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7 International adjustment under the Classical gold standard: evidence for the United States and Britain, 1879–1914

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Introduction

Links between disturbances in financial markets and those in real activity have 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 chapter, we provide evidence suggesting that those basic assumptions are at odds with the data from the period. Domestic autonomy was substantially limited by internationally integrated markets for gold, capital, and traded commodities. Such findings are likely to be important for studying business cycles during the period; for example, we have shown elsewhere (see Calomiris and Hubbard, 1989) that, when prices are flexible, observed cyclical movements can be related to a credit market transmission of deflationary shocks.

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 Eichengreen, 1985; Bordo and Schwartz, 1984). 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 roughly 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 latter "internationalist" approach argues that interest rates and traded goods 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 (e.g. that of Friedman and Schwartz, 1963) associated with the price–specie–flow mechanism posits the following – 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 (though 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, the "internationalist" approach implies far less domestic autonomy in the short run for interest rates, the money supply, and commodity prices. According to this view,[1] gold supply is highly elastic, capital markets for some securities (internationally traded commercial paper and bonds) are closely integrated internationally, and domestic traded goods' gold prices respond to international price movements in the short run within "narrow" band-widths of transaction cost (which includes transport and insurance fees, tariffs, and a fair rate of return to international commodity market speculators). 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.[2] The essential process of adjustment of traded goods' prices and interest rates does not depend on immediate synchronous changes in wages and nontraded commodity prices. In the absence of highly responsive (nontraded goods) prices, these results still hold, but the lagging adjustment of some domestic prices and wages to international price shocks entails real effects on the time path of output and the balance of trade.

Because the internationalist approach posits rapid endogenous gold movements, it places little emphasis on domestic money supply shocks as a source of output variation. Instead, it focuses on cyclical output responses induced by changes in autonomous influences on the IS curve, aggregate supply, or international changes in desired savings.

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 internationalist approach posits. Were gold flows "sufficiently" elastic? Were interest rates "closely" linked?

Our chapter approaches these questions in two ways: first, in the next section, we measure directly the responsiveness of gold flows and the band-widths of tolerance for autonomous interest rate movements. While these measures provide some evidence in favor of close international links, alone they are insufficient evidence to conclude that the internationalist approach is superior to the monetarist price–specie–flow view. The narrowness of band-widths must be measured relative to the macroeconomic importance of relative price deviations. That is, even if autonomous interest rate movements were bounded by band-widths of 100 basis points, if autonomous domestic interest rate movements of, say, 50 basis points accompany large macroeconomic effects, 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 the third section, we employ a monthly data set for the United States and Britain for the pre-World War I period 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 vector autoregression (VAR)" approach for simultaneous equations modeling developed by Blanchard and Watson (1986), Bernanke (1986), and Sims (1986). The fourth section concludes the chapter.

Evidence on international integration of 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 presented in the next section). The mean and standard deviation of the monthly net gold outflow over the period 1885–1914 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

Table 7.1 *ARMA identification of monthly US 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):

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

$DW = 1.87$

$R^2 = 0.24.$

MA(2):

$$GLDFUS = -\underset{(805923)}{125324} + \underset{(0.053)}{0.545}\epsilon_{-1} + \underset{(0.054)}{0.195}\epsilon_{-2} + \epsilon$$

$DW = 1.94$

$R^2 = 0.24.$

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 (M2) of approximately $11.6 billion.[3]

Autocorrelation and partial autocorrelation functions for monthly US gold flows are presented in table 7.1. These patterns suggest an MA(2) process, or possibly an AR(1). Under either specification, gold flows essentially 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 7.2 for both specifications.

Table 7.2 *US goldflow 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	0.04	0.03
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

The short time horizon for gold stock adjustment to demand shocks is confirmed by the response of gold flows to the panic of (October) 1907. The regional pattern of gold flows during the crisis supports the view of New York as an active entrepôt 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 US interior totalled $129 million. From January 3 to January 31, fully $69 million in net shipments had returned to New York. 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 totalled $122 million; from May to September 1908, net gold exports totalled $45 million.

Hence, in annual, – or, *a fortiori*, "business cycle" – time, the market for gold operated well enough that gold sluggishness *per se* cannot be faulted for persistent macroeconomic fluctuations. Second, the elasticity of gold movements within the country and across the Atlantic appear similar. Thus it seems arbitrary to use national borders to define regions of economic autonomy for the gold market.

These results are not surprising given the existence of the transatlantic cable, the markets 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 band-widths which average roughly half of 1 percent.[4]

Interest rate arbitrage between New York and London

Another approach to measuring the extent to which money markets were linked across the Atlantic is to examine the tolerance for interest rate differentials between New York and London, and the speed with which large differences in interest rates were eliminated. One difficulty in comparing interest rates is that the financial instruments whose interest rates were quoted in New York and London were not identical. The most frequently used US interest rates are single-name and double-name commercial paper rates of high-quality paper. In England, as in the rest of the world, commercial paper was not an important money market instrument.[5] The money market instrument quoted in English financial newspapers is the prime discount rate on bankers' bills (bankers' acceptances). Commercial paper and bankers' acceptances may have differed in their degree of risk or liquidity. Differences in average risk and liquidity, or in the timing of changes in risk and liquidity premia over time attendant to these differences in the types of money market instruments, complicate comparisons of rates of return between New York and London.

Another problem of comparing existing British and American interest rates is "silver risk." Nominal interest rates in the United States during the 1890s reflected inflation uncertainty as well as the real (i.e. gold-denominated) required rate of return (Garber, 1986; Calomiris, 1993a).

Fortunately, both of these problems can be solved by using bill of exchange prices to measure US interest rates rather than rates on commercial paper. Bills of exchange entailed the exchange of gold dollars in the present for a promise to deliver gold British pounds in the future. Prices for two types of bills of exchange were quoted: "sight" bills, which were redeemable as quickly as a ship could travel from New York to London; and 60-day bills, which were redeemable only in 60 days. Because bills were traded for both delivery dates, and because bills did not suffer from silver risk (since they entailed the exchange of gold today for gold tomorrow), it is possible to derive an implicit New York gold interest rate from the relative price of sight and 60-day bills. Moreover, bills of exchange are international bankers' acceptances; thus the implicit interest rate from this calculation is more comparable to the bankers' acceptance rate quoted in London than would be a US commercial paper rate.

