International Capital Mobility and the Potential Role of an American Central Bank within the Pre-1914 Gold Standard

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Abstract: In the pre-1914 U.S., a central bank would have had great powers to stabilize real activity and inflation without violating gold-standard constraints. This was partly because international capital flow to the U.S. was subject to imperfect international capital mobility, *not* uncovered interest-rate parity (UIP). Continental central banks followed practices that would have counteracted most of the shocks that caused American business cycles over 1879-1913. An American central bank that simply followed the examples of continental central banks would have prevented most of the era's big depressions, including the depressions of 1884, 1893, 1896 and 1910.

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In the years leading up to the passage of the Federal Reserve Act, proponents of a central bank for the United States cited a number of potential benefits from a central bank within the international gold-standard system, which they took for granted as the framework of monetary institutions. Looking back at the debate, modern economists (e.g. Eichengreen, 1992) echo their arguments. A central bank can accommodate money-demand fluctuations without introducing shocks to money supply, by passive discounting at slightly above-market rates. Thus, an American central bank could have accommodated America's seasonal peaks in demand for high-powered money, which otherwise drew in gold and disturbed interest rates throughout the world (Miron 1986; Clark 1986; Barsky, Mankiw, Miron and Weil 1988). A central bank can act as a lender of last resort in financial crises. Through constant contact with financial institutions and regulatory interactions, its governors and staff are uniquely prepped for the key job in a crisis: separating the illiquid from the insolvent, condemning the latter to destruction, and arranging for solvent firms to pick up the pieces.

One item is conspicuously absent from most lists of a pre-1914 central bank's benefits. That is the main function of central banks nowadays: manipulation of interest rates to stabilize inflation and real activity. Economists and financiers of the 1900s knew a lot about financial markets, but almost nothing about the mechanics of the macroeconomy. Economists of our own day view the gold standard as a fixed exchange rate system. It is known that central banks have no ability to manage the macroeconomy under the combination of fixed exchange rates, free international capital flow, and perfect international capital mobility or "uncovered interest rate parity" (UIP). The last condition is a ubiquitous assumption in international economics.

In this paper I argue that an American central bank would in fact have been able to help stabilize inflation and real activity under the pre-1914 gold standard. Following Bordo and MacDonald (2005), I observe that the gold standard did not fix exchange rates, but rather bound them within target zones, which gave a central bank some capacity for action even under UIP. Going further, I argue that UIP did *not* hold for the U.S. in this era. Pre-1914 America was instead characterized by "imperfect" international capital mobility, which gave a central bank even more power. Two types of shocks that caused business cycles in pre-1914 America, and that a central bank could counteract without in any way endangering the dollar's fixed gold parity, were shocks to export revenue and shocks to high-powered money demand. These two types of shocks were, in fact, responsible for most major American depressions within the gold-standard era, including specifically the depressions of 1884, 1893, 1896 and 1910. An American central bank could have prevented these depressions.

Of course, it is one thing to argue that an American central bank could have made a difference in theory. Would it have done so in practice, given the state of knowledge about central banking at the time? Yes. Prior to 1914, techniques to forestall macroeconomic effects of export-revenue and money-demand shocks were already being followed by continental central banks, most conspicuously the German Reichsbank. Thus, there is reason to believe that an American central bank not only *could* have, but *would* have made a big difference.

To make this argument, I begin in the first section of the paper by laying out questions about the role of a central bank under the gold standard, mean-reverting exchange-rate expectations and UIP *versus* imperfect capital mobility. In the second section, I present a Keynesian open-economy model with mean-reverting exchange-rate expectations under UIP, and under imperfect capital mobility. The model shows how the the behavior of the American economy in the absence of a central bank, and the powers of a potential central bank, depended on the nature of international capital mobility - that is, whether UIP held. In the third section, I review existing evidence on the nature of international capital mobility to the pre-1914 U.S. In the fourth section, I present some new evidence that clearly favors imperfect capital mobility. Finally, I discuss the policies actually followed by pre-1914 central banks, and how they would have interacted with the shocks that caused actual American business cycles of the era.

Throughout the paper I use the term *"money supply"* to refer specifically to the *high powered money supply* (monetary base), rather than an M1- or M2-style aggregate of liquid assets. Data sources are listed in Appendix 1.

