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INTERNATIONAL ADJUSTMENT UNDER THE CLASSICAL GOLD STANDARD: EVIDENCE FOR THE U.S. AND BRITAIN, 1879-1914

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ABSTRACT

Links between disturbances in financial markets and those in real activity have long been the focus of studies of economic fluctuations during the period prior to World War I. We emphasize that domestic autonomy was substantially limited by internationally integrated markets for goods and capital. Such findings are important for studying business cycles during the period; for example, when prices are flexible, observed cyclical movements can be related to a credit-market transmission of deflationary shocks.

Recent studies of the classical gold standard have revived interest in the process by which macroeconomic shocks were transmitted internationally during this period. The principal competing approaches — the "price-specie-flow," mechanism and the more modern "internationalist" view — differ according to the means by which international equilibrium is reestablished after a disturbance occurs in capital, money, or commodity markets. We present and interpret separate pieces of evidence on gold flows, interest rates, and selected commodity prices, all of which shed light on the alternative assumptions employed in the price-specie-flow and modern approaches. We employ a monthly data set for the U.S. and Britain for the pre-World War I frameworks. Using the "structural VAR" approach of Bernanke and Sims, we compare the actual historical importance of shocks and the observed patterns of short-run adjustment to shocks with the prediction of each of the two models. The evidence supports the "internationalist" view of close international linkages over the "specie-flow" view of circuitous linkages and domestic autonomy in money and capital markets.

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I. INTRODUCTION

Links between disturbances in financial markets and those in real activity have long been the focus of studies of economic fluctuations during the period prior to World War I. The standard "business cycle" analysis of the period emphasizes the importance of domestic monetary shocks in an environment of sticky prices and inelastic money supply. In this paper, we provide several consistent sets of evidence which show that those basic assumptions are at odds with the data from the period. That is, we emphasize that domestic autonomy was substantially limited by internationally integrated goods and capital markets. Such findings are likely to be important for studying business cycles during the period; we have shown elsewhere (see Calomiris and Hubbard, 1986) that, when prices are flexible, observed cyclical movements can be related to a credit-market transmission of deflationary shocks.[1]

The focus on international linkages has been common in the literature; indeed, recent studies of the operation of the classical gold standard have revived interest in the process by which macroeconomic shocks were transmitted internationally during this period (see Bordo and Schwartz, 1985). The principal competing approaches differ according to the means by which international equilibrium is re-established after a disturbance occurs in capital, money, or commodity markets. According to the "price-specie-flow" mechanism, shocks which raise (lower) the gap between the domestic money supply and its equilibrium level raise (lower) the domestic price level; this in turn decreases (increases) the balance of trade, which leads to outflows (inflows) of gold and eventually equilibration of the system at commodity price levels consistent with foreign prices. More recent models of international adjustment emphasize the roles of arbitrage and speculation in efficient markets for capital, currency, and commodities. This "modern" approach argues that interest rates and prices will maintain levels consistent with foreign interest rates and prices in the short run, while currency, capital, and commodity flows adjust to achieve long-run changes necessary to restore equilibrium in all markets. The intuition for this result is that speculative demands or supplies for commodities, capital, and money place bounds on **predictable** short-run deviations of prices.

A representative view associated with the circuitous price-specie-flow mechanism posits: sluggish international gold movements; sticky commodity prices; the cyclical importance of money supply shocks (mainly shocks to the money multiplier) and the consequent potential for central banks to influence the aggregate money supply and (through it) interest rates and economic activity. In order to argue that money multiplier shocks and central bank interventions have more than fleeting influence on the real money supply, one must assume both that commodity prices are rigid and that the supply of high-powered money is inelastic. This general view is consistent with the price-specie-flow sequence of events: International adjustment to monetary shocks follows gradual domestic price adjustment which, through changes in the terms of trade, brings about trade deficits (surpluses) and hence balance of payments surpluses (deficits).

On the other hand, advocacy of the modern approach implies far less domestic autonomy in the short run for interest rates, the money supply, and commodity prices. According to the modern (or "internationalist") view, gold supply is highly elastic, capital markets for some securities (internationally traded commercial paper and bonds) are closely integrated internationally, and domestic commodity gold prices are flexible and internationally determined within "narrow" bandwidths of transaction cost (which includes transport and insurance fees, tariffs, and a fair rate of return to international commodity market speculators).[2] These assumptions, in turn, imply demand determination of the real (and nominal) money stock, an internationally determined commercial paper rate (in gold units), and a minor role for any central bank with respect to its ability to influence the aggregate money supply or the rates of return on internationally traded securities.[3] Even in the absence of highly responsive domestic prices, these results still hold, but the lagging adjustment of domestic prices to international price shocks entails real effects on the time path of the balance of trade.

Essentially what is at issue in distinguishing these two views empirically is whether the deviations allowed by transaction and information costs in gold, capital, and commodity markets were sufficiently small to support the "close" short-run connections in prices and rates of return across the Atlantic which the modern approach posits. Were gold flows "sufficiently" elastic? Were interest rates "closely" linked?

Our paper approaches these questions in two ways: First, we measure the responsiveness of gold flows and the bandwidths of capital and commodity relative price variation directly. While these direct measures provide some evidence in favor of close international links, we argue that price bandwidths or correlations alone are insufficient evidence to conclude that the modern approach is superior to the price-specie-flow view. The **narrowness** of bandwidths must be measured relative to the macroeconomic **importance** of relative price deviations. That is, even if all relative prices were bounded by bandwidths of one percent, if autonomous domestic interest rate movements of, say, a half percent have large macroeconomic effects (if, for example, the IS curve is very flat) then the price-specie-flow view may provide a superior description of the macroeconomic transmission of shocks. Thus we argue that macroeconomic simulation models are the best way to establish which of the two views is a more useful historical model for explaining events of the period.

In sections II and III below we test various assumptions and conclusions associated with the two competing views of international adjustment. We begin in section II by presenting and interpreting separate pieces of evidence on gold flows, interest rates, and selected commodity prices, as well as summarizing related results from the literature, all of which shed light on the alternative assumptions employed in the price-specie-flow and the modern approaches. In section III we employ a monthly data set for the United States and Britain for the pre-World War I period in order to evaluate the overall explanatory power of the respective frameworks. We compare the actual historical importance of shocks and the observed patterns of short-run adjustment to shocks with the predictions of each of the two models. Here we employ the "structural VAR" approach for simultaneous-equations modeling recently developed by Bernanke (1986) and Sims (1986). Section IV concludes the paper.

II. EVIDENCE ON MONEY SUPPLY ELASTICITY AND INTERNATIONAL INTEGRATION OF COMMODITY AND CAPITAL MARKETS

Gold-Flow Responsiveness

Even an unsophisticated analysis of monthly gold flows leads one to question the so-called "stylized fact" of gold supply inelasticity; a formal treatment of the relationships among gold flows and other variables is relegated to section III. Figure 1 shows that transitory net flows of gold in the United States were often very large. The mean and standard deviation of the monthly net outflow over the period 1885 to 1914 are $45,000 and $11 million, respectively. Positive net outflows have a mean of $8 million and a standard deviation of $7.6 million, while net inflows have a mean of $6.2 million and a standard deviation of $8.7 million. The ratio of the potential monthly flow of gold to the existing stock of gold is high, as well — in December 1907 and January 1908, total net gold inflows amounted to $106 million, compared to a stock of currency in circulation outside the Treasury of $3.07 billion — composed of $1.86 billion held by the public and $1.21 held by banks — and a total money supply (M_2) of approximately $11.6 billion.[4]

Autocorrelation and partial autocorrelation functions for monthly U.S. gold flows are presented in Table 1. These patterns suggest an MA(2) process, or possibly an AR(1). Under either specification, gold flows adjust fully to disturbances within three months, with most of the adjustment occurring in the first month. Coefficients, autocorrelation functions and partial autocorrelation functions for residuals are presented in Table 2 for both specifications.

These results are not surprising given the existence of the transatlantic telegraph, the market for gold, and the available technology for transporting gold by steamship across the Atlantic in a matter of days. Officer (1986) carefully estimates the costs of international gold transport and finds that the observed gold price differentials virtually never violate his constructed cost bandwidths which average roughly half of one percent.[5]

Gold Flows and Capital-Market Integration

The evidence presented above suggests that any incipient rise in the expected riskless rate of return (in gold terms) in the U.S. relative to Britain of greater than 2 percent (annualized) would have been prevented by a short-term (six-month) capital inflow. The capital inflow could have been profitably accomplished through a transitory gold export (and re-import) to (and from) America.

More specifically, a British investor observing a 2-percent interest differential on six-month high-grade commercial paper could wire funds to New York though a correspondent in London. The commercial paper purchase in New York would be offset either by a temporary increase in American bankers' balances in London (until the paper came due), or by a gold flow to the United States. If the incipient interest rate gap had been the result of a money multiplier shock, the latter likely would be the case.

Such a calculation, unfortunately, is quite sensitive to the assumed holding period of capital inflows. If one assumed a three-month holding period instead of six months, the interest differential tolerance rises to 4 per cent. Investors certainly had access to commercial paper of six-month maturity, but they may have been reluctant to tie up their gold in the U.S. for six months due to the consequent loss in liquidity. Knowledge of a shadow-price-of-liquidity schedule for international investors would be necessary in order to establish a relevant range of tolerable interest differentials using this approach.

Interest Rate Arbitrage and Capital-Market Integration

The existence of currency spot and forward contracting provides a method for constructing another set of bandwidths on the gold interest rate differential. Forward contracting became increasingly prevalent beginning in the 1870s (see Perkins, 1974), but implicit forward contracting had been available for centuries in the form of bills of exchange. A bill of exchange is a promise to deliver some amount of one currency at a certain time in the future in exchange for some amount of another currency today. Thus a bill-of-exchange price can be derived from the interest rate on the currency paid today, the forward rate of exchange, the brokerage fee, and the date of delivery.

The existence of international markets in commercial paper and bills of exchange, together with the transatlantic telegraph, places limits on the variation of interest rates across countries. These limits can be described in terms of the exclusion of arbitrage profit.

Consider the three markets portrayed in Figure 2: the "sight" market in New York for immediate delivery of pounds in London, the sixty-day bill of exchange market in New York for delivery in London, and the London high-grade commercial paper market.[6] We define τ_1, τ_2, and τ_3 as proportional brokerage fees for dealing in these respective markets.

