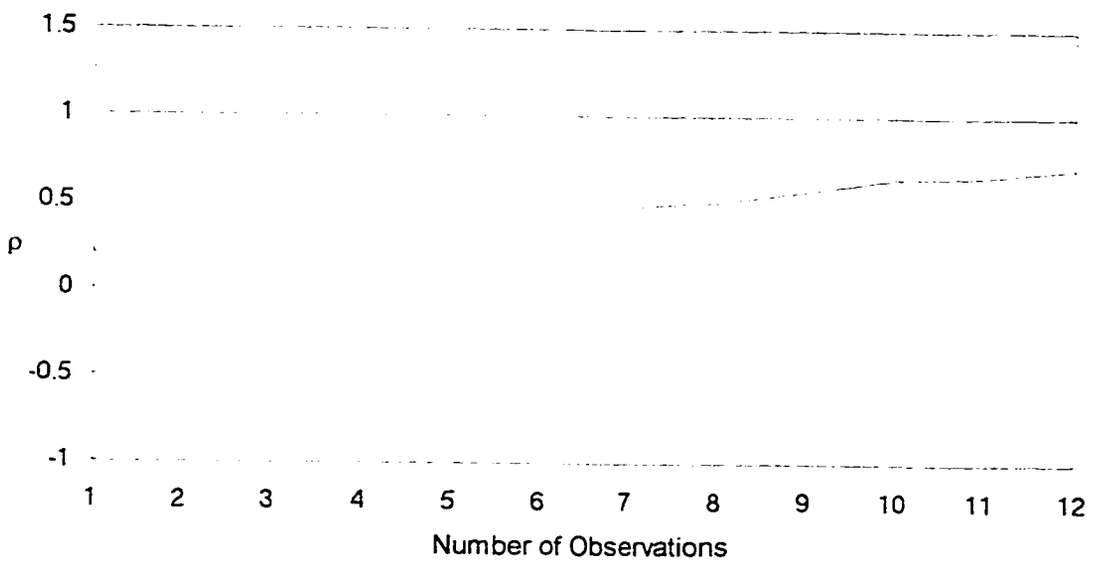
Figure 6.7.3
Partial Autocorrelation Function in Levels



6.7.2 A Bayesian perspective

Recursive estimates of ρ are illustrated in figure 6.7.4. As the sample size increases, ρ displays less volatility thus providing evidence of a unit root in the price level.

Figure 6.7.4
Recursive Estimates of ρ



6.8 Joint Test Results

The unit root hypothesis cannot be rejected for the standard unit root tests during the flexible exchange rate regime (1973-1991). The trend stationary hypothesis can be rejected for the KPS test during the post-war period, although there is insufficient information to reject the null hypothesis for the sub-period. However, the commodity price level in the U.S. may not be characterized by a stationary process under a flexible exchange rate regime.

Table 6.8.1
Joint Results of Stationarity Tests
U.S. Prices Under A Flexible Exchange Rate Regime
(1973-1991)

		ADF-PP tests	
		Reject H_o	Do Not Reject H_o
KPS test	Do Not Reject H_o	Stationary	No Decision
	Reject H_o	Misspecification Error	**Nonstationary**

VII Conclusion

Central banks throughout the world are moving to adopt long-run price stability as their primary goal. U.S. Federal Reserve Board Chairman Alan Greenspan remarked at a symposium on price stability, August 29, 1996, "We would deem our policies successful if we removed unproductive price-expectation-driven actions from economic activity, for that is a necessary condition for economic stability and maximum efficiencies...Price stability obtains when economic agents no longer take account of the prospective change in the general price level in their economic decision-making."[77]

Has price stability ever been achieved in the United States or Great Britain? Some economists have argued that the average price level in the U.S. and U.K. was stable during the classical gold standard period. Due to the lack of reliable tests, the behaviour of the price level could not be determined. However, the advancement of unit root testing over the last 20 years has given researchers more reliable tools to analyze the statistical properties of time-series data. A series with a mean-reverting tendency is said to be stationary. A series characterized by a random-walk process is said to contain a unit root (i.e. nonstationary).

The objective of this paper was to present an empirical investigation of the behaviour of prices during and after the classical gold standard period. The application of unit root tests to the price level in the United States and Great Britain shows that the price level can be characterized as a stationary process during the classical gold standard period. Therefore, the empirical results imply that price stability was achieved during this period.