1) Issues

The international gold standard came into being over the 1870s when European countries, particularly France and the German Empire, joined Britain and its Dominions in making their currencies convertible into gold at fixed parities (Meissner, 2005). The United States entered the system in January 1879, when the Treasury began to redeem American currency in gold.

Rates of exchange between gold-standard financial centers were tied to the "parity" values defined by the relative gold content of their local currencies. An exchange rate could not remain outside the bounds – the “gold points” - that just covered costs of transporting gold between the locations (including insurance, interest cost of funds to finance the operation, etc.). The level of the exchange rate within the gold points indicated whether, and in what direction, private agents were shipping gold between the localities. Shipment of gold from financial center A to financial center B was indicated by a depreciation of location A's currency toward the gold point. I say "toward," rather than "to" the gold point because the gold point was not necessarily a discrete threshold. Within the ultimate bounds, there might be a more or less continuous relationship between the exchange rate and the volume of gold shipped for profit, because there were many potential gold shippers with varying costs, each of whom could ship a given quantity of gold (there were low- and high-cost shippers), or because an individual shipper's costs might increase with the volume of gold he transported (Canjels, Prakash-Canjel and Taylor [2004] give reasons for this).

Between most financial centers the gold points were so narrow that the resulting variations were too small to make much difference to the relative price of foreign goods. Thus, the international gold standard is often viewed as practically equivalent to a system of fixed exchange rates. In the U.S., the effective foreign exchange rate was the New York dollar price of London sight exchange, as most international payments were negotiated through “sight” exchange claims to London sterling funds purchased from, or sold to, financial institutions in New York City (Myers 1931, pp. 338-350)..

Estimates of the New York - London gold points vary but most are within 0.7 percent above or below parity (Officer, 1985, p. 575; 1996). In fact, the London-New York exchange rate never strayed more than 1.06 percent from parity *on any day* from 1879 through 1913 (Canjels, Prakash-Canjels and Taylor, 2004, p. 870).

Most gold-standard countries had central banks that issued notes, took demand deposits from national Treasuries and private financial institutions ("reserve balances"), and exchanged these liabilities for gold more or less on demand. To this end they held reserves of gold, sometimes (but not always) subject to required ratios against their liabilities. They held domestic-currency bonds and bills, buying and selling actively in open-market operations, or buying passively at posted rates in discounting. Nearly all, with the exception of the Bank of England, also bought and sold reserves of foreign-currency financial assets, and occasionally bought and sold gold in foreign markets. International gold flows due to the latter were not related to exchange rates in the same way as private shipments for profit. As a matter of accounting, the change in the money supply from one period to the next was determined by the central bank's operations in domestic assets, its domestic lending, its unsterilized operations in foreign assets, and the international flow of monetary gold.

In the United States, lacking a central bank, currency (greenbacks, silver notes, national banknotes, token coins) was issued by the Treasury, which served some functions of a central bank, but not well. The rate at which new currency was created was mostly out of the Treasury's control.[1] The Treasury could add to (subtract from) the supply of money to banks and the public by reducing (increasing) the quantity of money held in Treasury vaults. Treasury officials occasionally did this deliberately to influence money-market conditions (Timberlake, 1978). But these operations were limited by the degree of slack between expenditures, tax receipts and bond sales. Generally, variations in American demand for money had to be accommodated by international flows of monetary gold.

American money demand was subject to strong seasonals. Rural households and businesses made relatively little use of bank accounts, so payments associated with autumn harvests, and to a lesser degree spring planting, boosted their demand for cash. This created a seasonal peak in America's high-powered money demand during the fall harvest months, which fell off to seasonal lows in the summer just before the next harvest season (Sprague, 1903; Kemmerer 1910). On the European side this meant a gold outflow, more or less coincident with gold outflows to some other agricultural countries. The Bank of England responded to these seasonal gold outflows with a regular seasonal increase in its discount rate (Hawtrey, 1938, p. 120-21), which was accompanied by increases in interest rates throughout the gold-standard world (Miron 1986; Clark 1986; Barsky, Mankiw, Miron and Weil 1988).