A British arbitrageur could sell British commercial paper for pounds, then sell those pounds for dollars through his agent in New York on the sight market, and then instruct his agent to purchase sixty-day pounds with those dollars. If the future pounds received, after considering transaction costs, were in excess of the present value of the amount of pounds placed in the initial transaction, arbitrage profits will be possible. Thus exclusion of arbitrage profit implies:

$$(1) \qquad \frac{\$_0}{£_0}(1-\tau_1)\frac{£_1}{\$_0}(1-\tau_2)\frac{1}{1+i^L}(1-\tau_3) < 1,$$

where subscripts 0 and 1 refer to the present and future, i^L is the sixty-day British commercial paper rate, and all exchange rates are quoted in New York. Working in the opposite direction, an American arbitrageur could acquire dollars by promising to deliver pounds in sixty days; then buy pound sight bills, and exchange them for British commercial paper in London. Here the exclusion of arbitrage profit implies:

$$(2) \qquad \frac{\$_0}{£_1}(1-\tau_2)\frac{£_0}{\$_0}(1-\tau_1)(1+i^L)(1-\tau_3) < 1.$$

Together (1) and (2) imply:

$$(3) \qquad (1-\tau_1)(1-\tau_2)(1-\tau_3) < \left(\frac{\$_0}{£_1}\right)\left(\frac{£_0}{\$_0}\right)(1+i^L) < \left(\frac{1}{1-\tau_1}\right)\left(\frac{1}{1-\tau_2}\right)\left(\frac{1}{1-\tau_3}\right).$$

In order to derive restrictions on the interest differential between London and New York, one must consider the arbitrage restrictions among the pure foreign exchange futures market in London, the bill of exchange market in New York, and the New York commerical paper market. Define τ_4 and τ_5 as the proportional transaction costs in London forward currency, and New York commercial paper contracting, respectively. Following the same logic as before:

$$(4) \qquad (1-\tau_2)(1-\tau_4)(1-\tau_5) < \left(\frac{\$_1}{£_1}\right)^*\left(\frac{£_1}{\$_0}\right)\left(\frac{1}{1+i^{NY}}\right) < \left(\frac{1}{1-\tau_2}\right)\left(\frac{1}{1-\tau_4}\right)\left(\frac{1}{1-\tau_5}\right),$$

where an (*) denotes a London exchange rate, and i^{NY} is the dollar interest paid on New York commercial paper.

Conditions (3) and (4) together imply that — were the gold standard parity known to be a permanent feature of both country's monetary systems — for low values of τ_1 through τ_5 (i.e., principally large scale transactions) and a small potential difference between sight rates in New York and London given by the cost of moving gold, high-grade commercial paper interest rates would be virtually identical in New York and London.

Previous studies have rejected capital-market integration (in the form of interest rate parity) between New York and London on the basis of a nearly constant spot exchange rate series and a potentially large (typically positive) interest differential between short-term high-grade commercial paper offered in the two cities (see for example Officer, 1986, p. 1072). As Figure 3 shows, this spread is potentially very high for the period before 1897.

Friedman and Schwartz (1983, p. 515) recognize the potential role of "silver risk" in causing spikes in the observed commercial paper interest differential. The possibility that the U.S. might have switched, *de facto*, from a gold to a silver standard implies that dollar interest rates were a probability-weighted, risk-discounted combination of gold and silver interest rates. Thus large observed differentials between dollar and pound commercial paper rates need not imply large differentials between U.S. and British rates in gold terms. Garber (1986) argues that silver risk associated with the Bland-Allison and Sherman Acts and the election of 1896 explains much of the interest differential between long-term U.S. and foreign securities in the late nineteenth century. Indeed, the role of silver risk in causing higher interest rates in, and capital flight from, the U.S. is a common theme in the popular literature of the day.[7]

The lack of reliable data on forward rates has discouraged further tests of this hypothesis. Fortunately, one does not need explicit forward rate data in order to test interest rate parity and establish the role of silver risk in the observed commercial paper interest differential. Bandwidths for condition (3) may be calculated given data on the dollar price of sixty-day bills of exchange and sight exchange rates in New York, and the relevant British interest rate, all of which are available.[8]

Define:

$$\frac{1}{1+i^L} \equiv \text{INVLON, and}$$

$$\frac{\$_0}{£_1} \cdot \frac{£_0}{\$_0} \equiv \text{FSR.}$$

In the absence of transaction costs these two series should be identical. We construct these variables using the monthly average of the London open-market discount rate (based on weekly quotations from The Economist) and a monthly average of daily sixty-day, and sight, bill prices ($\frac{\$_0}{£_1}$ and $\frac{\$_0}{£_0}$), respectively, from Statistics for the United States, 1867-1909, published by the National Monetary Commission. These two series are plotted in Figure 4. The close relationship between these series is clearly visible.

In order to measure transaction cost bandwidths we calculate the middle term in condition (3), which we call ARB. For the sample 1889:1 to 1909:12 ARB reached a maximum of 1.00001 and a minimum of 0.99646. For the subperiod 1897:1 to 1909:12 the range was essentially the same: 0.99657 to 0.99994. Under the assumption of identical τ's, (3) implies maximum τ values equal to one minus the cube root of 0.99646, or 0.00118. Combining (3) and (4) and assuming a proportional gold transport cost of 0.005, the allowable positive gold-denominated interest differential between New York and London is given by:

$$(5) \quad (1+i^L) = (1 - 0.005)(0.99646)(1 + i_g^{NY}),$$

where i_g^{NY} is the gold-denominated U.S. rate. This, and its complementary condition, imply that:

$$(6) \quad 0.9915 < \frac{1+i^{L}}{1+i_{g}^{NY}} < 1.0085.$$

The actual range of values for the middle term of condition (6) for the period for which U.S. interest rates are clearly gold-denominated (after 1897) is from 0.995 to 1.00057.

These calculations imply that the sixty-day U.S. interest rate implicit in the bill-of-exchange market is the same as the high-grade sixty-day U.S. commercial paper rate, adjusting for transaction costs. Thus gold interest parity is satisfied among the British open-market rate, the U.S. rate, and the implicit U.S. rate in the bill-of-exchange market, adjusting for transaction cost.[9]

Our results imply that the observed range of interest rate differentials between the U.S. and Britain for the period **after** the silver crisis is a good approximation of the range of **gold** interest differentials **before** the crisis, given the stability of arbitrage bandwidths. In other words, annual gold interest rate differentials on high-grade commercial paper in the U.S. and Britain were essentially within 2 percent of one another for the thirty years prior to World War I.

These calculations by themselves tell us little about the effective domestic autonomy of regions within the U.S., or the nation as a whole, for two reasons. First, we lack a standard against which to measure the **importance** of a 2 percent potential international interest rate spread. Second, the existence of imperfect capital markets implies that shocks to local "information capital" -- described in Calomiris and Hubbard (1986) -- will not be solved by capital inflows. That is, not all economic activity can be financed by the commercial paper market.

At the same time, the interest rate parity calculations are useful for two reasons. First, they demonstrate that the apparent relative weakness of capital market links prior to 1896 is an artifact of the mismeasurement of the numeraire, rather than a substantive difference. Second, the 2-percent bandwidths place limits on the potential for explaining macroeconomic fluctuations in a perfect-capital-markets, closed-economy, IS-LM framework.

In particular, the latitude for domestic money-multiplier shocks to be transmitted to output through the domestic money market's effect on the interest rates of traded securities is substantially circumscribed. The exact limitations on the causal role of money supply shocks, per se, depend on — inter alia — the responsiveness of investment and consumption to interest rate shocks. If one found that investment were unresponsive to interest rate movements of 2 percent — i.e., if business cycles are hard to explain as movements **along** an IS curve within 2 percent bandwidths — then an emphasis on IS shocks, or on credit-market disturbances under imperfect capital markets, would be warranted. These issues will be taken up again in our discussion of changing interest rate seasonality, and in section III.

Defining the Scope of the Financial Market: Tests of Integration

McCloskey and Zecher (1985) point out that what is primarily at issue in the debate over the international transmission of disturbances is the geographical boundaries of the basic unit of macroeconomic analysis. Defining a national monetary aggregate, the domestic balance of trade and national GNP and organizing one's discussion around these definitions implicitly presumes that market integration within the United States is substantially greater than, say, the integration between New York and London markets. McCloskey and Zecher argue cogently that the proper way to test our aggregation boundaries and models of the international transmission of shocks is to compare arbitrage limits within a country with those between countries. They call this the "Genberg-Zecher criterion." McCloskey and Zecher (1976) find that commodity price co-movements within the United States are no stronger than those between New York and London. They conclude that national boundaries are an arbitrary means of defining economic units for commodity trade under the classical gold standard.[10]

One may apply the Genberg-Zecher criterion to the gold market by comparing international gold points with exchange rate premia and discounts across different cities within the United States. International gold points derived from Officer (1986) for the period October 1900 to March 1907 are always less than 0.5 per cent. Data for this period for exchange rates on New York from Chicago, St. Louis, New Orleans, and San Francisco show that deviations from New York gold prices in Chicago, St. Louis and New Orleans are contained within bandwidths of 0.1 percent (with the exception of the suspension of 1907). For San Francisco, inter-city bandwidths are often slightly higher.[11]

These results illustrate the difficulty of employing the Genberg-Zecher criterion as a test of market integration. While this criterion offers sufficient grounds for rejecting the extreme view of nationally integrated, domestically autonomous economies, it does not by itself tell us which direction to go in placing boundaries on the basic macroeconomic unit. Is a large international scope or a narrow regional scope more appropriate? What is lacking is an independent measure of how "small" a gold point of 0.1 or 0.5 percent is in economic terms.

The speed of adjustment and reversal of gold flows following transient money-multiplier disturbances sheds some light on the question of whether regional or international scope is best for understanding macroeconomic phenomena at, say, an annual time horizon. The regional pattern of gold flows during crisis supports the view of New York as an active entrepot between the domestic interior and London, with elastic gold flows in both directions. For example, from October 18 to December 27, 1907 net shipments of gold from banks in New York to the U.S. interior total $129 million. From January 3 to January 31 fully $69 million in net shipments had returned to New York.[12] International accounts also show this rapid inflow and outflow of gold. From June through September 1907 net gold exports total $29 million; from October 1907 to April 1908 net gold imports total $122 million; from May to September 1908 net gold exports total $45 million. The upshot of these findings is that in annual — or _a fortiori_ "business-cycle" — time, the market for gold operates well enough that gold sluggishness per se cannot be faulted for persistent macroeconomic fluctuations.

In analyzing these international gold flows it is important to note that the elasticity of gold flows does not imply that real shocks -- in particular, shocks to credit markets which affect borrowers' wealth and banks' creditworthiness — will be alleviated by gold flows. Gold flows are endogenous to aggregate real economic activity and generally will respond procyclically, as well as in response to shifts in the domestic demand for gold relative to other commodities.

Capital-Market Integration and the Changing Seasonality of Interest Rates

Miron (1986) reports a significant reduction in the seasonality of call loan rates after the founding of the Federal Reserve System. By itself, this result seems to argue in favor of viewing the U.S. money supply as significantly (if not importantly) domestically determined. Miron explains this finding by an appeal to "sluggish" gold flows, and hence, at least short-run domestic autonomy. In particular, Miron argues that gold supply sluggishness made the economy vulnerable to large seasonal swings in interest rates due to money-multiplier disturbances.

Clark (1986) disputes Miron's interpretion that the establishment of the Fed was responsible for the reduction in interest rate seasonality. Clark demonstrates that the reduction in interest rate seasonality was an **international** phenomenon, and that the timing of the seasonality shift occurs prior to the seasonality shift in currency and high-powered money. Moreover, the changes in seasonal patterns Miron observes are not evenly spread — that is, the overall reduction in seasonality is mainly due to reductions in the largest seasonals which represent average interest rate fluctuations of between 3 and 5 percent. Our interest rate parity calculations imply that such large fluctuations could not have occurred in the United States in the absence of similar movements in international interest rates. Thus Clark's findings — together with the 2-percent bandwidths of interest rate parity we report — argue against the view that large swings in interest rates in the U.S. before 1914 were caused by inelastic gold and capital flows. Of course, as we pointed out before, the Fed could have had important macroeconomic influence as a creditor to banks, regardless of its influence over the aggregate supply of money, per se. This would be consistent with Miron's finding of increased loan seasonality after the founding of the Fed.