With the extinction of the gold standard, countries looked to establish a new monetary arrangement. The institutional framework negotiated at the Bretton Woods conference established a fixed-exchange rate regime. This monetary regime operated for merely a quarter of a century after World War II. The results of the unit root tests show that the price level in the U.K. and the U.S. could not be characterized as a stationary process. It appears that the price level was nonstationary during the Bretton Woods arrangement. This would imply that price stability was not achieved during this period.

---

[77] Greenspan (1996), p.1.

The collapse of the Bretton Woods system created an environment of flexible exchange rates. Rising price levels have prevailed. The results of unit root tests suggest that the price level in the U.S. and U.K. has not been characterized by a stationary process during the period of flexible exchange rates. Therefore, price stability was not achieved during this period.

Appendix A

The Wizard of Oz: A Case For Bimetallism

Ever since its publication in 1900, Lyman Frank Baum's *The Wonderful Wizard of Oz* has been immensely popular providing the basis for a profitable musical comedy, several movies and a number of plays. However, the book is not only a child's tale but also a sophisticated commentary on the political and economic debates of the Populist Era. It is fraught with references to the monetary debates of the 1890's. Few students of money and banking or economic history will forget the battle between the advocates of free silver and the defenders of the gold standard when it is explained through the *Wizard of Oz*.[78]

L. Frank Baum's early life proved to be ideal preparation for writing a monetary allegory. Born near Syracuse in 1856, Baum was brought up in a wealthy home and became interested in theater at an early age. He wrote some plays that enjoyed brief success and then, in 1887, journeyed to South Dakota, where he viewed at close hand the frontier life that gave rise to the populist movement. In 1890, Baum moved to Chicago, where he was surrounded by the dynamic elements of reform that made the city so notable during the 1890's. In Chicago Baum saw the results of the frightful depression that had closed down upon the nation in 1893. He undoubtedly heard a great deal about the battle for the free coinage of silver, especially in 1896 when Chicago hosted the Democratic National Convention at which William Jennings Bryan (the Democratic presidential nominee) made his famous "Cross of Gold" speech. Bryan's platform rested mainly on the issue of adding silver to the nation's gold standard in order to ease the plight of Western farmers.

The *Wizard of Oz*, conceived over several years, was written mostly in 1899. It is a cautionary tale, recounting "the first battle" of 1896 and warning of the dangers that lay ahead. Baum's main purpose was to tell a good story, and his need for symmetry, interesting characters, and so on took precedence over historical accuracy. The allegory always remains in a minor key, subordinated to the major theme and readily abandoned whenever it threatens to distort the appeal of the fantasy. But through it, in the form of a subtle parable, Baum delineated a Midwesterner's vibrant and ironic portrait of the country as it entered the twentieth century.

---

[78] Previous interpretations have focused on the political and social aspects of the allegory. What follows is a monetary interpretation from Rockoff (1990) and Littlefield (1964).

The heroine is Dorothy, a little girl who lives with her Aunt Em on an impoverished farm in Kansas. Dorothy represents America- honest, kindhearted and plucky. Her best friend is her dog, Toto. Toto represents the Prohibition party, *Toto* being a play on *teetotaler*. Prohibitionists' hearts were in the right place on many issues: in addition to opposing alcohol, they supported free coinage of silver in 1896. They were a minor and eccentric group, always pulling in the wrong direction, and not to be taken all that seriously. The Populist movement began in the West, so it is natural that the story begins there. Dorothy is in her home when she is carried by a tornado to the land of Oz. This is Baum's fantasy counterpart to America, a land in which, especially in the East, the gold standard reigns supreme and in which an ounce (Oz) of gold has almost mystical significance. The tornado is the free silver movement itself. It came roaring out of the West in 1896, shaking the political establishment to its foundations.

Dorothy's house lands on the Wicked Witch of the East. The Witch dries up completely leaving only her silver shoes.[79] These represent the silver component of a bimetallic standard and are given to Dorothy by the Good Witch of the North. The silver shoes have a magical power that the Wicked Witch of the East understood but which the Munchkins (citizens of the East) do not. On a general level the Wicked Witch of the East represents eastern business and financial interests, but in personal terms a Populist would have one figure in mind: Grover Cleveland. It was Cleveland who led the repeal of the Sherman Silver Purchase Act (which provided for the regular purchasing and coining of silver in limited quantities), and it was his pro-gold forces that had been defeated at the 1896 convention, making it possible for America to vote for Bryan and free silver. The American people, like the Munchkins, never understood the power that was theirs once the Wicked Witch was dead.