We use data on sight and 60-day New York bills from the National Monetary Commission (1910) for the period 1889–1909, taken from end-month quotations.[6] We chose the dates for these observations to correspond

to the dates of publication of *The Economist*'s quotations of London prime bill discount rates. Prior to 1897, the London rates appear to represent that day's rate, while beginning in 1897, the London quotations are averages for the previous week.

We converted London discount rates into annualized yields. To calculate the New York annualized yield from bill of exchange prices, one must first estimate a delivery time for sight bills. We assume sight bills are deliverable ten days after they have been purchased (a rough estimate of the travel between New York and London). The difference of the dollar price of sight bills and 60-day bills, divided by the price of sight bills, provides a measure of a 50-day interest rate beginning ten days in the future. From this we derived an annualized 60-day rate, assuming that holding period returns for the first ten days are the same as returns for the following 50 days.

Figures 7.1 and 7.2 plot the gold-denominated interest rates on bankers' bills in New York and London, and the difference between the two. The rates are not identical; the average differential between them is 1.13 percent. With the exception of one observation, interest rates in New York are always higher than in London. The interest rate differential was not constant over time. For 1889–1893, the average differential was 1.60, while the average for 1894–1909 was 0.99.

Clearly, interest rate parity did not hold perfectly across the Atlantic. Three factors account for this. First, physical transaction costs created a tolerance for independent movements of interest rates. For example, a British investor faced a cost of moving funds from his British bank account to his American bank account. Even if these funds were transferred by wire, there was still a brokerage fee. And if funds were transferred by shipping gold abroad – as we will argue was sometimes necessary – then the foreign investor paid 0.5 percent of the gold shipment in transportation costs. It is also worth noting that a fund transfer via a gold shipment would not be riskless, since the American interest rate could fall once the gold was in transit.[7]

Second, if wire transfers were sometimes not feasible as a means for British investors to reap higher interest rates in New York, then shipments would sometimes have been required. During these episodes, the tolerance for real interest rate differences should have risen, due to the higher transportation cost and risk associated with capital market arbitrage via gold shipments. Given the risk of a reversal of the interest rate differential while the funds were in transit, it could conceivably have taken weeks or months for British investors to have been willing to send sufficient gold abroad to bring US rates down significantly.

Why would gold flows, rather than wire transfers, have been required of foreign investors seeking to reap higher rates of return in the United States?

A sufficient condition for this constraint would be that New York banks did not regard the deposits of foreign banks as perfect substitutes for gold deposits in New York. Most of the time, deposits held in London banks (which were virtually riskless) would have been regarded as close substitutes for gold by New York banks. But during a banking crisis in New York this would probably not have been the case. If New York banks faced the risk of large withdrawals of gold by depositors, and if those depositors were unwilling to accept checks written by the New York banks on London as a substitute form of payment, then New York banks would have preferred gold to deposits in London banks, and would have paid higher interest rates for gold deposits than they would have paid for wire transfers. Thus, during a period when the New York banks were threatened with a run, our measured interest rate differences could be significantly higher than otherwise.

Third, during times of financial strain, the acceptances of banks in New York or London may have become relatively riskier than before. Large money center banks in New York were among the US banks with the lowest risk of failure during this period, and London banks were the most stable financial intermediaries of their time. Nevertheless, during panic episodes, increased risk on bankers' acceptances of money center banks may have distorted interest rate comparisons between financial centers. In particular, during financial crises that threatened New York banks, and not London banks, one should expect to see a rise in the New York/London interest rate differential because of an increase in risk.

To sum up, the maximum allowable interest rate differential between London and New York should have reflected permanent and transitory factors. Physical costs of wire transfers imply a constant minimum tolerance for interest rate differences. Additionally, occasional changes in the cost of arbitrage that required gold shipments, and occasional increases in the riskiness of bankers' acceptances on New York, should have caused temporary increases in the allowable interest rate differential during financial crises. To the extent that bank risk caused the increase in the observed differential, the measured differential overstates the true (risk constant) differential between London and New York.

Thus it is useful to consider whether financial crises – defined by some measure other than interest rate movements themselves – witnessed unusual changes in the tolerance for interest rate differences. Calomiris and Gorton (1991) argue that during the period 1889–1909 there were four episodes that can be considered New York banking panics – defined as episodes when New York City Clearinghouse banks instituted formal measures to coordinate actions in response to their perception that a crisis was upon them. These were the panics of November 1890, June–August 1893, October 1896, and October 1907. Many other lesser panics have been identified in the literature on the basis of stock price movements or interest rate changes, but these four panics stand out as important times of strain for New York banks.

Figure 7.1 shows that during the panic of 1890 (November 1890–January 1891) there was an unusually large interest differential between New York and London. August 1893 also witnessed an unusually large differential. In 1896 and 1907, however, there is no evidence of any influence of the panics on the interest differential, although in both cases interest rates in New York and London rose in the months surrounding the panics.

With the exception of the panics of 1890 and 1893, the interest rate differential remained small. For the period 1889–1909, there are only three months in which the interest differential exceeded 2.5 percent. Two of these months occurred during the panics of 1890 and 1893; the third was October 1889. For 1889–November 1893, the interest differential exceeded 1.5 percent in 30 out of 59 months, and exceeded 2.0 in 10 months; for the 16-year period after November 1893, the interest rate differential exceeded 1.5 percent in only eight months, including the consecutive months of October–December 1899 (which Kemmerer, 1910, identifies as a "minor panic"), and never exceeded 2.0 percent. Even during the period of relatively high interest differentials (1889–1893), interest rate differentials in excess of 2.0 percent did not occur in consecutive months, except for the brief periods, October–November 1889 and November 1890–January 1891.[8]

To preserve the narrow differential between New York and London bankers' acceptance rates, interest rate levels often increased by large amounts in both countries simultaneously, as shown in figure 7.2. For example, in the wake of the panic of 1896 in the United States, London interest rates rose from 0.69 percent in July to 3.8 percent in December. In response to the panic of 1907, from July to December, London interest rates rose from 3.8 percent to 6.4 percent.