Why Construct Bandwiths of Autonomous Relative Commodity Price Variation?

Short-run commodity price linkages across countries are not a necessary condition for money supply elasticity. Bandwidths of relative international commodity price variation, however, place restrictions on the variations in the short-run terms of trade, and hence on short-run movements in the current account, which may have important macroeconomic consequences.

Much of the previous work on international commodity price linkages — summarized in McCloskey and Zecher (1985) — has focused on comparisons of price co-movements as measured by regression coefficients of one price or price level on another, or by simple correlation. This is not an appropriate method for answering the question, "how closely linked are prices?," in an environment where transaction and information costs create bandwidths of autonomous domestic price variation. To see this, suppose that most important incipient macroeconomic disturbances — say, to the domestic money multiplier — would imply (*ceteris paribus*) nominal price changes of at least, say, 5-percent. Furthermore, suppose that estimated relative price bandwidths are 1-percent. This is an environment in which autonomous domestic shocks are not important, one in which the "law of one price" is the most useful assumption for understanding price movements over the business cycle.

Will the economy — under the conditions we have assumed — necessarily show a high correlation between national commodity prices or price levels? The answer is no. If substantial shocks occur infrequently and if most of the time prices move independently within the 1-percent bandwidths, correlation between the two may be weak. This example illustrates the importance of measuring bandwidths and evaluating the economic importance of their size, rather than calculating correlations or regression coefficients to determine the validity of the assumption of close short-run international price linkages.[13]

From the outset it is important to separate two potential motivations for constructing relative price bandwidths. One is to determine whether observed deviations of relative commodity prices from unity can be explained in a manner consistent with zero economic profit; the second is to determine whether the bandwidths are narrow enough to preclude **important** potential relative price changes important for macroeconomic fluctuations.

With respect to the first motivation one can adjust price differentials for tariffs, insurance costs, the cost of transportation, and a "fair" rate of return, and then test to see if observed relative prices violate the constructed bounds. Assuming we can thus explain relative price deviations as the drift between speculative bandwidths, we must then ask whether these speculative bandwidths are "narrow" or "wide" from the standpoint of macroeconomic importance. For example, how much of the variation in the balance of trade can be attributed to domestic price disturbances within the relative price bandwidths? Section III provides the best framework for quantifying — inter alia — the importance of autonomous domestic price movements for the balance of trade.[14]

Testing the zero-economic-profits assumption is interesting in itself, because of the connection between zero economic profits and domestic price flexibility. Domestic price flexibility — i.e., the responsiveness of prices to aggregate demand shocks — is separable from the question of narrow international price bandwidths. Domestic prices may be responsive, but insulated by transaction costs from international price movements. Therefore, price flexibility is a necessary, but not a sufficient, condition for short-run international price parity. Thus evidence of responsive domestic prices for this period — as described in Calomiris and Hubbard (1986), DeLong and Summers (1986), Rush (1985), and Sachs (1980), — is encouraging but not conclusive for the proponents of price arbitrage, while the demonstration of international price linkages across many commodities provides direct support for the assumption of price flexibility, even if price bandwidths are very large. In other words, demonstrating that prices can change quickly when there exists an incentive to change them — i.e., that long-run bandwidths are the same as short-run bandwidths — provides evidence in favor of flexible prices regardless of the size of the bandwidths. Thus the important issue of domestic price flexibility is logically related to the question of whether arbitrageurs earn zero economic profits, rather than to the question of how much the terms of trade may vary with aggregate demand shocks.

Testing the Zero-Economic-Profit Hypothesis: Cotton, Wheat, and Sugar

In principle, one could construct bandwidths for all traded goods and describe the restrictions they impose on the price level in a disaggregated macroeconomic model with many individual supply and demand equations. Alternatively, one could argue for a particular weighting scheme across commodities and derive representative price bounds for traded goods as a whole. This would be different, of course, from inferring price bounds from the wholesale price index and assuming such bounds are representative.

We undertake neither of these procedures for the following reasons. First, even if one had a plausible set of weights to establish representative bandwidths, the issue of a standard against which to judge whether such bounds are wide or narrow naturally arises. As we have argued at length above, simulation models are the proper way to evaluate the economic importance of drift within speculative bandwidths. Second, in practice we have found it difficult to construct comparable price series for Britain and the United States for many commodities. Some data reported in, or summarized from, trade journals fail to quote prices at clearly specified points in time. Often the precise grade of the commodity is left vague, as well. Many times even the unit of measure is unclear. For example, there are many meanings to the word "bushel," some of which may vary in use geographically within England. Many sources fail to distinguish explicitly among "shipping," "railroad freight," "dry," "liquid," and "avoirdupois" measures, which can be very different. Often units can be inferred from long-run price ratios, but obviously such an inference precludes tests of price linkages.

For these reasons we only report results for three commodities — cotton, wheat, and raw sugar. Calculations for these commodities will serve to test the zero-profit condition and thereby establish the degree of price **flexibility** for internationally traded goods.

First, we consider cotton, defined in pounds of middling-grade raw fiber.[15] Each country's end-of-month price series, and the ratio of the two price series, are given in Figure 5. There was no tariff applied to raw cotton in either Britain or the U.S. The relative price of U.S. cotton is almost always in the neighborhood of 0.9. The lower U.S. price is explained by the fact that cotton is indigenous to the United States and not to Britain. There are virtually no persistent deviations beyond the bounds 0.88 and 0.95. Any penetration of these bounds may be viewed as unforseeable and transitory. These bounds are narrow relative to the short-run variation in prices within each country — cotton prices frequently fall or rise by 50-100 percent within a matter of months.

Is a 12-percent sustainable price differential consistent with a "fair" rate of return? It would seem so. The shipping costs for cotton quoted in Fairplay for 1880 through 1913 are in the range of 5 percent, including primage. We abstract from reductions over time in transport costs, which were gradual and small relative to total speculative costs. Table 3 shows the reduction in the nominal and real transport cost index from 1880 to 1910. If one adds to transport cost a standard insurance fee of between 1 and 2 percent and considers "shoe-leather" costs, cotton price risk, and a two-month financing cost of 1 percent (assuming a two-month response lag due to the time it takes to purchase, deliver, and receive payment for a shipment), a persistent deviation in relative price of 10 to 12 percent seems reasonable.

When performing similar calculations for wheat and sugar one must adjust for the tariffs placed on these commodities by the United States. Tariffs do not affect the incentives of speculators contemplating a shipment from the United States, but do affect the incentives to ship from Britain to the United States. To be explicit, efficient speculation implies:

(7) $P^W_{US}(1-d) - c > P^W_{GB}$, and

(8) $P^W_{US} < P^W_{GB} - c$,

where P^W_{US} and P^W_{GB} are the American and British prices of wheat, respectively, d is the ad valorem duty on wheat in the United States, and c is speculative cost — inclusive of finance, transport, insurance, and shoe-leather costs, and price risk. If (7) were violated, shipments of goods from Britain to the U.S. would imply excess profit; if (8) were violated, shipments from the U.S. to Britain would imply excess profit.

This provides two independent means of testing bounds on c. Persistent deviations below unity in the unadjusted relative price (P^W_{US}/P^W_{GB}) should be greater than (1-c); persistent deviations above unity in the tariff-adjusted relative price should be bounded by (1+c). End-of-month wheat prices and price ratios — simple and tariff-adjusted — appear in Figure 5. The unadjusted price ratio is almost always above 0.9, while the adjusted ratio almost never is above 1.1. These results thus imply similar price bounds to those derived for cotton.

The same exercise may be performed for sugar prices, plotted in Figure 7. As in the case of wheat and cotton, price variations within each country are potentially great, while price bounds imply that persistent relative-price deviations are contained by bounds on speculative profit. That is, the sugar price ratio adjusted for tariffs is generally below 1.1, while the simple ratio never falls below unity because tariffs rendered unprofitable the export of sugar from the U.S.

This last observation illustrates the difficulty in drawing inferences about domestic autonomy from tests of economic profit. No profits were possible for exporting sugar from the U.S. **because** tariffs insulated the U.S. price of sugar from the prices in other markets.

In summary, wholesale prices for traded goods appear to have been flexible. Speculators responded quickly to profit incentives and thereby preserved price parity, adjusted for cost. Given the homogeneity of most goods and the relative absence of long-term contracting during our period, we view wholesale price data as representative of prices more generally. This period contrasts with the current economic setting in which long-term contracting and product differentiation make the assumption of wholesale price representativeness dubious (see Hicks, 1974). Mills (1932, pp. 78-86) finds that the variation in manufactured goods prices on an annual basis for the pre-World War I years matches that of raw materials, but that raw materials prices are more volatile from month to month. Mills also finds that overall monthly consumer price variability matches that of producer prices, with the same distinction between the volatility of raw and processed goods prices.

Summary of Findings on International Integration in Capital Markets and Commodity Markets

We have established several propositions relevant for understanding international adjustment under the gold standard. Gold flows were elastic, in the sense that innovations in the desired distribution of gold led to rapid adjustment (i.e., full adjustment occurs in under three months). Commodity flows were similarly responsive, though the bandwidths of autonomous relative price movement are greater (10 to 12 percent as opposed to 0.5 percent). The tolerance for the gold-denominated interest differential between the U.S. and Britain is essentially constant throughout the period (if one adjusts properly for currency risk) at roughly 2 percent. Changes in interest rate seasonality are explained mainly by events which have international scope.

As we have noted frequently in our discussion, these results alone do not provide a conclusive test of short-run domestic autonomy because they cannot tell us how **important**, from a macroeconomic perspective, were autonomous domestic deviations in interest rates and prices. To this end, section III develops a simulation model of macroeconomic disturbances.

III. SIMULATION OF THE MACROECONOMIC IMPORTANCE OF DOMESTIC AND INTERNATIONAL SHOCKS

Our goal here is to measure the relative importance of domestic and international shocks in financial and commodity markets for influencing output, interest rates, prices, gold flows, and the balance of trade. For example, were domestic money supply shocks, per se, an important source of macroeconomic disturbance? How do money-supply shocks compare in importance to disturbances in money-demand, or other macroeconomic disturbances? How important are changes in the terms-of-trade for short-run movements in the balance of trade? In order to answer these questions we construct a model of the U.S. economy and its international linkages.

Data and Econometric Approach

Our results from section II imply potentially rapid adjustment of interest rates, prices, and commodity and gold flows. In order to capture important features of shocks and responses, we construct a monthly dataset which includes U.S. and British interest rates and wholesale price indices, and U.S. data on exports, imports, gold flows, and output (using pigiron production as a proxy).[16] We begin our sample in January 1897 — after the "silver crisis" years — and end it in June 1914, before the outbreak of war.

In order to analyse dynamic adjustment to disturbances we adopt an approach recently developed by Bernanke (1986) and Sims (1986) as an alternative to "reduced-form" recursive identification of disturbances. The alternative "structural VAR" approach permits one to solve a simultaneous-equations model in innovations in which orthogonalized shocks and their interrelations are associated with **functions**, not with **variables.** The first stage of a structural VAR model is identical to a standard VAR — lagged values of all variables are included to estimate reduced-form predictions, and to derive series of unpredicted innovations (which are correlated across variables). In the next stage, one posits a matrix of contemporaneous functional relationships which can be tested and which imply time series of orthogonalized shocks to the hypothesized functions.