The friendly inhabitants of the land that Dorothy enters cannot tell her how to return to Kansas. She is advised to seek the answer in the Emerald City (Washington, D.C.), which can be found at the end of the yellow brick road (symbolic of the gold standard); although the solution to Dorothy's problems will not be found there. Thus the silver shoes and the yellow brick road are Baum's primary symbols of the two metals.

The first person whom Dorothy meets along the way is the Scarecrow. The Scarecrow is the western farmer. He thinks that he has no brains because his head is stuffed with straw. We soon learn that he is shrewd and capable. He brings to life a major theme of the free silver movement: that the people, the farmers in particular, were capable of

---

[79] MGM made numerous changes in the text, some of which, such as changing the silver slippers of the book into the famous ruby slippers of the movie, obscure the allegory.

understanding the complex theories that underlay the choice of a standard. They did not have to accept a monometallic gold standard simply because the experts said that it was necessary.

Next, Dorothy and the Scarecrow meet the Tin Woodman, Baum's symbol for the workingman. He was once flesh and blood but was cursed by the Wicked Witch of the East. As he worked, his ax would take flight and cut off part of his body. A tinsmith would replace the missing part, and the Tin Woodman could work as well as before. Eventually there was nothing left but tin. For all his increased power to work, the Tin Woodman was unhappy for he had lost his heart. This tale is a powerful representation of the populist idea that industrialization had alienated the workingman, turning an independent artisan into a mere cog in a giant machine. The joints of the Tin Woodman have rusted, and he can no longer work. He has joined the ranks of those unemployed in the depression of the 1890's, a victim of the unwillingness of the eastern goldbugs to countenance an increase in the stock of money through the addition of silver. After his joints are oiled, the Tin Woodman wants to join the group to see if the Wizard can give him a heart.

The last character to join the group is the Cowardly Lion. This character is William Jennings Bryan himself. The sequence is not accidental. Baum is following history in suggesting that the movement was started first by the western farmers, was joined (to a limited extent) by the workingman, and then, once it was well under way, was joined by Bryan. An excellent orator, Bryan's stirring speech on the silver plank of the platform, ending with his challenge to the Republicans, "Thou shalt not crucify mankind upon a cross of gold," won him the Democratic nomination. Though he lost, it was almost obvious after the election of 1896 that Bryan would again be the standard-bearer in 1900. By the late 1890's, with the return of prosperity, he continually received advice to soft-pedal silver and concentrate on new issues such as opposition to the trusts and anti-imperialism, which would appeal to the eastern wing of the party. Many Populists considered this line of action pure cowardice. They wanted the Great Commoner to fight for silver in 1900 as he had in 1896.

Along the way Dorothy and her friends meet a series of challenges that show that each character really has the quality he feels he is missing. The most mysterious challenge is the Deadly Poppy Field. The Cowardly Lion falls asleep in the field and is pulled to safety, but with the greatest difficulty. This is another reference to the dangers of putting anti-imperialism ahead of silver. Falling asleep in a field of poppies symbolizes the populist fear that Bryan would fall asleep in the midst of these new issues. Anti-imperialism was predominantly a middle-class and intellectual issue. Bryan's Populist

advisors were concerned that if he failed to stress the issues of greatest concern to rank-and-file Populists (particularly silver), he would fail to win overwhelming support from them. It is therefore appropriate that it is the field mice (little folk concerned with everyday issues), who pull the Cowardly Lion from the Deadly Poppy Field.

At last the group arrives at the Emerald City. The Guardian of the Gate assures them that the Wizard can solve their problems. Before Dorothy and her friends can enter the city, they must don a pair of green-coloured glasses. Everyone in the city must wear them and they must be locked on with a gold buckle by order of the Wizard. The conservative financiers who run the Emerald City, in other words, force its citizens to look at the world through money-coloured glasses. Dorothy and her friends are taken to the Emerald Palace, the White House itself, where they must stay the night before they can have their audience with the Wizard. Dorothy is led to her room through seven passages and up three flights of stairs. It is not surprising that the layout of the Emerald Palace should reflect the numbers seven and three. The Crime of '73 was a crucial event in populist monetary history. Legislation in that year eliminated the coinage of the silver dollar. At that time the price of silver bullion was well above the traditional mint price, so the decision to eliminate the silver dollar had no immediate impact and aroused little public opposition. In later years when the bullion price fell below the mint price, the decision taken in 1873 began to appear as the source of all future difficulties.