Seasonal patterns also confirm the potential for shocks originating in America to cause large increases in interest rates abroad. The seasonal demand for loans in the United States, which was associated with planting and marketing crops, produced seasonal fluctuations in interest rates, as shown in figure 7.3. These fluctuations, it should be noted, are substantially smaller than those apparent in nominal interest rates on other money market instruments discussed by Miron (1986), but are similar in magnitude to those found by Barsky *et al.* (1988). Figure 7.4 shows that Britain, which did not experience large domestic loan demand shocks from seasonal agricultural needs, nevertheless showed virtually identical seasonality of interest rates to the United States (see also Clark, 1986; Barsky *et al.*, 1988).

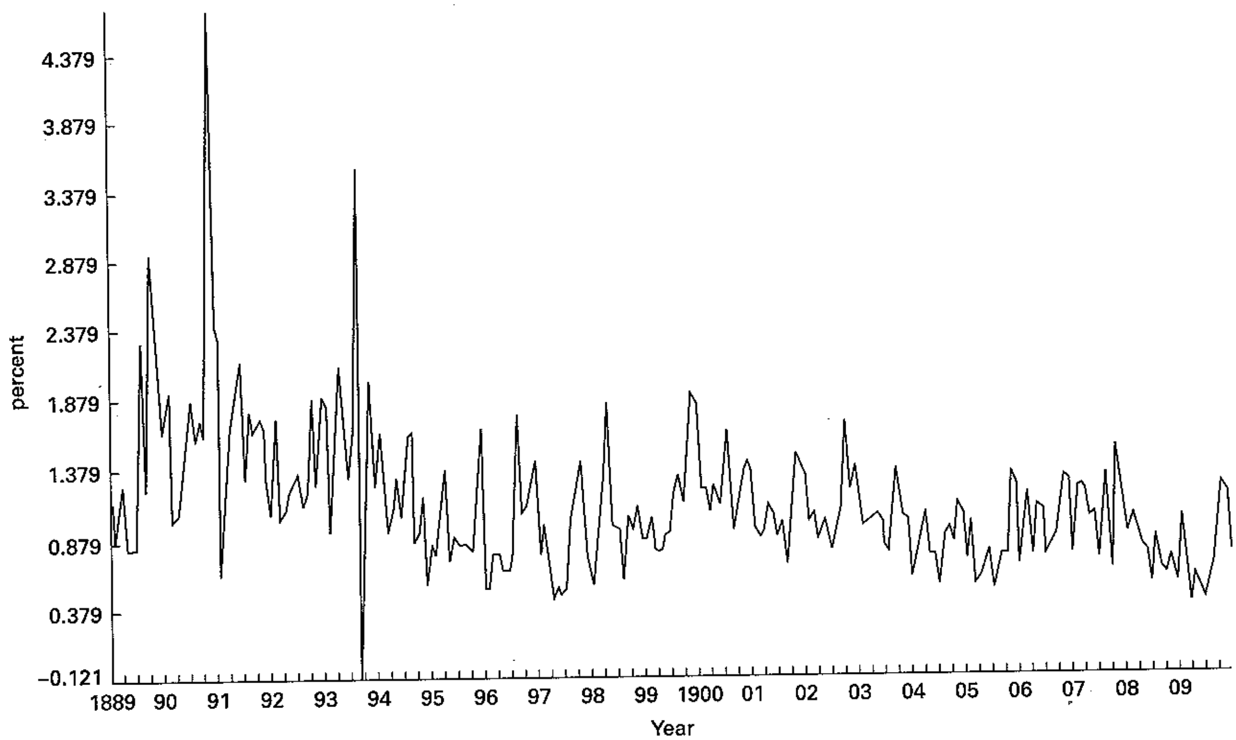

Figure 7.1 Interest rate differential between New York and London, 1889–1909, end-month data