One then calculates impulse responses of each variable in the system to shocks which originate in particular functions, and decompositions of each variable's forecast variance, which attribute one's uncertainty regarding the future of any particular variable to each of the functional shocks. Impulse responses and variance decompositions together permit one to infer the time-path of a given shock's influence on all variables, as well as its economic importance.

A Simultaneous-Equations Model for the U.S.

We posit seven functional relationships for our seven-variable model: an equilibrium-output equation for the U.S., an exogenously determined international (British) riskless interest rate, U.S. money-supply and money-demand equations, demand functions for U.S. imports and exports, and a desired short-run capital-flow equation, which we set equal to the balance of trade net of gold flows. These functions are described in equations (9) through (15) below.

(9) $i_t^L = i_t^{L^*}$, [International interest rate],

(10) $i_t^{NY} = a_1 i_t^L + a_2 G_t + i_t^{NY^*}$ [U.S. money supply],

(11) $X_t - M_t - G_t = a_3 i_t^L - a_4 i_t^{NY} + X_t^*$ [Desired net savings],

(12) $Y_t = - a_5 i_t^{NY} + a_6 P_t + Y_t^*$ [Equilibrium output],

(13) $M_t = a_7 P_t - a_8 i_t^{NY} + a_9 Y_t + M_t^*$ [Import demand],

(14) $P_t = - a_{10} X_t \pm a_{11} i_t^L + P_t^*$ [Export demand],

(15) $G_t = a_{12} Y_t + a_{13} P_t - a_{14} i_t^{NY} + G_t^*$ [U.S.money demand],

where all variables are defined as innovations, and where Y denotes the growth rate of output, i^{NY} and i^L are the New York commercial paper rate and London open-market discount rate respectively, G is U.S. net **imports** of gold, X and M are U.S. commodity exports and imports, and P is the log ratio of the U.S. to British wholesale price indices. All terms with an asterisk are mutually orthogonal. i^{L^*} is the exogenously determined innovation in the British open-market discount rate. i^{NY^*} is the orthogonal money-supply shock. X^* is the disturbance to desired net foreign savings, Y^* is the equilibrium-output disturbance (which includes IS shocks and supply-side credit shocks, as discussed in the Appendix). M^* is the shock to the demand for imports. P^* is the export-demand disturbance. G^* is the innovation in U.S. demand for money (gold).

The U.S. money-supply equation assumes that net gold imports respond positively to U.S., and negatively to British, interest-rate innovations.

Equation (11) posits that U.S. desired short-run net savings responds positively to foreign, and negatively to own, interest-rate changes.

Our specification of the equilibrium output equation (12) assumes negative interest elasticity in aggregate demand, as well as a positive relative domestic price response in aggregate supply. In addition, we posit a negative interest elasticity in aggregate supply and a positive price-response in aggregate demand and supply which arise in the presence of imperfect capital markets and nominal contracting (see the Appendix and Calomiris and Hubbard, 1986, and 1987).

The U.S. demand for imports is assumed to depend positively on P and Y, and negatively on i^{NY}. We write export demand as a negative function of P, and an indeterminate function of i^L. The sign of i^L in equation (14) depends on whether foreign interest-rate innovations are associated mainly with expansion or contraction abroad.

The money demand equation assumes a standard formulation in which shocks to desired money balances, and hence net gold inflows, are related to disturbances in price, income, and the interest rate.

There are two criteria against which to measure the reasonableness of this identification of functional disturbances. One is the estimated coefficients (and standard errors) of the matrix of contemporaneous disturbances — i.e., how many coefficients are of the right sign? The other involves the time paths of the impulse response functions to each functional disturbance. If, for example, negative shocks to the supposed money-supply innovation equation (positive i^{NY^*} shocks) imply positive output and negative interest rate responses, it would be difficult to believe that one properly had identified a money-supply disturbance.

Estimation Results

We regress each of the original seven variables in our model on six lagged values of all variables, monthly dummies, a time trend, and the tariff on pigiron. We include the tariff in order to abstract from relative supply shifts, given our use of pigiron as the output proxy. We save these reduced form equations for use in simulation and define their residuals as the innovations Y, i^{NY}, i^{L}, X, M, P, and G, modeled in system (9) through (15).

The results for the simultaneous-equations model in innovations are given below (standard errors appear in parentheses):

$$(\hat{10})\quad i_t^{NY} = \underset{(0.050)}{0.252}\ i_t^L + \underset{(0.070)}{0.110}\ G + i^{NY^*},$$

$$(\hat{11})\quad X_t - M_t - G_t = \underset{(0.269)}{0.112}\ i_t^L - \underset{(0.462)}{0.048}\ i_t^{NY} + X_t^*,$$

$$(\hat{12})\quad Y_t = -\underset{(0.120)}{0.136}\; i_t^{NY} + \underset{(0.335)}{0.700}\; P_t + Y_t^{*},$$

$$(\hat{13})\quad M_t = -\underset{(0.205)}{0.019}\; i_t^{NY} + \underset{(0.112)}{0.321}\; Y_t + \underset{(0.580)}{3.190}\; P_t + M_t^{*},$$

$$(\hat{14})\quad P_t = -\underset{(0.022)}{0.021}\; i_t^{L} - \underset{(0.019)}{0.099}\; X_t + P_t^{*},$$

$$(\hat{15})\quad G_t = -\underset{(0.614)}{0.344}\; i_t^{NY} - \underset{(0.140)}{0.117}\; Y_t + \underset{(0.93)}{2.66}\; P_t + G_t^{*}.$$

Only one of the coefficients in this system of equations contradicts our model — the sign on Y in the money-demand equation is negative. All thirteen other estimated coefficients are of the right sign and some are measured precisely. As Sims (1986, p. 12) notes, however, the method we use for constructing standard errors need not be very accurate since it is based on an approximate second-derivative matrix.

As we noted before, the coefficients in the contemporaneous-association matrix are not conclusive by themselves. The best way to verify our functional identification of disturbances is to determine the "reasonableness" of the simulated responses to the hypothesized shocks.

At the same time, not all impulse responses merit equal weight in determining the reasonableness of our identification. Rather, one wishes to ascertain whether the **important** sources of disturbances in the model are consistent with our identification matrix. The importance of disturbances for influencing any variable's future may be measured by the forecast variance decomposition of that variable. For example, functional disturbances in export demand are important for gold inflows if they play a large role in explaining future uncertainty about gold inflows.

Simulation Results

Forecast-variance decompositions which describe the percent contribution from each functional disturbance to each variable in the system at time horizons of 3, 12, and 20 months are given in Table 4. Beside these figures, we indicate whether the sign of the impulse response at that time horizon is positive (+), negative (-), or essentially zero (N). Table 4 allows us to test our identifying assumptions by making sure that important sources of disturbances have effects consistent with our model.

At the same time, Table 4 allows us to assign relative importance to domestic and international factors in the determination of output, prices, interest rates, gold flows, and foreign trade. In particular, one can ascertain: whether — as the modern approach predicts — exports and imports are responsive in the short run to relative price changes; whether prices or income respond importantly to money-supply shocks; and whether shocks to net savings, and export and import demand, contribute greatly to price and interest-rate variation (as the modern approach predicts), relative to domestic shocks which are independent of international developments (i^{NY^*}, Y^*, and G^*).

The signs of impulse responses are quite supportive of the model's identifying assumptions. U.S. money-supply contractions not explained by gold flows — i.e., money-multiplier shocks — are captured in i^{NY^*}. Such shocks produce unimportant contractions in output and have a less persistent effect on i^{NY} than do changes in international interest rates (i^{L^*}). Money supply shocks have a persistent, positive effect on gold flows, though this accounts only for roughly 4 percent of gold-flow forecast variance. U.S. money-supply shocks have virtually no effect on relative international prices in the short, or long, run. This provides strong evidence against the causal role of autonomous money supply shocks for U.S. business cycles.

British interest rate innovations seem to be associated with international expansion, reflected in lagging, but important, positive effects on U.S. exports. A direct link to the U.S. economy comes from the negative impact of higher foreign interest rates on output through interest-rate parity.

Innovations in desired net savings (X^*) play an important role in the determination of the U.S. interest rate, short-run commodity price movements (which dampen quickly), imports, and exports. All of these effects are of the predicted signs — a desire to save more leads to a period of high exports, low commodity and gold imports, low relative domestic prices, and a lower U.S. interest rate. The response of output to the savings shock is harder to explain. The initial positive, and subsequent negative, response of output may reflect a very short-run "Keynesian" contraction followed by a longer-run "equilibrium" expansion in response to a reduction in the propensity to consume.

Shocks coming from domestic aggregate supply and demand (Y^*) which are unrelated to monetary disturbances, saving preferences, international interest-rate disturbances and the demands for imports and exports play an important role in short-run domestic interest rate determination. Imports respond positively to income innovations, as do interest rates. The positive response of both interest rates and income to equilibrium output shocks reflects — in the context of the model described in the Appendix — a positive correlation between aggregate supply and demand disturbances. In Calomiris and Hubbard (1986) we argue that disturbances to credit markets will be a source of positive correlation between aggregate supply and demand shocks (see also Blinder, 1985, and Bernanke, 1981, and 1983).

The negative response of gold flows to output innovations — which mirrors the negative estimataed coefficient on $\hat{Y}$ in equation (15) appears puzzling and is a relatively important contributor to future gold flows.

One way to explain this finding is to appeal to the relationship between **current** output innovations and predictable **future** changes in the money multiplier. If current positive innovations in output lead to increased overall money demand **and** predict an increase in the money multiplier, then output innovations may be negatively associated with current gold flows through anticipatory gold demand. Evidence for co-movements between output growth and the money-multiplier appears in Cagan (1965, p. 25). Cagan finds that at peaks and troughs money-multiplier changes are more closely associated with income than variations in high-powered money, and that the money-multiplier is pro-cyclical. Our use of monthly data precludes a direct test of this hypothesis since we lack data on the currency-to-deposit and reserve-to-deposit ratios at that frequency.

Another explanation — which also relies on a supposed negative correlation between output shocks and the money multiplier — emphasizes the role of credit, as opposed to money shocks. In an environment of imperfect capital markets, the effects of money-multiplier shocks may not be fully captured by money-supply shocks $\left(i^{NY^*}\right)$. In this case, output movements (Y^*) will contain marginal information regarding current money-multiplier shocks, over and above i^{NY^*}. In this case gold flows are not **anticipatory**; rather it is **current** money-multiplier shocks which account for the correlation between

Y^* and G. It is important to note that this does **not** imply that Y^* should be interpreted as a money-supply disturbance in disguise. Money-supply shocks, per se, will be fully reflected in the shadow price of liquidity $\left(i^{NY}\right)$. Y^* may contain additional information, however, related to **credit** shocks which follow from reductions in the money multiplier. For an extended discussion of this point, see Bernanke (1983) and Calomiris and Hubbard (1986).

These potential connections between output movements and money-multiplier shocks raises the possibility that — contrary to our model's restriction — G^* and Y^* should be correlated, because of the omission of the money-multiplier from the model. In this case, equation (15) will properly measure **gold** demand, but not money demand defined more broadly. G^* shocks have effects on U.S. prices and interest rates consistent with viewing equation (15) as a gold-demand function.