The next day, Dorothy and her friends are brought to see the Wizard. One by one, each is taken into a big round room (oval office) to meet the Wizard. As each enters the throne room, the Wizard assumes different shapes, representing different views toward national leadership. To Dorothy he appears as an enormous head, "bigger than the head of the biggest giant," which would be an apt image for a naive and innocent little citizen. To the Scarecrow he appears to be a lovely, gossamer fairy, a most appropriate form for an idealistic Kansas farmer. The Woodman sees a horrible beast, as would any exploited Eastern labourer after the depression, and the Cowardly Lion sees a ball of fire. Each of them receives the same message: the Wizard will help them, but they first must do something for the Wizard; "In this country," explains the Wizard, "everyone must pay for everything he gets." The Wizard has asked them to kill the Wicked Witch of the West. If Cleveland was the Wicked Witch of the East "slain" in 1896, Republican William McKinley was the very much alive Wicked Witch of the West. The golden road does not go in that direction and so they must follow the sun, as have many pioneers in the past. The land they now pass through is "rougher and hillier, for there were no farms nor houses in the country of the West and the ground was untilled."

Dorothy and her friends must face biblical plagues-wolves, crows, and black bees-thrown at them by the Witch but they defeat each of them. The Wicked Witch is thus forced to turn to her Golden Cap (another symbol of the gold standard) which gives her the power to call the Winged Monkeys. The Winged Monkeys represent the Plains Indians; free spirits brought to earth by the relentless western march of the frontier. They, too, cannot avoid the overarching power of the gold standard. The Wicked Witch commands the Winged Monkeys to attack Dorothy and her friends. They attack the little girl and dispose of her companions. Like many Indian tribes, Baum's monkeys are not inherently bad; their actions depend wholly upon the bidding of others. Under control of an evil influence, they do evil. Under the control of goodness and kindness, as personified by Dorothy, the monkeys are helpful and kind.

Dorothy is taken to the castle and made to do household chores. The Witch covets Dorothy's silver shoes, for the Witch knows their power. At last she devises a scheme: she trips Dorothy over an invisible iron bar and snatches one of the silver shoes. With the silver shoes divided, Dorothy cannot use them. This refers to McKinley's position on silver. McKinley and the Republicans did not argue that only gold monometallism would do. Their position was that bimetallism should be established, but only after an international agreement. The Republicans argued that this would raise the world demand for silver sufficiently to prevent the dollar from being devalued when bimetallism was reestablished.

Dorothy is so angry with the Wicked Witch for tripping her that she pours a bucket of water over her. To her surprise, the Witch melts away. The point is that all it takes is some water to make the dry plains bloom. In the 1890's the "rain line" moved east, causing farmers in Kansas, Nebraska, and the Dakotas great hardships in addition to those generated by the depression in agricultural prices. To the western farmer, it appeared that what he needed to get out of debt was some good rain and some good crops.

With the Wicked Witch dead, Dorothy is able to free her friends. Tinsmiths repair the Tin Woodman, and he is given a new ax. The handle is made of gold, and the blade is polished until it "glistens like burnished silver." The new ax is a good symbol of a point often made by the Populists: that they did not want to replace a gold standard with a silver standard; they wanted a genuine bimetallic standard. The advocates of the gold standard argued that bimetallism was unworkable because a rise in the bimetallic ratio could produce an outflow of gold and an inflow of silver that left only silver in circulation; a fall in the ratio might leave only gold in circulation. There could be alternating gold and silver standards, but there could not be a true bimetallic standard in

the sense of two metals circulating side by side, except in the accidental case in which the mint ratio was equal to relative prices in world markets.

Dorothy and her friends return to the Emerald City confident that the Wizard will grant them their wishes. They soon unmask the Wizard and learn that he is nothing but a humbug who has been fooling the people. With a little shrewd psychology, the Wizard solves the problems of Dorothy's friends but Dorothy still cannot get back to Kansas. The Wizard promises to take her in a hot air balloon but at the last moment, the line holding the balloon breaks and the Wizard is carried away, leaving Dorothy behind. The promises of the Wizard are partly hot air.