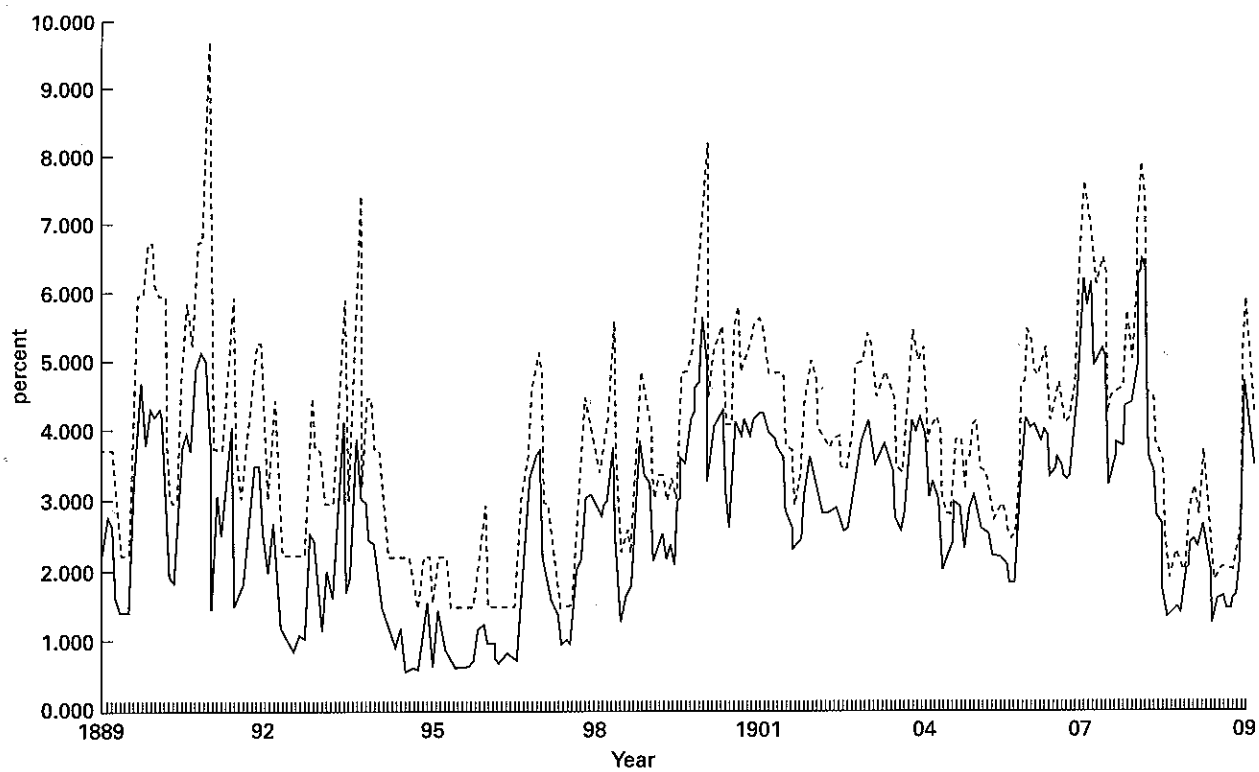

Figure 7.2 Interest rates on bills of exchange traded in New York and bankers' bills in London, 1889–1909, end-month data

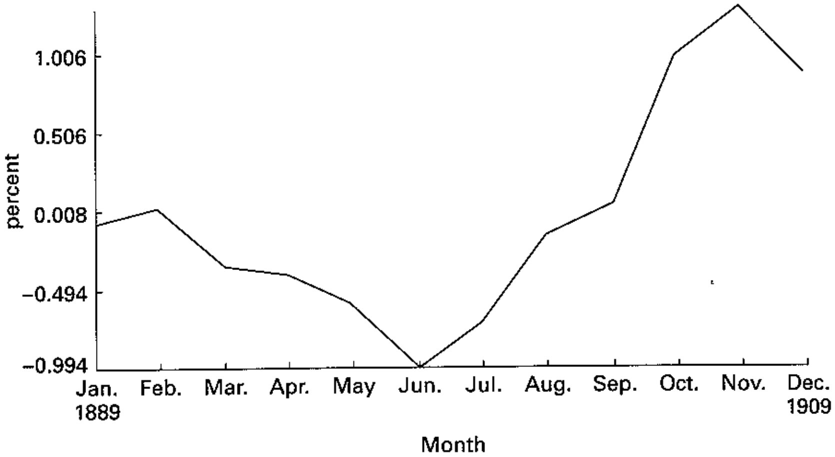

Figure 7.3 Average seasonal effects in New York: interest rates for bills of exchange traded in New York, 1889–1909, end-month data

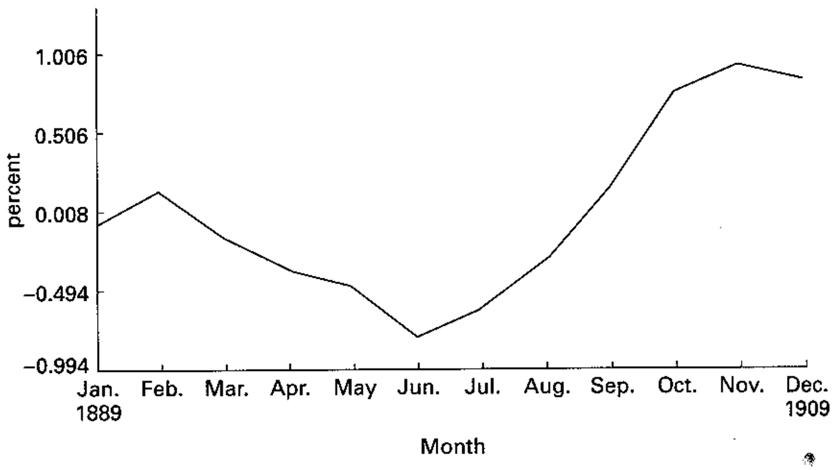

Figure 7.4 Average seasonal effects in London: interest rates on bankers' bills in London, 1889–1909, end-month data

As shown in figure 7.5, average differences in interest rates were only slightly higher in the Fall peak lending season.

To summarize, interest rate differentials typically were less than 1.5 percent. Interest rate differentials in excess of 1.5 percent did not last for long. With the exception of a panic episode (in 1890) – when larger interest differentials were expected – and autumn 1889, the interest rate differential

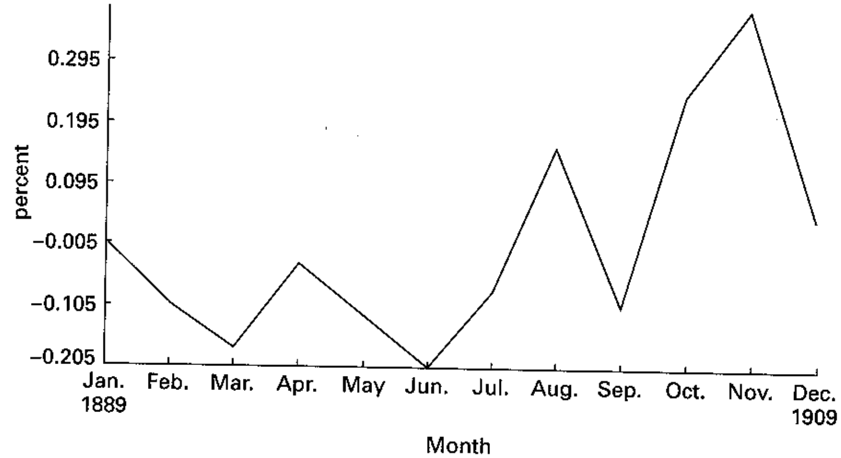

Figure 7.5 Average seasonal effect on interest rate differential between New York and London, 1889–1909, end-month data

never exceeded 2.0 percent for more than one consecutive month. Seasonal shocks to loan demand in the United States did not produce average seasonal differences between New York and London greater than 0.4 percent. It is worth emphasizing that the data on which all these calculations are based are bill of exchange prices observed on particular days at monthly intervals, so that these results do not reflect the smoothing of differentials that would result from constructing monthly averages of daily observations.

There are two small "surprises" from the above analysis of interest rate differences that are worthy of mention: First, interest rate differentials are unusually high in late 1889, given that this period did not coincide with a banking panic. Second, it is curious that the 1896 and 1907 panics had smaller effects on interest differentials than the panics of 1890 and 1893.