Innovations in export and import demands — which may reflect, inter alia, changes in preferences, tariff changes not captured by price indices, or measurement errors due to price aggregation — provide strong support for our model. Impulse responses to a positive shift in import demand imply the predicted negative U.S. relative-price response, a lesser response in exports and a rise in the interest differential between U.S. and British securities, which implies a consistent movement along the net foreign savings function.

Response patterns to shocks from export demand provide further support for the model. Export demand shocks raise relative U.S. prices, and produce a positive repsonse in commodity imports and gold inflows.

On the whole, our results provide evidence in favor of elastic responses to relative commodity prices. Moreover, shocks to desired savings and export and import demands, explain between 70 and 75 percent of the forecast variance of relative price at all time horizons. Export and import demands by themselves account for roughly 50 percent. This contrasts sharply with the relatively small contributions to relative prices from Y^* or money-supply shocks.

IV. CONCLUSION

To summarize, in section II we find evidence which supports close direct asset and commodity price linkages across countries in the short run. Gold flows respond rapidly to the demand for gold. Interest rate parity, adjusted for "silver risk" and transaction costs, held with the same force throughout our sample. Commodity prices were flexible in the sense that short-run wholesale price adjustment across countries was not sluggish relative to long-run movements.

Our results from section III indicate that the bandwidths of transaction costs in markets for internationally traded securities were narrow in the sense that domestic money-supply shocks, per se, were not an important source of output variation. Domestic money-supply shocks did influence exports and gold flows by affecting incentives for capital and money accumulation. The short-run price elasticities of import and export demand functions are a significant and important channel of influence from international disturbances to relative international prices, while autonomous domestic disturbances are unimportant for the ratio of international price indices.

Though a more thorough treatment of the sources of unexplained disturbances in output is beyond the scope of this paper, we argue elsewhere (Calomiris and Hubbard, 1986) that capital market disturbances — which affect both aggregate supply and demand in an environment of imperfect information — account for the (equilibrium) fluctuations in output which characterize pre-World War I business cycles. This approach proves fruitful for explaining the priority of price to output shocks noted by DeLong and Summers (1986), and their long-run co-movements (i.e., the Phillips curve). It also provides a rationale for the predictive role of money for nominal income — i.e., the money stock is linked to **real** changes in bank loan supply which respond, *inter alia*, to deflationary shocks.

Notes

[1] Specifically, we show that price flexibility can have adverse effects on macroeconomic performance through constraints on the availability of credit in the presence of nominal contracting in financial markets. We examine links between price flexibility and credit rationing within the framework of models of imperfect information in loan markets.

[2] We discuss below the difficulty of defining "narrow" in a way which permits a useful test of domestic price autonomy.

[3] It is important to note that these assumptions do not imply the irrelevance of central bank lending to domestic banks; merely that the influence such loans may have does not come from an effect on the money supply per se. In Calomiris and Hubbard (1986) we argue that capital-market imperfections, and hence the well-being of banks and borrowers, played an important role in propagating pre-World War I business cycles. In this context, government assistance to beleaguered banks could have had important macroeconomic consequences. In that paper, we show that the observed correspondences between money and nominal income growth, and between inflation and real income growth (the Phillips Curve), are consistent with a regime of elastic gold supply, flexible prices, and capital market imperfections. This contrasts with the standard approach to explaining these correspondences which abstracts from capital market imperfections, and assumes an inelastic money supply and rigid prices.

[4] Gold flows are defined as the difference between gold imports and exports (See Data Appendix). Currency holdings of banks and individuals, and total money supply, are taken from Friedman and Schwartz, Monetary Statistics of the United States, p. 402 and p. 65, respectively.

[5] Officer reports costs which vary over time and depending on country of origin. Because the British had lower interest rates, which enter into the cost of shipping, gold export costs are typically higher than half a percent with an average of 0.65 percent over the period 1890 to 1904. Officer's calculations overstate the gold cost of U.S. exports, however, because he interprets U.S. interest rates to be gold interest rates. As we show below, U.S. interest rates in gold terms were much closer to British levels than previously recognized, once one adjusts for silver devaluation risk.

[6] Figure 2 is inspired by Deardorff (1979).

[7] That currency risk was a significant potential problem was certainly on the minds of contemporary chroniclers of international business conditions. The large outflows of gold associated with the fulfillment of the Sherman Act precipitated a lack of confidence in the ability of the U.S. Treasury to maintain its commitment to the gold standard. Consider for example these representative accounts from foreign correspondents of the Economist magazine.

"The first bomb which was dropped this week was that by the President in his decision not to issue or sell bonds, in order to maintain the $100,000,000 of gold reserve in the Treasury ... The first effect of this unexpected news was to intensify the feeling of depression which had gone before, and prices of the more active securities promptly declined. Europe was not slow to observe the drift here and joined the ranks of sellers." (March 4, 1893, p. 265).

"While President Cleveland's inaugural address shows that he holds sound views on the currency question, it remains to be seen to what extent he will be able to make those views prevail." (March 11, 1893, p. 289).

"...it would appear, therefore, that for some time longer doubts as to the ability of the Treasury to maintain the parity of silver and gold will continue to act as a drag upon business in the States, to depreciate the value of American securities, and to cause a certain uneasiness and want of stability in the European money markets." (March 11. 1893, p. 290).

"With the renewal of gold exports from the United States, the fear that the Treasury will not be able to maintain gold payments, and that the country will, by force of circumstance, be compelled to content itself with the single silver standard, has revived ... Now it is quite evident that the Treasury cannot go on losing gold, and at the same time piling up liabilities payable in gold on demand in the way it has been doing, without imperilling the convertibility of its notes." (April 15, 1893, p. 442).

"In 1890, prior to the passing of the Sherman Act, the reserve exceeded £38,000,000 while the outstanding government notes redeemable in gold amounted to a little under £67,000,000. Since then, however a two-fold process has been in operation. The Treasury has been steadily losing gold, while it has been continuously issuing notes to the amount of £11,000,000 a year in payment of its compulsory purchases of silver. ... the reserve continues to dwindle, and the volume of paper money to increase, with the result that the apprehensions that have long been felt lest the Treasury should be unable to maintain gold payments have at least reached the acute stage. ... it is this that is at the bottom of all the trade and financial disturbance to which our New York correspondent today calls attention. ...the ability of the Treasury to maintain the gold value of all this money has come to be seriously questioned; there is a sharp contraction of credit, and a consequent collapse of many over-inflated concerns." (June 3, 1893, p. 656).

[8] New York prices for sixty-day and sight bills are from Statistics for the United States, 1867-1909, published by the National Monetary Commission in 1910. The monthly average of the London open-market rate is NBER series 13016, based on weekly data from The Economist.

[9] Another approach to establishing this three-way parity relationship, which abstracts from the existence of transaction costs, is to compare the results of the following two regressions:

(a) $i_t^{NY} = \alpha_0 + \alpha_1 i_t^L + \varepsilon_t$, and

(b) $i_t^{NY} = \beta_0 + \beta_1 (FSR)_t^{-1} + \eta_t$.

If the New York commerical paper rate is equal to the London rate plus a time-varying error term which captures silver risk, α_1 and β_1 should be unity; α_0 should be zero and β_0 negative one; the R-squared for the two regressions should be the same; and the correlation between ε_t and η_t should be perfect. Our results are as follows (standard errors are in parentheses):

$$(\hat{a})\ i_t^{NY} = \underset{(0.0003)}{0.0056} + \underset{(0.056)}{0.486}\ i_t^L + \hat{\varepsilon}_t,$$

R-squared = 0.23;

$$(\hat{b})\ i_t^{NY} = \underset{(0.0508)}{-\ 0.4925} + \underset{(0.051)}{0.497}\ (FSR)^{-1} + \hat{\eta}_t,$$

R-squared = 0.28;

$$(\hat{c})\ \hat{\eta}_t = \underset{(0.009)}{0.956}\ \hat{\varepsilon}_t + \hat{\omega}_t\ ,$$

R-squared = 0.98.

In the presence of transaction costs, these estimated coefficients will be biased, since cost bandwidths imply a tolerance for the independent movement of asset prices. The regression coefficients will represent an averaging of episodes when interest rates move large distances together and small distances independently. This explains why -- even though interest rates are closely linked -- the exact predictions of the model which abstracts from transaction costs do not hold in regressions $(\hat{7})$ through $(\hat{9})$. This also explains why the $\hat{\beta}_1$ coefficient is slightly larger than $\hat{\alpha}_1$, and why the R-squared for $(\hat{8})$ is larger than that for $(\hat{7})$: the nominal U.S. rate is more closely linked to the U.S. gold rate (FSR^{-1}) than to the London gold rate (i^L). As we will point out again in our discussion of commodity bandwidths, this is an argument against using regression coefficients, and in favor of calculating bandwidths, if one is interested in evaluating the economic importance of autonomous domestic price movements.

[10]We discuss the McCloskey and Zecher approach to measuring price co-movements in more detail below. We argue that the price bandwidths we report provide a better measure of market integration than correlation or regression statistics like those reported in McCloskey and Zecher (1976, 1985).

[11]Data are from Statistics for the United States, 1867-1909, pp. 209-229.

[12]Data are from Statistics for the United States, 1867-1909, p. 231.

[13]We discuss a similar point in the context of interest rate parity in footnote 9.

[14]McCloskey and Zecher (1985) regress the balance of trade on ratios or relative price indices and find insignificant and unimportant coefficients on the relative price terms in their regressions. Evidence we report below indicates that these results may be a misleading indicator of the effect of relative price differences on the balance of trade.

[15]For sources of commodity price data see the Data Appendix.

[16]The well-known Persons (1931) index of industrial production relies mainly on bank clearings and other variables of questionable relevance for output. Another alternative, the level of imports, is unattractive for our purposes because price effects on imports are contaminated by the terms-of-trade effect. Pig iron is highly correlated (with a correlation coefficient of 0.84 in **growth rates**) with total non-agricultural commodity output, on an annual basis. Hull (1911) argues that iron is the "barometer of trade" because of its ubiquitous presence as an output.

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APPENDIX

DERIVING THE EQUILIBRIUM OUTPUT EQUATION

We begin by considering the aggregate supply function:

$$Y = s_1 P + s_2 L(i) + \sigma \ ,$$

where s_1 and s_2 are positive coefficients, L is the supply-determined level of bank loans; Y, i, and P are innovations in output, the interest rate, and the price level; and σ is a positive unexplained aggregate-supply shock. We let

$$L(i) = - ai + L^*, \ a > 0.$$

Loan supply enters the aggregate supply equation as a proxy for the availability of "information capital" in the economy (Blinder, 1985; Calomiris and Hubbard, 1987) and as a measure of the "cost of credit intermediation" (Bernanke, 1981, 1983). In Calomiris and Hubbard (1986), we find evidence for the importance of bank loan supply in generating business cycles during the period considered here. We also find that loan supply is a **negative** function of the low-risk commercial paper rate, which is consistent with the multiple-markets approach to credit allocation described in Calomiris and Hubbard (1987).