Dorothy then decides to seek out Glinda, the Good Witch of the South. The South was generally sympathetic to free silver, so it is not surprising that it is ruled by a good witch. After further adventures the party reaches Glinda, who solves all the party's remaining problems. Dorothy is told how to return to Kansas. All that is necessary is that she click the heels of her silver shoes together three times. The power to solve her problems (by adding silver to the money stock) was there all the time. When Dorothy awakes in Kansas, she finds that the silver shoes have disappeared, just as the silver issue was disappearing in the late 1890's. Baum's observation that the silver cause would become a distant memory proved to be true. The Gold Standard Act, committing the United States firmly to the gold standard, was passed in 1900.

Appendix B

Standard Unit Root Tests

U.K. Classical Gold Standard, 1717-1931

Dickey-Fuller Tests: Lags=0

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%	
No Constant, No Trend				
A(1)=0 Z-Test	-1.2169	-5.70	-8.0	AIC= 4.769
A(1)=0 T-Test	-0.7467	-1.62	-1.94	SC= 4.785
Constant, No Trend				
A(1)=0 Z-Test	-15.613	-11.2	-14.1	AIC= 4.744
A(1)=0 T-Test	-2.8592	-2.57	-2.86	SC= 4.775
A(0)=A(1)=0	4.0912	3.78	4.59	
Constant, Trend				
A(1)=0 Z-Test	-16.832	-18.2	-21.7	AIC= 4.751
A(1)=0 T-Test	-2.8993	-3.13	-3.41	SC= 4.798
A(0)=A(1)=A(2)=0	2.8500	4.03	4.68	
A(1)=A(2)=0	4.2713	5.34	6.25	

Phillips-Perron Tests: Truncation Lag=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%
Constant, No Trend			
A(1)=0 Z-Test	-17.945	-11.2	-14.1
A(1)=0 T-Test	-3.0558	-2.57	-2.86
A(0)=A(1)=0	4.6772	3.78	4.59
Constant, Trend			
A(1)=0 Z-Test	-19.499	-18.2	-21.7
A(1)=0 T-Test	-3.1209	-3.13	-3.41
A(0)=A(1)=A(2)=0	3.2933	4.03	4.68
A(1)=A(2)=0	4.9368	5.34	6.25

U.K. Bretton Woods, 1946-1971

Dickey-Fuller Tests: Lags=0

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%	
No Constant, No Trend				
A(1)=0 Z-Test	1.0932	-5.70	-8.0	AIC= 5.150
A(1)=0 T-Test	5.8752	-1.62	-1.94	SC= 5.199
Constant, No Trend				
A(1)=0 Z-Test	1.0064	-11.2	-14.1	AIC= 5.229
A(1)=0 T-Test	1.2551	-2.57	-2.86	SC= 5.327
A(0)=A(1)=0	16.555	3.78	4.59	
Constant, Trend				
A(1)=0 Z-Test	0.18383	-18.2	-21.7	AIC= 5.308
A(1)=0 T-Test	0.04240	-3.13	-3.41	SC= 5.454
A(0)=A(1)=A(2)=0	10.587	4.03	4.68	
A(1)=A(2)=0	0.7733	5.34	6.25	

Phillips-Perron Tests: Truncation Lag=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%
Constant, No Trend			
A(1)=0 Z-Test	0.9686	-11.2	-14.1
A(1)=0 T-Test	1.1357	-2.57	-2.86
A(0)=A(1)=0	14.625	3.78	4.59
Constant, Trend			
A(1)=0 Z-Test	-0.9838	-18.2	-21.7
A(1)=0 T-Test	-0.2289	-3.13	-3.41
A(0)=A(1)=A(2)=0	9.2952	4.03	4.68
A(1)=A(2)=0	0.7024	5.34	6.25

U.K. Flexible Exchange Rate Regime, 1973-1991

Dickey-Fuller Tests: Lags=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%	
No Constant, No Trend				
A(1)=0 T-Test	1.3425	-1.62	-1.94	AIC= 8.232
				SC= 8.330
	Estimate	Standard Error		T-Ratio
Lag 1	0.7694	.1886		4.0795
Constant, No Trend				
A(1)=0 T-Test	0.28332	-2.57	-2.86	AIC= 8.210
A(0)=A(1)=0	2.0215	3.78	4.59	SC= 8.357
	Estimate	Standard Error		T-Ratio
Lag 1	0.5589	0.2327		2.4018
Constant, Trend				
A(1)=0 T-Test	-3.0798	-3.13	-3.41	AIC= 7.767
A(0)=A(1)=A(2)=0	5.4410	4.03	4.68	SC= 7.964
A(1)=A(2)=0	4.9415	5.34	6.25	
	Estimate	Standard Error		T-Ratio
Lag 1	0.8342	0.2027		4.1155