Particular historical circumstances may shed some light on what made 1889 special, and on why 1890 and 1893 witnessed seemingly less elastic gold flows than 1896 and 1907. While an informal discussion of the circumstances of these five episodes (1889, 1890, 1893, 1896, and 1907) "proves" nothing, it does raise some interesting questions about how policy within the United States, the policies of foreign central banks, and the state of the London market may have affected the degree and speed of adjustment in international markets for capital and gold. At issue here is the fundamental question of whether adjustment under the gold standard occurred "automatically," or whether policies of central banks, or circumstances peculiar to a regular trading partner, might have hindered or helped the adjustment process.

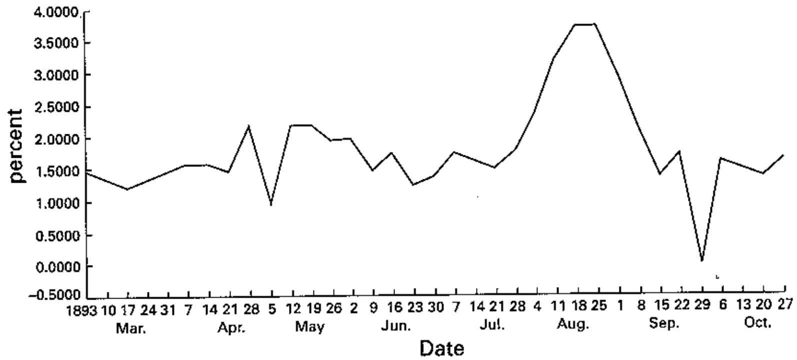

Figure 7.6 Interest rate differential between New York and London during the panic of 1893, March–October 1893, end-week data

During our period, the major policymakers in the international markets for capital and gold were the central banks of Europe (especially Britain, France, and Germany), and the US Treasury Department. Friedman and Schwartz (1963, 149–152) discuss the growing importance of the Secretary of the Treasury as a source of assistance to banks during the pre-Fed period. The Treasury acted to offset outflows of funds from banks by depositing Treasury reserves in the banking system. Friedman and Schwartz argue that this policy was pursued especially aggressively by Secretary Shaw during his tenure (1902–1906), although other Secretaries had initiated the policy much earlier. Apparently successful publicly announced interventions to offset interest rate increases were reported in the *Commercial and Financial Chronicle* regularly throughout our sample period. Delays in effective Treasury intervention were blamed for the protracted stringency of 1889.

Friedman and Schwartz's portrayal of the increasing aggressiveness of Treasury interventions over this period is consistent with the lower tolerance for interest rate differentials between New York and London in years after 1889–1893. This could explain why the panics of 1896 and 1907 elicited less of a differential than the panics of 1890 and 1893. This argument could also explain why, after 1902, the interest differential never exceeded 1.54 percent (its value during October 1907).

On the other hand, there are alternative explanations for these facts, and there have been challenges to the claim that Treasury intervention was effective. Allen (1986) questions whether Secretary Shaw's policies helped to stabilize the New York money market. Allen shows that call loan interest rate seasonality actually increased during his tenure, and that Shaw's announced willingness to intervene was associated with declines in New York banks' desired excess reserve holdings. Allen argues that Shaw's policy ultimately was counterproductive because it reduced the available stock of gold in New York banks. Furthermore, Shaw's successor was not as willing to intervene to assist banks. Allen argues that the unannounced change in policy, combined with the low level of excess reserves, may have contributed to producing the panic of 1907.

In part, differences in the extent and duration of interest rate spreads across panics may simply have reflected differences in the severity of the events. The panic of 1896 was the mildest of the major shocks to the New York banks. During this panic, unlike all the others, the New York banks were never forced to actually issue Clearinghouse certificates.

Another possible explanation for differences across the panic episodes is the actions of central bankers abroad. French, British, and German central banks effectively coordinated the transfer of gold to New York during the panic of 1907 (Eichengreen, 1992, 50–57), but during the stringency of 1889 and the Baring crisis of 1890, they were not willing to sponsor the shipment of gold to the United States. Financial commentators in the *Commercial and Financial Chronicle* noted the low supply of gold in Britain during the stringency of 1889. In the case of the Baring crisis of 1890, the Bank of England and the commercial banks of London were in no position to send resources to New York, since they were borrowing heavily from the Bank of France to shore up their own resources (Clapham, 1958, 326–339). It may have been that during those episodes the effective cost of importing gold was higher, since it had to come from more distant, less coordinated, and less closely related, financial centers in Europe.

It is hard to say whether foreign central bank coordination was important for explaining differences in the tolerance for high interest differentials across the various episodes. Rich (1989) argues that Canadian–American linkages in international credit markets were crucial for stabilizing the New York market, particularly during the panic of 1907. These connections were entirely private, as neither Canada nor the United States had a central bank. This evidence, along with Dick and Floyd's (1991) analysis of the rapid international adjustment process in Canada during the Classical gold standard, seems to argue for the strength of "automatic," private mechanisms of international adjustment (see also chapter 8 in this volume).

Whatever the causes of rapid international adjustment and close ties across countries, the comovement of interest rates between London and New York raises the possibility that American money supply shocks may have produced cyclical change within and outside the United States through their effects on world interest rates. But despite the fact that American seasonal and cyclical loan demand shocks seem to have been capable of moving British interest rates by large amounts at monthly frequency, that does not imply that money supply shocks originating in the United States were important sources of world or US business cycles, for three reasons.

First, interest rate disturbances may not all reflect monetary shocks. Second, for interest rate shocks related to monetary disturbances to have been important at business cycle frequencies, they should have persisted in their effect on interest rates (and been expected to persist) for several months. Otherwise, their influence on aggregate demand should have been minimal. It may be that the high elasticity of endogenous international capital and gold flows shortened the duration of high-interest rate episodes, and thus limited the impact of monetary shocks on the business cycle. Third, the measurement of tolerances for interest rate differentials above does not answer the fundamental question of how important money supply disturbances – or other disturbances affecting interest rates – were for output, because a simple measurement of interest rate differences does not consider the linkages between these disturbances and output. To investigate the potential importance of domestic money supply disturbances, therefore, requires a dynamic model of the US economy in the context of trans-Atlantic markets for capital and gold.