Suppose that aggregate demand can be written as

$$Y = - d_1 i + d_2 Y + d_3 P + \eta; \ d_1, d_2, d_3 > 0.$$

Equilibrium in the goods market requires that

$$- d_1 i + d_2 Y + d_3 P + \eta = - s_1 a \ i + s \ L^* + s_2 P + \sigma \ .$$

so that

$$Y = d_2^{-1} [(d_1 - s_1 a) \ i + s_1 L^* + (s_2 - d_3) \ P + (\sigma - \eta)].$$

If $s_2 > d_3$, price shocks will be expansionary. As long as $d_1 > s_1 a$, then shocks to η, σ, and L^* will be reflected in negative co-movements between output and the interest rate.

The approach outlined above suggests that, even in an environment of flexible prices, shocks to aggregate supply and demand — which during this period certainly include deflationary shocks and other shocks to "information capital" — will lead to co-movements in the interest rate and income. This provides an alternative to the sticky-price, IS-shock interpretation of negative co-movements between the interest rate and income posited in equation (12) in the text.

Figure 1
U.S. Net Gold Imports

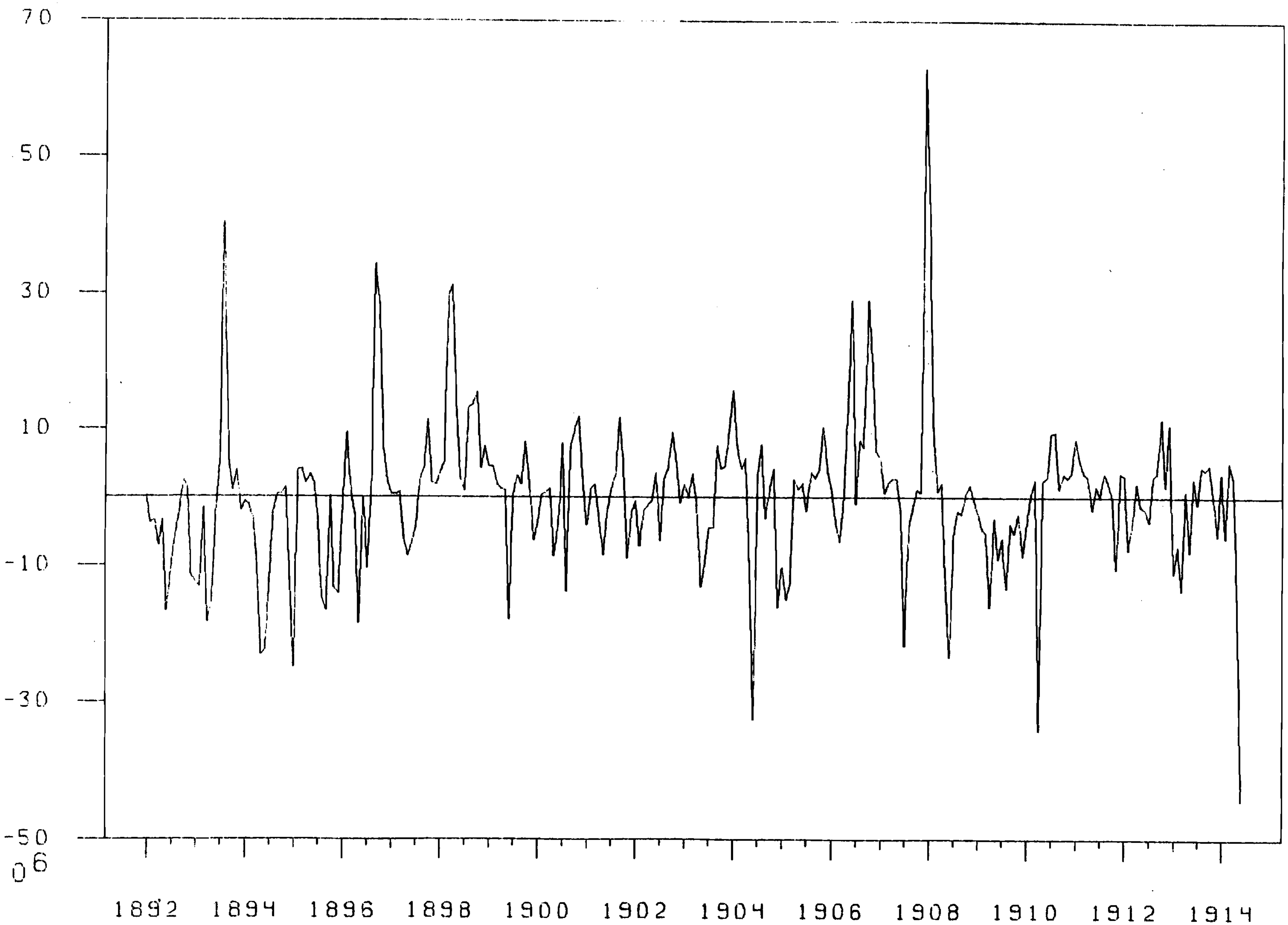


Figure 2

Arbitrage Across Three Financial Markets

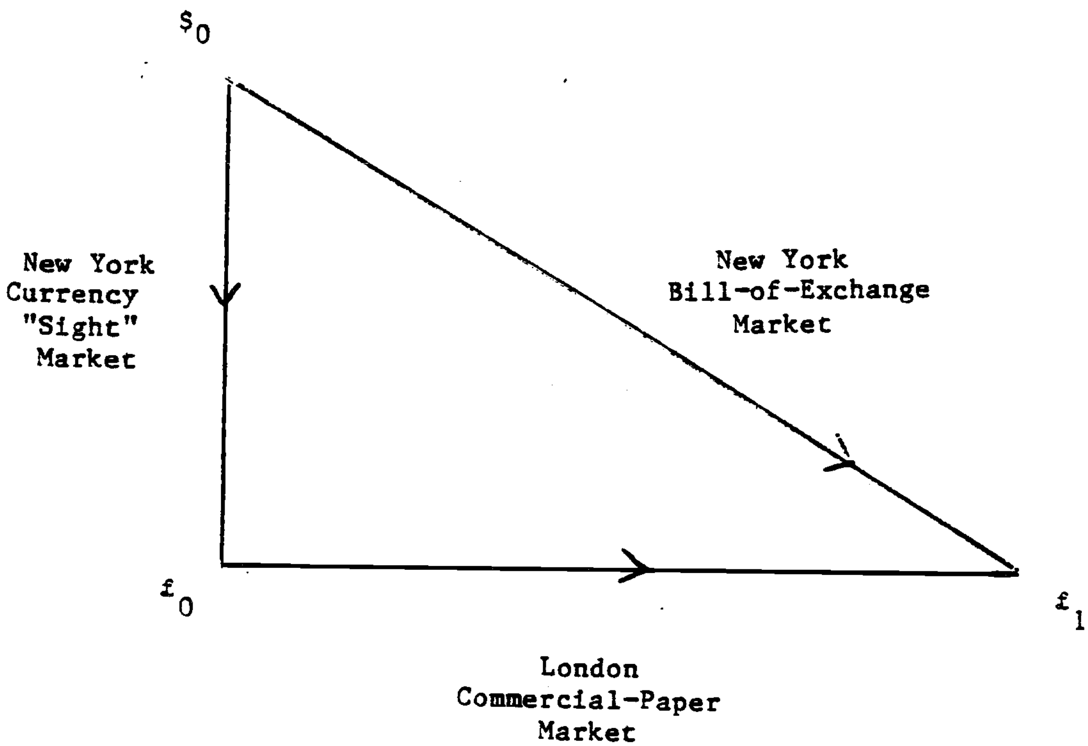


Figure 3
Difference between London Open-Market
Rate and New York Commercial Paper Rate