Phillips-Perron Tests: Truncation Lag=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%
Constant, No Trend			
A(1)=0 Z-Test	0.3234	-11.2	-14.1
A(1)=0 T-Test	0.8112	-2.57	-2.86
A(0)=A(1)=0	42.788	3.78	4.59
Constant, Trend			
A(1)=0 Z-Test	-6.6428	-18.2	-21.7
A(1)=0 T-Test	-1.5229	-3.13	-3.41
A(0)=A(1)=A(2)=0	29.331	4.03	4.68
A(1)=A(2)=0	1.6621	5.34	6.25

U.S. Classical Gold Standard, 1793-1933

Dickey-Fuller Tests: Lags=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%	
No Constant, No Trend				
A(1)=0 T-Test	-0.88471	-1.62	-1.94	AIC= 5.194 SC= 5.237
	Estimate	Standard Error		T-Ratio
Lag 1	0.19402	.083708		2.3178
Constant, No Trend				
A(1)=0 T-Test	-3.3220	-2.57	-2.86	AIC= 5.136
A(0)=A(1)=0	5.5204	3.78	4.59	SC= 5.200
	Estimate	Standard Error		T-Ratio
Lag 1	0.25164	0.083013		3.0314
Constant, Trend				
A(1)=0 T-Test	-3.3268	-3.13	-3.41	AIC= 5.150
A(0)=A(1)=A(2)=0	3.7017	4.03	4.68	SC= 5.234
A(1)=A(2)=0	5.5501	5.34	6.25	
	Estimate	Standard Error		T-Ratio
Lag 1	0.25124	0.083286		3.0167

Phillips-Perron Tests: Truncation Lag=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%
Constant, No Trend			
A(1)=0 Z-Test	-16.680	-11.2	-14.1
A(1)=0 T-Test	-2.9223	-2.57	-2.86
A(0)=A(1)=0	4.2797	3.78	4.59
Constant, Trend			
A(1)=0 Z-Test	-16.810	-18.2	-21.7
A(1)=0 T-Test	-2.9342	-3.13	-3.41
A(0)=A(1)=A(2)=0	2.9039	4.03	4.68
A(1)=A(2)=0	4.3553	5.34	6.25

U.S. Bretton Woods, 1946-1971

Dickey-Fuller Tests: Lags=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%	
No Constant, No Trend				
A(1)=0 T-Test	2.6378	-1.62	-1.94	AIC= 2.945
				SC= 3.044
	Estimate	Standard Error		T-Ratio
Lag 1	0.4135	0.1539		2.6866
Constant, No Trend				
A(1)=0 T-Test	2.0744	-2.57	-2.86	AIC= 2.918
A(0)=A(1)=0	4.9366	3.78	4.59	SC= 3.065
	Estimate	Standard Error		T-Ratio
Lag 1	0.4003	0.1493		2.6810
Constant, Trend				
A(1)=0 T-Test	-0.3103	-3.13	-3.41	AIC= 2.972
A(0)=A(1)=A(2)=0	3.4255	4.03	4.68	SC= 3.169
A(1)=A(2)=0	2.4070	5.34	6.25	
	Estimate	Standard Error		T-Ratio
Lag 1	0.4658	0.1730		2.6914

Phillips-Perron Tests: Truncation Lag=1

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%
Constant, No Trend			
A(1)=0 Z-Test	0.3413	-11.2	-14.1
A(1)=0 T-Test	0.3084	-2.57	-2.86
A(0)=A(1)=0	9.8448	3.78	4.59
Constant, Trend			
A(1)=0 Z-Test	-4.8010	-18.2	-21.7
A(1)=0 T-Test	-1.1068	-3.13	-3.41
A(0)=A(1)=A(2)=0	6.6927	4.03	4.68
A(1)=A(2)=0	0.7961	5.34	6.25