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 an important source of macroeconomic disturbances? 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 US economy and its international linkages.

Data and econometric approach

Our results so far 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 data set which includes US and British interest rates and wholesale price indices, and US data on exports, imports, gold flows, and output (using pigiron as an output proxy).[9] Our measure of the British interest rate is the monthly average of weekly quotations for the prime rate on bankers' bills, plotted on p. 199. As our measure of the US interest rate we use the monthly average of the

double-name, choice New York commercial paper rate (Macaulay, 1938). This variable has several advantages over other interest rates: it is a rate paid by firms for credit as well as a measure of portfolio opportunities for investors, and it is available as a monthly average over a long period. The chief disadvantage of using this, or any other, nominal interest rate is that prior to 1897 "silver risk" complicates the interpretation of the interest rate. For this reason, we begin our sample in January 1897. Our sample ends in June 1914, before the outbreak of war.

Despite the exclusion of the panics of 1890, 1893, and 1896 from our sample, our sample still contains many episodes which have been identified as severe monetary contractions. Kemmerer (1910) identifies December 1899, May 1901, March 1903, and October 1907 as "major panics," and March 1898, September 1899, July 1901, September 1901, September 1902, December 1904, April 1905, April 1906, March 1907, and September 1908 as "minor panics."

In order to analyze dynamic adjustment to disturbances, we adopt the "structural VAR" approach developed by Blanchard and Watson (1986), Bernanke (1986), and Sims (1986) as an alternative to recursive (nonstructural) identification of disturbances. The "structural VAR" approach permits one to solve a simultaneous equations model of the shocks to each series in which orthogonalized shocks and their interrelations are associated with behavioral functions rather than variables. The first stage of the 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 that originate in particular functions, and decompositions of each variable's forecast variance, which attribute the 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 macroeconomic model for the United States

We posit seven functional relationships for our seven-variable model: an equilibrium-output equation for the United States, an exogenously determined international (British) riskless interest rate, US money supply and money demand equations, demand functions for US 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 (1)–(7) below.

$$i_t^L = i_t^{L*} \qquad \text{(International interest rate)} \qquad (1)$$
$$i_t^{NY} = a_1 i_t^L + a_2 G_t + i_t^{NY*} \qquad \text{(US money supply)} \qquad (2)$$
$$X_t - M_t - G_t = a_3 i_t^L - a_4 i_t^{NY} + X_t^* \qquad \text{(Desired net savings)} \qquad (3)$$
$$Y_t = -a_5 i_t^{NY} + a_6 P_t + Y_t^* \qquad \text{(Equilibrium output)} \qquad (4)$$
$$M_t = a_7 P_t - a_8 i_t^{NY} + a_9 Y_t + M_t^* \qquad \text{(Import demand)} \qquad (5)$$
$$P_t = -a_{10} X_t \pm a_{11} i_t^L + P_t^* \qquad \text{(Export demand)} \qquad (6)$$
$$G_t = a_{12} Y_t + a_{13} P_t - a_{14} i_t^{NY} + G_t^* \qquad \text{(US money demand)}, \qquad (7)$$

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 US net imports of gold, X and M are US commodity exports and imports, and P is the log ratio of US to British wholesale price indices. All disturbance terms with an asterisk are mutually orthogonal. i^{L*} is the innovation in the British open market discount rate. i^{NY*} is the orthogonal money supply shock. X^* is the disturbance to desired net savings (which might include *IS* shocks and supply side credit shocks). M^* is the shock to the demand for imports. P^* is the export demand disturbance. G^* is the innovation in US demand for money (gold).

By setting $i^L = i^{L*}$ we do not mean to suggest that British interest rate were unrelated to American rates, or that Britain was the source of all comovement between the two. Rather, i^{L*} is simply a statistical construct that combines shocks originating abroad with those originating in the United States that moved interest rates abroad. This definition is useful for modeling gold flows between countries, and for defining "autonomous" movements in US interest rates (those unrelated to foreign interest rates).

The US money supply equation assumes that net gold imports respond positively to US and negatively to British, interest rate innovations. International influence on domestic money supply takes the form of gold movement induced by interest differentials. Autonomous movements in i^{NY*}, by construction, are unrelated to these international effects, and thus are best viewed as capturing the effects of domestic money multiplier shocks on interest rates, holding other functions unchanged.

The savings equation (3) posits that US desired short-run net savings responds positively to foreign, and negatively to US interest rate changes.

Our specification of the output equation (4) assumes negative interest elasticity in the *IS* curve, as well as a positive relative terms of trade response in aggregate supply. Y^* will be a mixture of supply and *IS* disturbances.

The US demand for imports (5) 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 on i^L in (6) depends on whether foreign interest rate innovations are associated mainly with expansion or contraction abroad.

The money demand equation (7) 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 had properly 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 saved these reduced form equations for use in simulation and defined their residuals as the innovations Y, i^{NY}, i^L, X, M, P, and G, modeled in system (1)–(7).

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

$$i_t^{NY} = \underset{(0.050)}{0.252} i_t^L + \underset{(0.070)}{0.110} G + i^{NY*} \qquad (2)$$

$$X_t - M_t - G_t = \underset{(0.269)}{0.112} i_t^L - \underset{(0.462)}{0.048} i_t^{NY} + X_t^* \qquad (3)$$

$$Y_t = -\underset{(0.120)}{0.136} i_t^{NY} + \underset{(0.335)}{0.700} P_t + Y_t^* \qquad (4)$$

$$M_t = -\underset{(0.205)}{0.019} i_t^{NY} + \underset{(0.112)}{0.321} Y_t + \underset{(0.580)}{3.190} P_t M_t^* \qquad (5)$$

$$P_t = -\underset{(0.022)}{0.021} i_t^L - \underset{(0.019)}{0.099} X_t + P_t^* \qquad (6)$$

$$G_t = -\underset{(0.614)}{0.344} i_t^L - \underset{(0.140)}{0.117} Y_t + \underset{(0.93)}{2.66} P_t + G_t^*. \qquad (7)$$

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 13 other estimated coefficients are of the right sign and some are measured precisely. As Sims (1986, 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 functional identification of disturbances is to examine the "reasonableness" of simulated responses to 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 percentage contribution from each functional disturbance to each variable in the system at time horizons of 3, 12, and 20 months are given in table 7.3. Beside these figures, we indicate whether the sign of the impulse response at that time horizon is positive (+), negative (−), or essentially zero (N), defined roughly as a cumultive response of less than one tenth of the initial standard deviation shock. Table 7.3 allows us to examine whether important sources of disturbances have effects consistent with our model.