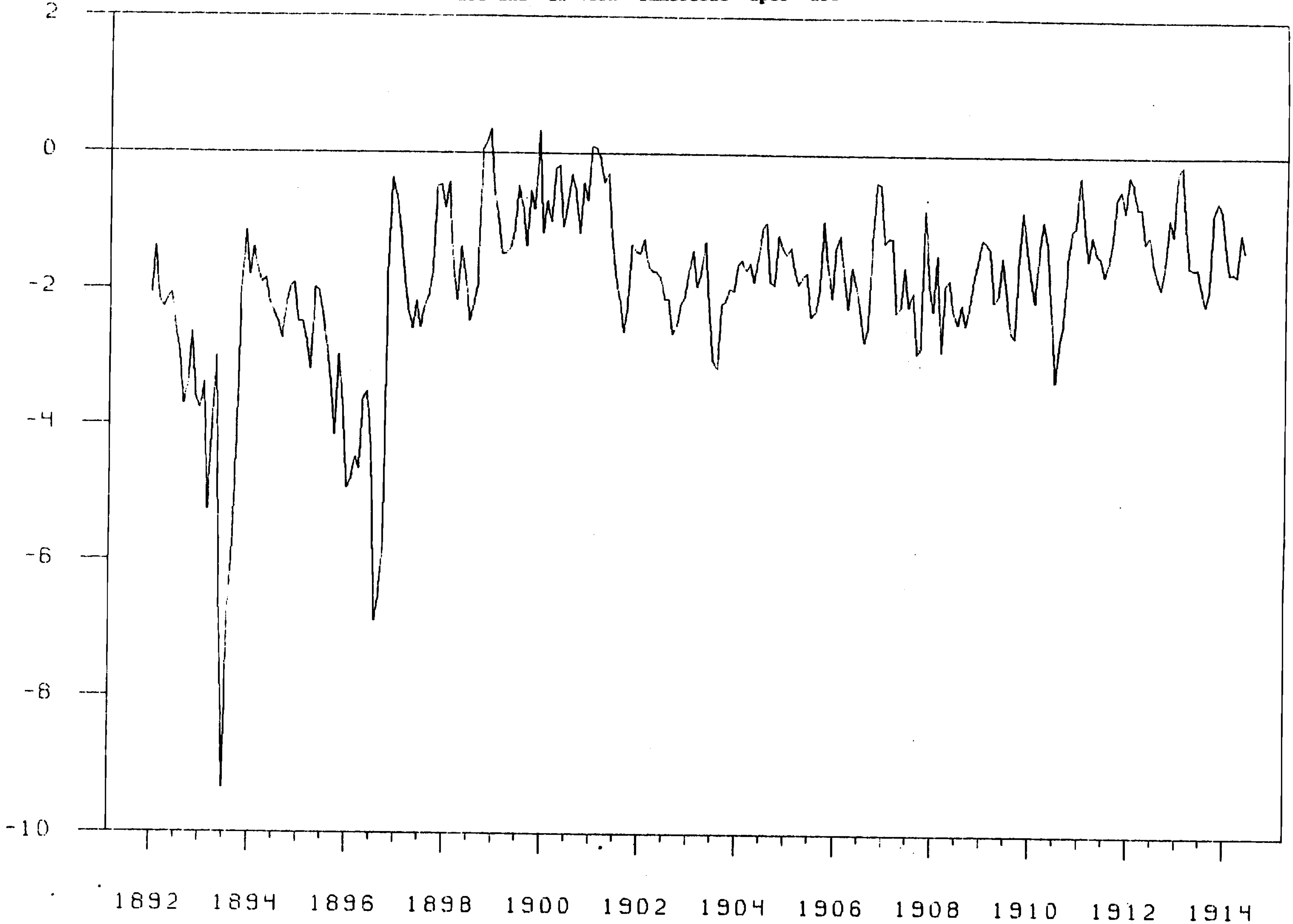


Figure 4

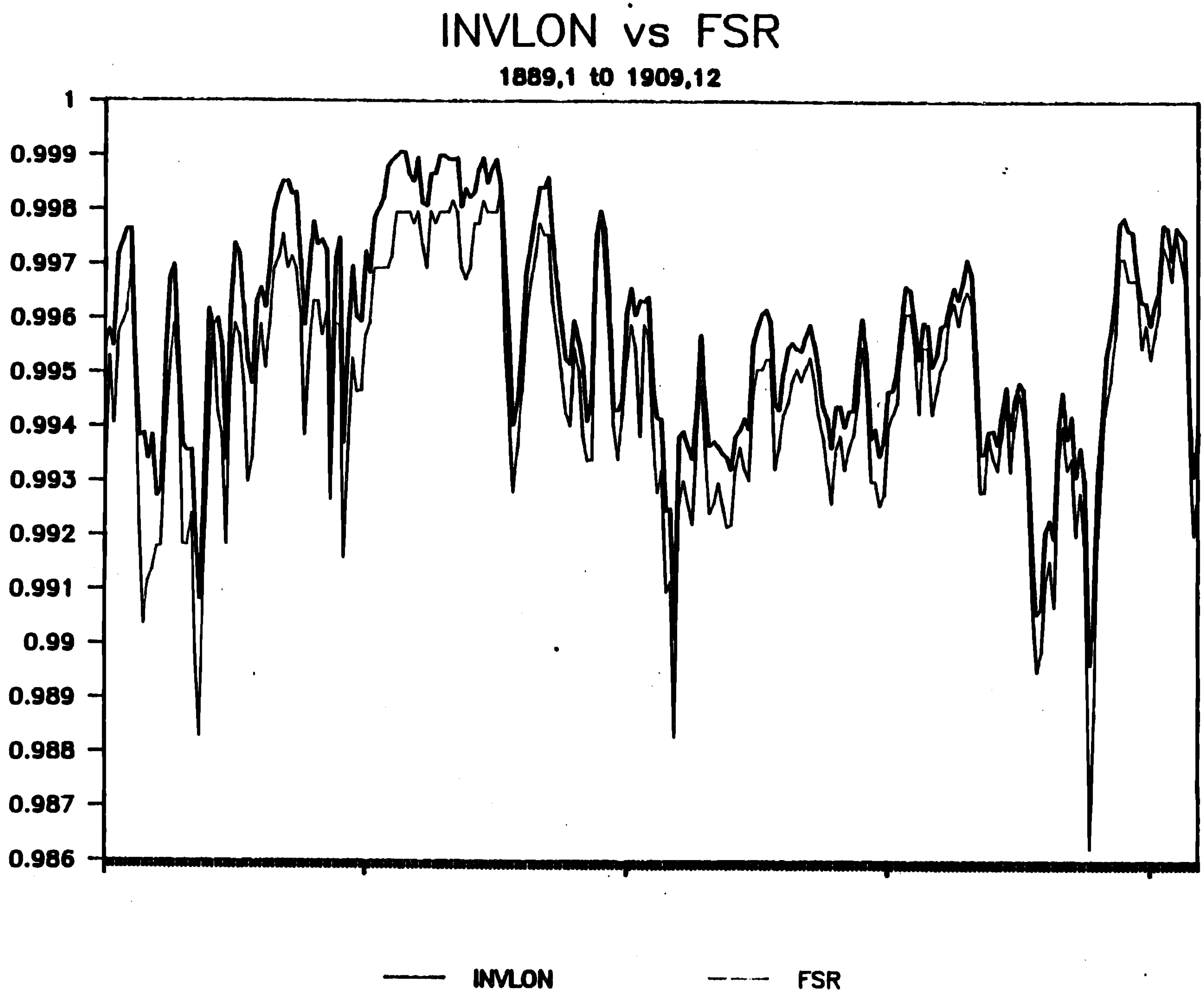
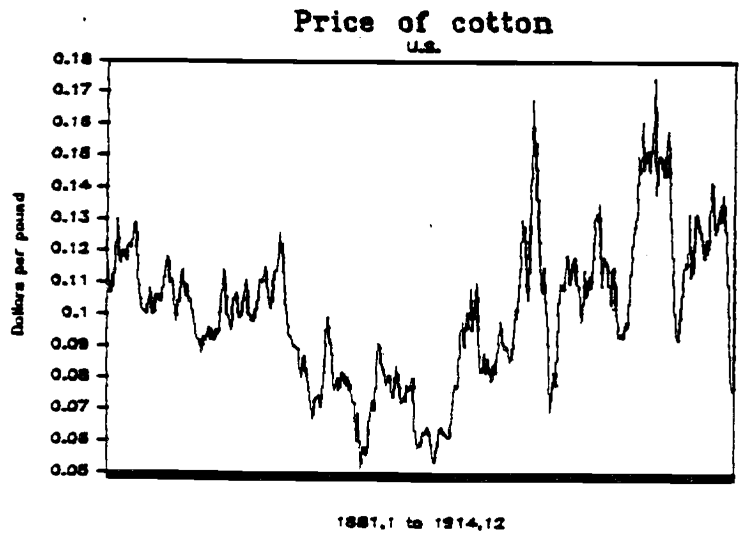
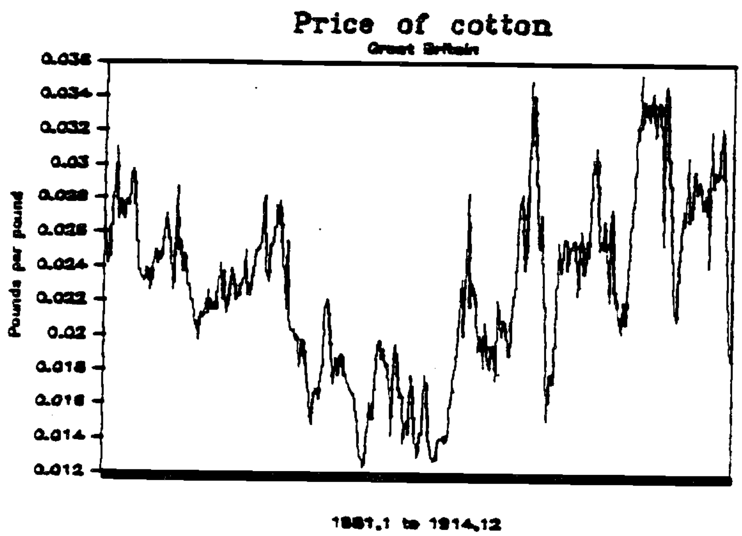

INVLON vs FSR
1889,1 to 1909,12
1
0.999
0.998
0.997
0.996
0.995
0.994
0.993
0.992
0.991
0.99
0.989
0.988
0.987
0.986
INVLON
FSR

Figure 5


Price of cotton
U.S.
Dollars per pound
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
1881,1 to 1914,12


Price of cotton
Great Britain
Pounds per pound
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
1881,1 to 1914,12

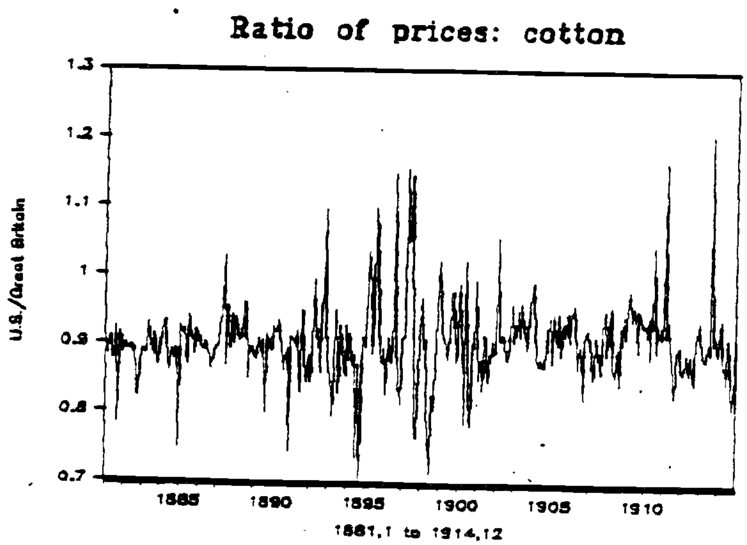
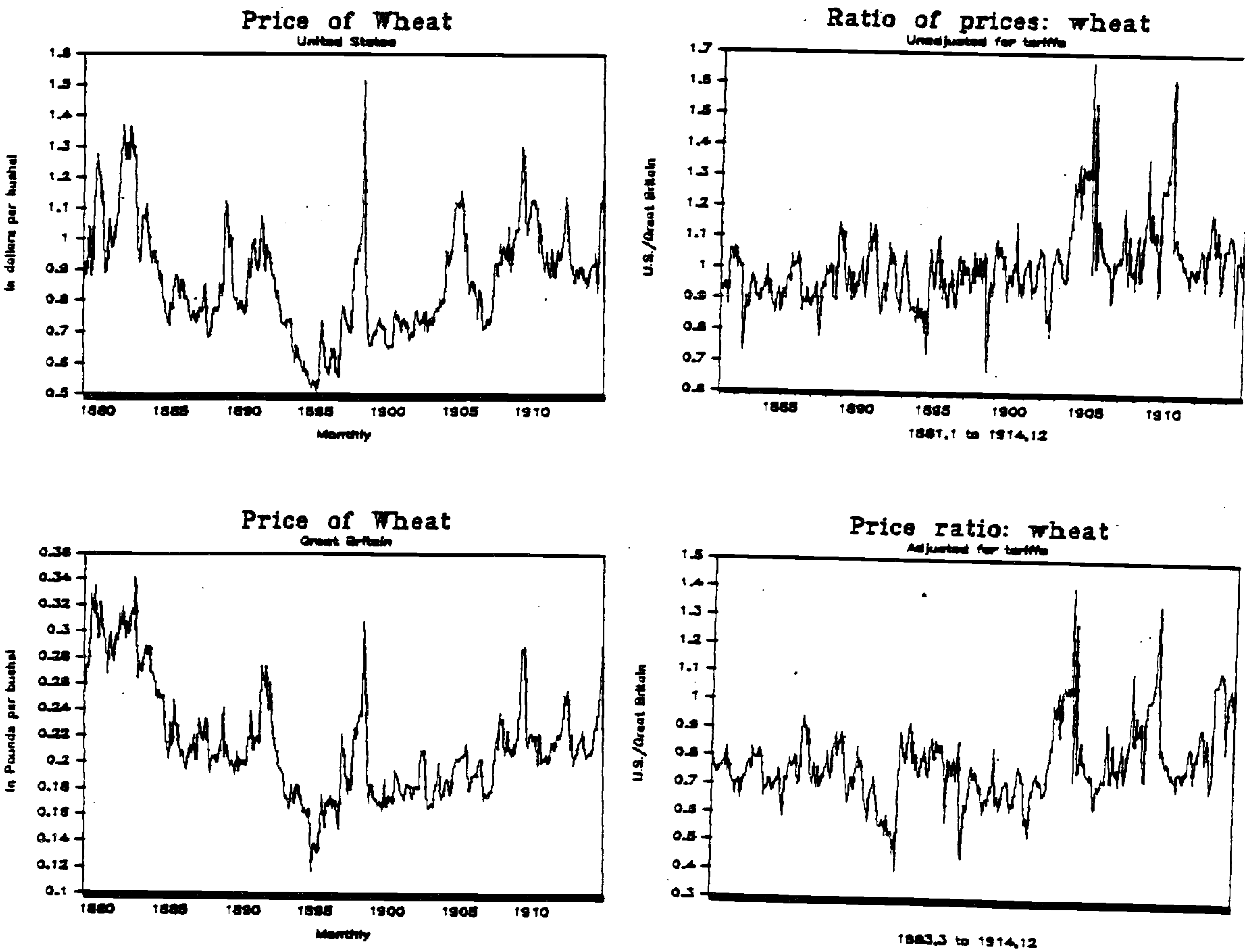