U.S. Flexible Exchange Rate Regime, 1973-1991

Dickey-Fuller Tests: Lags=2

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%	
No Constant, No Trend				
A(1)=0 T-Test	1.5761	-1.62	-1.94	AIC= 5.123 SC= 5.268
	Estimate	Standard Error		T-Ratio
Lag 1	1.1381	0.2576		4.4181
Lag 2	-0.4562	0.2601		-1.7538
Constant, No Trend				
A(1)=0 T-Test	-0.6294	-2.57	-2.86	AIC= 4.926
A(0)=A(1)=0	3.8591	3.78	4.59	SC= 5.119
	Estimate	Standard Error		T-Ratio
Lag 1	1.0316	0.2336		4.4152
Lag 2	-0.5886	0.2387		-2.4656
Constant, Trend				
A(1)=0 T-Test	-1.8833	-3.13	-3.41	AIC= 4.785
A(0)=A(1)=A(2)=0	4.1934	4.03	4.68	SC= 5.027
A(1)=A(2)=0	1.9120	5.34	6.25	
	Estimate	Standard Error		T-Ratio
Lag 1	0.8841	0.2283		3.8720
Lag 2	-0.1309	0.3319		-0.3946

Phillips-Perron Tests: Truncation Lag=2

Null Hypothesis	Test Statistic	Critical Value 10%	Critical Value 5%
Constant, No Trend			
A(1)=0 Z-Test	-0.0900	-11.2	-14.1
A(1)=0 T-Test	-0.2084	-2.57	-2.86
A(0)=A(1)=0	29.357	3.78	4.59
Constant, Trend			
A(1)=0 Z-Test	-6.3338	-18.2	-21.7
A(1)=0 T-Test	-1.7407	-3.13	-3.41
A(0)=A(1)=A(2)=0	20.732	4.03	4.68
A(1)=A(2)=0	1.5860	5.34	6.25

Appendix C

The U.S. Price Series

The index of wholesale prices of all commodities from 1793-1933 is obtained from Warren and Pearson (1935). The U.S. Bureau of Labour Statistics wholesale price index from 1934-1991 is obtained from McCusk (1992).

The U.K. Price Series

Price data come primarily from Mitchell and Deane (1962) and Mitchell and Jones (1971). The wholesale price index for 1846-1965 is the Sauerbeck-Statist Overall Price Index, which is the index used by Keynes in his discussion of interest rates and prices during the gold standard. The series was linked to other series by multiplying by the average ratio of the two series for five overlapping years. In this manner, the Gayer-Rostow-Schwartz Domestic and Imported Commodities Index was linked to the Sauerbeck-Statist series for the years 1790-1845. This in turn was linked to the Schumpeter-Gilboy Consumer's Goods Index for the period 1717-1789. Since the Sauerbeck-Statist series was discontinued in 1965, the wholesale price index number from McCusk (1992) is linked to the series for the period 1966-1991. Though the Sauerbeck-Statist index may be less representative as time goes on, its continuation to 1965 gives a long period for comparison.

References

Amano, R. and S. van Norden (1992), "Unit Root Tests and the Burden of Proof," *Bank of Canada*, Ottawa.

Banerjee, A., J. Dolado, J.W. Galbraith, and D.F. Hendry (1993). *Co-integration, Error-Correction and the Analysis of Non-stationary data*. Oxford, Oxford University Press.

Bank of Canada. *Economic Behaviour and Policy Choice under Price Stability*. Ottawa, 1994.

Barro, R. (1979), "Money and the Price Level Under the Gold Standard," *Economic Journal* 89, pp.13-33.

Bordo, M. and A. Schwartz. *A Retrospective on the Classical Gold Standard*. Chicago: Univ. Chicago Press, 1984.

Campbell, J.Y., and P. Perron (1991), "Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots," in S. Fischer ed., *NBER Macroeconomics Annual 1991*, Cambridge, MIT Press, pp.141-201.

Dam, Kenneth. *The Rules of the Game*. Chicago: Univ. Chicago Press, 1982.

Dickey, D.A. and W.A. Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association* 74, pp.427-431.

Dickey, D.A. and W.A. Fuller (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica* 49, pp.1057-1072.

DeJong, D.N. and C. Whiteman (1991), "Reconsidering 'Trends and Random Walks in Macroeconomic Time Series,'" *Journal of Monetary Economics* 28, pp.221-254.

DeJong, D.N., J.C. Nankervis, N.E. Savin, and C.H. Whiteman (1992), "Integration versus Trend Stationarity in Time Series," *Econometrica* 60, pp.423-433.

Eichengreen, Barry. *The Gold Standard in Theory and History*. New York: Methuen, 1985.

Federal Reserve Bank of Kansas City. *Achieving Price Stability*. Jackson Hole, Wyoming, 1996.

Fischer, Stanley. (1996), "Why are Central Banks Pursuing Long-Run Price Stability?" *Achieving Price Stability: a symposium sponsored by the Federal Reserve Bank of Kansas City*, p.7-34.