At the same time, table 7.3 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: exports and imports are responsive in the short run to international relative price changes; prices or income respond importantly to money supply shocks; and shocks to desired net foreign savings, and export and import demand, contribute greatly to short-run price and interest rate variation, as the internationalist approach predicts.

It is important to note that the diagonal elements of the forecast variance matrix in table 7.3 are always the largest single contributor to forecast variance. This is not a coincidence. Shocks to variables not captured by the functional relationships posited in the model (unexplained errors) will appear as diagonal disturbances, and may have persisting autoregressive explanatory power. Thus diagonal forecast variances will overstate the relevance of diagonal functional shocks.

The signs of impulse responses are supportive of our identifying assumptions. US autonomous money supply contractions not explained by gold flows – those due to 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*}). Autonomous money supply shocks have a persistent, positive effect on gold flows, but this accounts only for roughly 4 percent of gold flow forecast variance. Autonomous US 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 US business cycles.

To what extent can one argue that US money supply shocks (autonomous or not) mattered for US output? The effects of monetary shocks should be captured either in i^{NY*} or in i^{L*}. Even if all of the variation in i^{L*} were caused by shocks from the US money supply, the total effect of both shocks on US output is too small to indicate an important influence from US money supply shocks.

Furthermore, i^{L*} shocks are at least partly associated with expansions in economic activity abroad (e.g. positive *IS* shocks in Britain). British interest rate innovations produce lagging, but important, positive effects on US exports. The negative impact of higher foreign interest rates on output may reflect either interest rate parity, or a US source of some i^{L*} shocks.

Innovations in desired net saving (X^*) play an important role in determining the US interest rate, short-run commodity price movements (which dampen quickly), imports, and exports. All of these effects are of the predicted sign – a desire to save more leads to a period of high exports, low commodity and gold imports, low relative domestic prices, and a lower US interest rate. The response of output to the savings shock is harder to explain. The initial negative, and subsequent positive, 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 the *IS* function (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 these output shocks may reflect a positive correlation between aggregate supply and demand disturbances. In Calomiris and Hubbard (1989), we

Table 7.3 *Simulation results for the simultaneous equations model*

Shocks originating in:	time horizon (months)	Cumulative responses of: i^L (a)[a]	i^L (b)[b]	i^{NY} (a)[a]	i^{NY} (b)[b]	X (a)[a]	X (b)[b]	Y (a)[a]	Y (b)[b]	M (a)[a]	M (b)[b]	P (a)[a]	P (b)[b]	G^c (a)[a]	G^c (b)[b]
World interest rate (i^L)	3	90.0	+	19.0	+	1.5	+	2.2	–	0.4	+	0.6	–	1.9	+
World interest rate	12	62.1	+	19.7	+	7.3	+	4.1	–	3.2	–	7.5	–	4.3	+
World interest rate	20	53.0	N	17.9	N	7.4	N	4.2	–	3.7	N	8.8	–	4.4	+
US money supply (i^{NY})	3	2.6	+	68.0	+	0.4	N	1.9	–	0.6	+	3.0	+	4.9	+
US money supply	12	2.7	+	34.6	+	0.4	N	4.5	–	4.5	–	1.2	N	6.2	+
US money supply	20	3.1	N	31.7	N	3.9	N	4.5	–	4.7	N	1.1	N	6.2	+
US desired savings (X)	3	1.4	N	2.6	–	47.9	+	6.1	–	16.9	–	32.4	–	7.8	N
US desired savings	12	3.9	N	10.7	–	37.7	+	8.0	+	15.6	N	26.1	–	7.7	–
US desired savings	20	4.1	N	10.1	N	35.6	N	8.1	+	16.2	N	23.2	N	7.8	–
Equilibrium–output (Y)	3	3.0	+	0.3	+	0.3	+	81.5	+	8.6	+	0.7	+	5.7	–
Equilibrium–output	12	15.8	+	13.0	+	3.8	+	65.1	+	13.4	N	2.9	–	9.6	–
Equilibrium–output	20	15.5	N	13.4	N	4.2	+	64.3	N	12.5	N	4.0	–	9.9	N
US import demand (M)	3	2.1	+	0.3	+	16.6	+	2.5	N	52.4	N	9.4	–	2.0	–
US import demand	12	12.3	+	8.9	+	16.8	+	10.2	N	41.9	N	10.2	–	4.3	+
US import demand	20	14.4	+	11.4	+	16.8	N	10.6	–	37.7	N	11.4	–	4.5	+
US export demand (P)	3	0.4	N	4.6	+	12.8	+	4.2	+	16.2	+	39.9	+	5.4	+
US export demand	12	1.4	N	9.3	+	14.5	N	5.6	N	15.8	N	40.3	+	9.9	–
US export demand	20	4.9	–	9.9	N	15.7	N	5.7	N	18.3	N	39.2	+	9.8	–

Table 7.3 (*cont.*)

Shocks originating in:	time horizon (months)	Cumulative responses of: i^L (a)[a]	i^L (b)[b]	i^{NY} (a)[a]	i^{NY} (b)[b]	X (a)[a]	X (b)[b]	Y (a)[a]	Y (b)[b]	M (a)[a]	M (b)[b]	P (a)[a]	P (b)[b]	G^c (a)[a]	G^c (b)[b]
US money demand (G)	3	0.5	+	5.3	–	20.5	+	1.6	–	5.0	–	14.0	–	72.3	+
US money demand	12	1.9	+	3.8	+	16.0	+	2.5	+	5.6	+	11.9	–	58.0	+
US money demand	20	4.9	+	5.5	+	16.4	N	2.6	–	6.9	N	12.3	–	57.4	+

Notes:

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

[b] 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.