Ratio of prices: cotton
U.S./Great Britain
1.3
1.2
1.1
1
0.9
0.8
0.7
1885
1890
1895
1900
1905
1910
1881,1 to 1914,12

Figure 6



Price of Wheat
United States
In dollars per bushel
Monthly
Ratio of prices: wheat
Unadjusted for tariffs
U.S./Great Britain
1881.1 to 1914.12
Price of Wheat
Great Britain
In Pounds per bushel
Monthly
Price ratio: wheat
Adjusted for tariffs
U.S./Great Britain
1883.3 to 1914.12

Figure 7

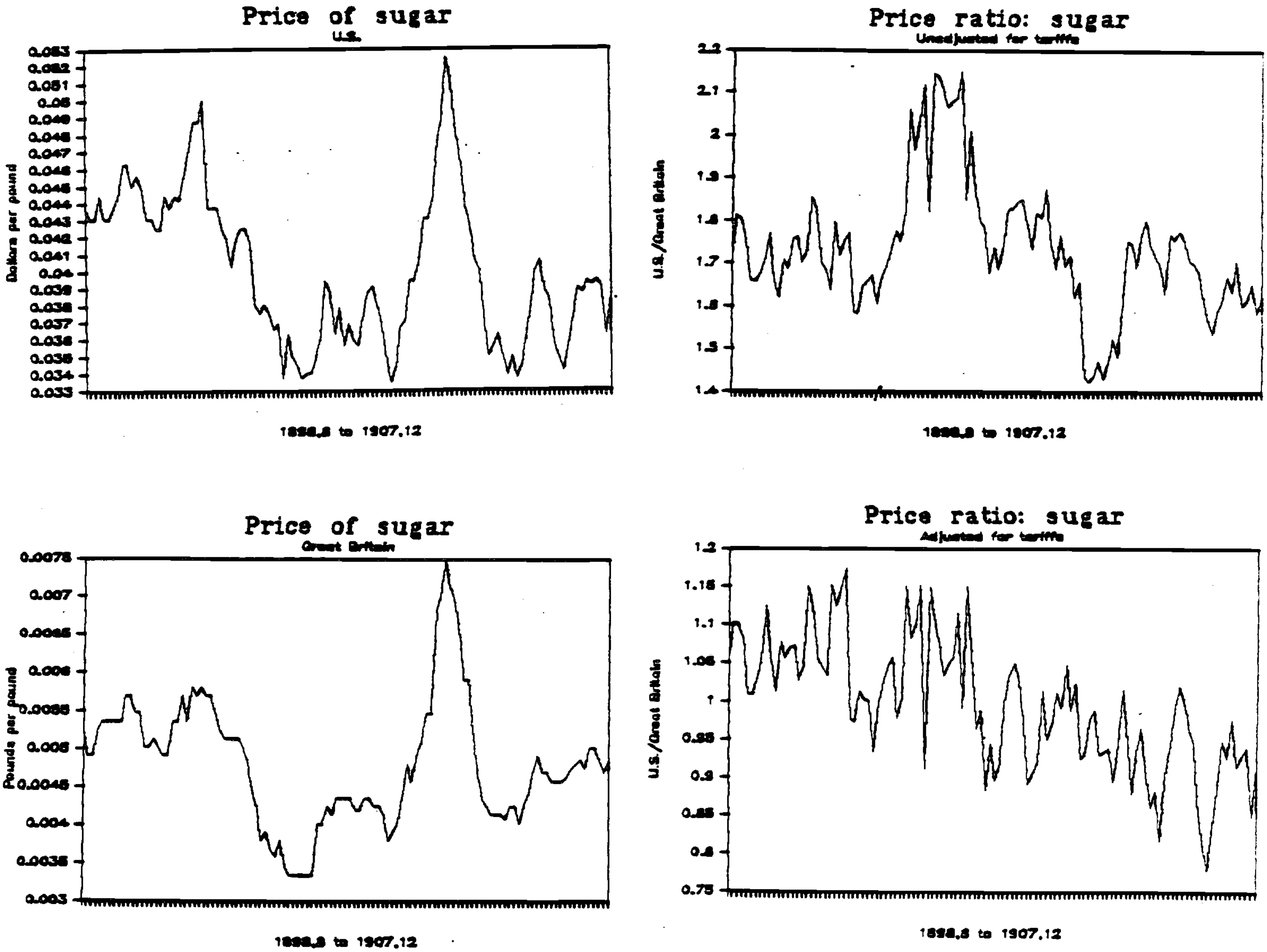

Price of sugar
U.S.
Dollars per pound
1898.8 to 1907.12
Price ratio: sugar
Unadjusted for tariffs
U.S./Great Britain
1898.8 to 1907.12
Price of sugar
Great Britain
Pounds per pound
1898.8 to 1907.12
Price ratio: sugar
Adjusted for tariffs
U.S./Great Britain
1898.8 to 1907.12

Table 1
ARMA Identification of Monthly
U.S. Net Gold Outflows (GLDFUS)
1885-1914

Lag	Gold-Flow Autocorrelations	Partial Autocorrelations
1	0.48	0.48
2	0.18	-0.07
3	0.04	-0.02
4	-0.02	-0.03
5	-0.11	-0.10
6	-0.06	0.05
7	-0.01	0.02
8	-0.01	-0.03
9	-0.04	-0.04
10	0.02	0.07
11	0.09	0.07
12	0.11	0.05

AR(1) and MA(2) Specifications (Standard Errors in Parentheses)

AR(1):

$$GLDFUS = -\underset{(466224)}{87855} + \underset{(0.048)}{0.509}\ GLDFUS_{-1} + \hat{\varepsilon},$$

D. - W. = 1.87,

$\bar{R}$ - Squared = 0.24.

MA(2):

$$GLDFUS = -\underset{(805923)}{125324} + \underset{(0.053)}{0.545}\ \hat{\varepsilon}_{-1} + \underset{(0.054)}{0.195}\ \hat{\varepsilon}_{-2} + \hat{\varepsilon},$$

D. - W. = 1.94,

$\bar{R}$ - Squared = 0.24.

Table 2
U.S. Gold-Flow Residuals for
(AR(1) and MA(2) Models

Lags	Autocorrelations MA(2)	Partial Autocorrelations MA(2)	Autocorrelations AR(1)	Partial Autocorrelations AR(1)
1	0.00	0.00	0.04	0.04
2	0.02	0.02	-0.04	-0.05
3	0.04	0.04	-0.04	-0.03
4	0.00	0.00	0.00	0.00
5	-0.10	-0.10	-0.11	-0.12
6	-0.03	-0.03	-0.03	-0.02
7	0.03	0.03	0.04	0.03
8	0.02	0.03	0.02	0.01
9	-0.07	-0.07	-0.08	-0.08
10	0.02	0.00	0.00	0.00
11	0.05	0.04	0.05	0.04
12	0.07	0.08	0.08	0.08

Table 3
Trends in Transport Cost

Year	Fairplay Transport Cost Index	Wholesale Price Index	Deflated Transport Cost
1880	6.25	1.00	6.25
85	5.00	0.85	5.88
90	5.35	0.81	6.60
95	3.50	0.72	4.86
1900	4.63	0.85	5.45
05	3.00	0.89	3.37
10	2.44	1.02	2.39

Sources: See Data Appendix.

Table 4

Simulation Results for the Simultaneous-Equations Model

Responses of:

Shocks Originating in:	Time Horizon (months)	i^L (a)*	i^L (b)**	i^{NY} (a)*	i^{NY} (b)**	X (a)*	X (b)**	Y (a)*	Y (b)**	M (a)*	M (b)**	P (a)*	P (b)**	G^{***} (a)*	G^{***} (b)**
World Interest Rate (i^L)	3	90.0	+	19.0	+	1.5	+	2.2	-	0.4	+	0.6	-	1.9	+
"	12	62.1	+	19.7	+	7.3	+	4.1	-	3.2	N	7.5	-	4.3	+
"	20	53.0	N	17.9	N	7.4	N	4.2	N	3.7	N	8.8	-	4.4	+
U.S. Money Supply	3	2.6	+	68.0	+	0.4	N	1.9	-	0.6	N	3.0	+	4.9	+
"	12	2.7	N	34.6	N	4.0	N	4.5	N	4.5	-	1.2	N	6.2	+
"	20	3.1	N	31.7	N	3.9	N	4.5	N	4.7	N	1.1	N	6.2	+
U.S. Desired Savings	3	1.4	N	2.6	-	47.9	+	6.1	-	16.9	-	32.4	-	7.8	N
"	12	3.9	N	10.7	-	37.7	N	8.0	+	15.6	N	26.1	N	7.7	-
"	20	4.1	N	10.1	N	35.6	N	8.1	+	16.2	N	23.2	N	7.8	-
Equilibrium-Output Eq.	3	3.0	+	0.3	+	0.3	+	81.5	+	8.6	+	0.7	+	5.7	-
"	12	15.8	+	13.0	+	3.8	+	65.1	+	13.4	N	2.9	-	9.6	-
"	20	15.5	N	13.4	N	4.2	N	64.3	N	12.5	N	4.0	-	9.9	N
U.S. Import Demand	3	2.1	+	0.3	+	16.6	+	2.5	N	52.4	+	9.4	-	2.0	-
"	12	12.3	+	8.9	+	16.8	+	10.2	N	41.9	N	10.2	-	4.3	N
"	20	14.4	N	11.4	N	16.8	N	10.6	-	37.7	N	11.4	-	4.5	+
Demand for U.S. Exports	3	0.4	N	4.6	+	12.8	+	4.2	+	16.2	+	39.9	+	5.4	+
"	12	1.4	N	9.3	N	14.5	N	5.6	N	15.8	N	40.3	+	9.9	N
"	20	4.9	N	9.9	N	15.7	N	5.7	N	18.3	N	39.2	+	9.8	N
U.S. Money Demand	3	0.5	N	5.3	N	20.5	+	1.6	-	5.0	-	14.0	-	72.3	+
"	12	1.9	+	3.8	N	16.0	+	2.5	+	5.6	+	11.9	-	58.0	+
"	20	4.9	+	5.5	+	16.4	N	2.6	-	6.9	N	12.3	-	57.4	+

* Column (a) represents the percentage contribution of a functional shock to a variable's forecast variance at the given time horizon.

** Column (b) provides the sign of the impulse response at the given time horizon. N denotes that the sign is essentially zero at that horizon.

*** Column (b) impulse response signs are described for accumulated gold flows.