Fisher, I. *The Purchasing Power of Money*. New York: Macmillan, 1922.

Greenspan, A (1996). "Opening Remarks," *Achieving Price Stability: a symposium sponsored by the Federal Reserve Bank of Kansas City*, p.1-5.

Hawtrey, R.G. *The Gold Standard in Theory and Practice*. London: Longmans, 1927.

Homer, Sidney and R. Sylla. *A History of Interest Rates*. New Brunswick, N.J.: Rutgers Univ. Press, 1991.

Hume, David (1752). *On the balance of trade*. London: Longmans, reprinted in Eichengreen, 1985.

Jastram, Roy. *The Golden Constant*. New York: John Wiley and Sons, 1977.

Kwiatkowski, D., P. Phillips and P. Schmidt (1992), "Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root," *Journal of Econometrics* 54, pp. 159-178.

Littlefield, Henry (1964), "The Wizard of Oz: Parable on Populism," *American Quarterly* 16, pp.47-58.

McCusk, John (1992), "How Much is That in Real Money?" *American Antiquarian Society*.

Mitchell, B.R., and Deane, P. *Abstract of British Historical Statistics*. Cambridge: Cambridge Univ. Press, 1962.

Mitchell, B.R., and Jones, H. *Second Abstract of British Historical Statistics*. Cambridge: Cambridge Univ. Press, 1971.

Nelson, C.R. and C.I. Plosser (1982), "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics* 10, pp.139-162.

Newey, W.K. and K.D. West (1987), "A Simple Positive Definite Heteroskedasticity and Autocorrelation Consistent Covariance Matrix, " *Econometrica* 55, pp. 819-847.

Perron, P. (1988), "Trends and Random Walks in Macroeconomic Time Series," *Journal of Economic Dynamics and Control*, pp.297-332.

Perron, P. (1989), "The Great Crash, the Oil price Shock, and the Unit Root Hypothesis," *Econometrica* 57, pp. 1361-1401.

Phillips, P. (1986), "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics* 33, pp.311-340.

Phillips, P. (1987), "Time Series Regression with a Unit Root," *Econometrica* 55, pp.277-301.

Phillips, P. (1991), "To Criticize the Critics," *Journal of Applied Econometrics* 6, pp.333-364.

Phillips, P. and P. Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrika* 75, pp.335-346.

Pindyck, R. and D. Rubinfeld. *Econometric Models and Economic Forecasts*. New York: McGraw Hill, 1992.

Ricardo, David (1816), "Proposals for an economical and secure currency; with observations on the profits of the Bank of England as they regard the public and the proprietors of bank stock," in Piero Sraffa (ed.), *The Works and Correspondence of David Ricardo*, IV, Cambridge: Cambridge University Press, 1951.

Rockoff, Hugh (1990), "The 'Wizard of Oz' as a Monetary Allegory," *Journal of Political Economy* 98, pp. 739-759.

Rockwell, L. *The Gold Standard: An Austrian Perspective*. Lexington: D.C. Heath and Co., 1985.

Said, E.S. and D.A. Dickey (1984), "Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order," *Biometrika* 71, pp.599-607.

Schwert, G.W. (1989), "Tests for Unit Roots: A Monte Carlo Investigation," *Journal of Business and Economic Statistics* 7, pp.147-159.

Shiller, R.J. and P. Perron (1985), "Testing the Random Walk Hypothesis: Power Versus Frequency of Observation," *Economic Letters* 18, pp. 381-386.

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

Sims, Christopher (1988), "Bayesian Skepticism on Unit Root Econometrics," *Journal of Economic Dynamics and Control* 12, pp.463-474.

Taylor, John. (1996), "How Should Monetary Policy Respond to Shocks While Maintaining Long-Run Price Stability?- Conceptual Issues" *Achieving Price Stability: a symposium sponsored by the Federal Reserve Bank of Kansas City*, p.181-194.

Tooke, Thomas. *A History of Prices*. New York: Johnson Reprint Corp., 1972.

Viner, Jacob (1937), *Studies in the Theory of International Trade*, New York: Harper, reprinted by A.M. Kelley, New York, 1975.

Warren, G.F. and Pearson, F.A. *Gold and Prices*. New York: John Wiley and Sons, 1935.

Yarbrough, B. *The World Economy: Trade and Finance*. New York: Dryden Press, 1988.