[c] Column (b) impulse response signs are described for accumulated gold flows.

argue that disturbances to credit markets will be a source of positive correlation between aggregate supply and demand shocks.

The negative response of gold flows to output innovations – which mirrors the negative estimated coefficient on Y in (7) appears puzzling and is a relatively important contributor to future gold flows. We offer two possible explanations for this anomaly.

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 money demand and predict a greater increase in the money multiplier, then output innovations may be negatively associated with current gold flows because of reductions in anticipated gold demand. Evidence for comovements 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 movements in the money multiplier are procyclical. Our use of monthly data precludes a direct test of this hypothesis since we lack data on the currency/deposit and reserve/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 (i^{NY*}). 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 that account for the correlation between Y^* and G.

This does not imply that Y^* should be interpreted as a money supply disturbance in disguise. Money supply shocks, *per se*, should be fully reflected in the shadow price of liquidity (i^{NY}). Y^* may contain additional information, however, related to *credit* shocks which follow from reductions in the money multiplier. Unlike markets for gold, bankers' acceptances, and commercial paper, markets for bank lending often involve local relationships. Foreign suppliers of bank credit, therefore, will not be able to supply bank loans to firms as easily as they can ship gold, wire funds to banks, or purchase commercial paper. Thus close international linkages in traded commodities and financial instruments that limit price and interest rate fluctuations may not limit variation in the supply of bank credit or its cost. For an extended discussion of this point, see Bernanke (1983) and Calomiris and Hubbard (1989).

These potential connections between output movements and money multiplier shocks raise 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, (7) will properly measure gold demand, but not money demand defined more broadly. G^* shocks have effects on US prices and interest rates consistent with viewing (7) as a gold demand function.

Innovations in export and import demand – 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 US relative price response, a lesser response in exports and a rise in the interest differential between US 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 US prices, and produce a positive response in commodity imports and gold inflows.

In summary, our results provide substantial 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 autonomous money supply shocks. Furthermore, disturbances relating to the balance of trade – desired net savings and the supply of exports (demand for imports) – prove to be the most important sources of output fluctuations other than Y^*.

Conclusions and implications

We have presented evidence that supports close direct asset and commodity price linkages between the United States and Great Britain in the short run. Gold flows respond rapidly to the demand for gold. Interest rate differentials, adjusted for risk, remained small (less than 2 percent).

Our results indicate 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, presumably by affecting incentives for 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 domestic output and prices.

Though a more thorough treatment of the sources of unexplained disturbances in output is beyond the scope of this chapter, we argue elsewhere

(Calomiris and Hubbard, 1989) that disturbances in credit markets in an environment of imperfect information account for much of the variation in output which characterizes pre-World War I business cycles. We find this approach fruitful for explaining the priority of price to output shocks noted by DeLong and Summers (1986), and for providing a rationale for the predictive role of money for nominal income. Money stock changes may proxy for *real* changes in bank loan supply.

Data appendix

US commodity imports and exports: US Department of Commerce, *Historical Statistics of the United States, 1789–1945*, 1st edn., 1949, 339–341; original data taken from *Monthly Summary of Commerce and Finance of the United States*, various issues

British interest rate: London open market discount rate; weekly data from *The Economist*

US interest rate: Double-name, choice commercial paper rate in New York City; US Department of Commerce, *Historical Statistics of the United States, 1789–1945*, 1st edn. 1949, 346–347; original monthly averages taken from F. R. Macaulay, *The Movement of Interest Rates, Bond Yields, and Stock Prices in the United States Since 1856*, NBER, 1938

US net gold exports: Department of Commerce, *Monthly Summary of the Foreign Commerce of the United States*, various issues

US pig iron output: US Department of Commerce, *Historical Statistics of the United States, 1789–1945*, 1st edn., 1949, 332–333; original data taken from F. R. Macaulay, *The Movement of Interest Rates, Bond Yields, and Stock Prices in the United States since 1856*, NBER, 1938

US sight and 60-day bill of exchange prices: National Monetary Commission, *Statistics for the United States, 1867–1909*, 1910, 188–208

Notes

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1. In the late 1920s, advocates of the classical price–specie–flow view noted that the priorities of adjustment of prices and quantities seemed often to contradict their model (see, for example, Taussig, 1927, 286–290), but it was not until Whale's (1937) work on direct linkages that a theoretical framework capable of explaining these phenomena emerged.
2. 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 (1989), 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. For further evidence that financial intermediation, but not money *per se*, was important for output determination, see Rush (1985).
3. Gold flows are defined as the difference between gold imports and exports (see data appendix, p. 214). Currency holdings of banks and individuals, and total money supply, are taken from Friedman and Schwartz (1970, p. 402 and p. 65, respectively).
4. 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 for the United States are typically higher than half a percent, with an average of 0.65 percent over the period 1890–1904. Officer's calculations slightly overstate the gold cost of US exports, however, because he interprets US interest rates to be gold interest rates. As we show below, US interest rates in gold terms were closer to British levels once one adjusts for silver devaluation risk.
5. Unit banking in the United States seems to have been the essential institutional difference that produced the American commercial paper market. In other countries banks' operating branches provided financing to customers through bankers' acceptances, which did not become important in the United States until the 1920s (see Calomiris, 1993b).
6. For 1889–1895 the data are described as "posted" rates of exchange; for 1896–1909 the data are described as "actual" rates of exchange.
7. For example, in response to the gold inflows after the panic of 1893, the New York interest rate fell precipitously from 7.5 percent on August 25 to 3.0 percent on September 29. Gold shipments that had been sent to New York from London during the interim would have proved a disappointing investment.
8. To see whether the conclusions about tolerances for interest rate differentials or their persistence were sensitive to the specific dates chosen, we collected additional data at weekly frequency for 1893 and 1896, and found no differences.
9. 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. Pigiron is highly correlated (with a correlation coefficient of 0.84 in *growth rates*) with total nonagricultural commodity output, on an annual basis. Hull

(1911) argues that iron is the "barometer of trade" because of its ubiquitous presence as an input.

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