Arbitrage across national borders was unconstrained, active and well-capitalized. The most liquid financial markets were in London, so much international arbitrage ran between London and each peripheral country's financial center. Within London, the most liquid asset was trade bills. Financial institutions all over Europe held London bills. Local-currency bills quite similar to London bills were traded in major continental markets such as Paris and Berlin. Continental bill rates were tightly linked to London rates, more so than to bill rates in other continental financial centers (Bordo and MacDonald, 2005).

America's financial center was New York city. At long maturities, there were obvious forms of arbitrage between New York and Europe. Europeans held large fractions of outstanding American securities. American stocks and bonds were traded in London and other European markets alongside European securities. The transatlatic telegraph allowed nearly instantaneous arbitrage between prices

[1] The quantity of greenbacks was simply fixed; the rate at which the Treasury created silver notes was governed by longstanding political factors; the rate at which banks created national bank notes was insensitive to variations in interest rates and business activity (Myers, 1931, pp. 396-98, 402-03; Cagan, 1965, p. 91).

in New York and European markets.[2]

At short maturities, the closest New York equivalents to London bills were commercial paper, and time-money loans collateralized by baskets of stocks and bonds. These assets matched London bills in maturity but not in other characteristics. Certainly they were much less liquid.[3] Nonetheless, there was active arbitrage between London and New York in short-term lending. Americans borrowed in London by selling "finance bills," one-to-three month paper "drawn" on a London bank like a trade bill but collateralized by American stocks and bonds like New York time money (Margraff, 1912, pp. 34-42). Americans financing security portfolios shifted between London finance bills and New York time money depending on relative interest rates and expected exchange rates (Morgenstern, 1959, p. 527). Some firms borrowed in London through finance bills to lend time money in New York (Margraff, 1912, p. 41). Arbitrage between London bill rates and New York also operated through the mechanics of foreign exchange.[4] Within New York, there were many forms of arbitrage between time money and commercial paper. Commercial paper rates in the New York market are available at a monthly frequency throughout the gold-standard era; New York time money rates are available beginning in 1890. From quarter to quarter changes in time money rates were very closely correlated

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[2] Arbitragers responded immediately to any difference between the New York and European prices of an American security, buying in one market and selling in the other through "joint accounts" (*New York Times,* July 6, 1914, business section p. 5; Morgenstern 1959, p. 120, footnote 40). See Wilkins (1989) on European holdings and markets for American securities. New York brokers kept in touch with London colleagues by cable, and with traders on the NYSE floor by pneumatic tube; there was a special section of the floor reserved for London arbitragers (the "arbitrage rail"). Brokers devised joint accounts so that clients could arbitrage between London and New York without paying both exchanges' commission fees. Arbritrage may have been more difficult after July 1911, when the New York exchange banned joint accounts as part of a larger effort to enforce mandated comission charges. At that time the New York Times reported that "a difference of 1/4 of a point between the prices in New York and London used to be sufficient for trading by cable at a profit," because under joint accounts "there was only the matter of cable tolls and incidental costs to be deducted...Theoretically, trading in London continues only two hours after the opening of the New York exchange, but the continuation of the market on the street until 8 P.M. in London makes it possible to trade back and forth through the five-hour session in New York" " ("London Buying Few Stocks Here," New York Times, July 6 1914, business section p. xx5).

[3] Unlike today, there was very little secondary market for commercial paper: banks bought it, then held it to maturity (James, 1978).

with changes in commercial paper rates.[5] Through commercial paper, New York markets were linked to the American hinterland. Commercial paper was distributed throughout the U.S. by national dealers and was, outside New York City, the only available short-term open-market investment.[6] Thus, the New York commercial paper rate was linked to a bank's required return to local lending, for banks all over the country.

Many economists assume that unconstrained international arbitrage such as prevailed under the pre-1914 gold standard implies UIP. Under UIP, expected returns to holding domestic assets equal the expected domestic-currency return to holding foreign assets accounting for expected future changes in exchange rates, *plus* premiums to compensate for differences between the particular assets in question with respect to liquidity, default risk or transactions costs. The distinctive feature of UIP is that these premiums do not depend on the distribution of total assets between domestic and foreign holders - that is, on whether the marginal investor is domestic or foreign. Demand for domestic assets is perfectly elastic. The required return to domestic assets is determined by foreign interest rates, expected future exchange-rate movements, and the exogenous liquidity-default risk-transactions cost premium. UIP is a standard feature of models in international economics and New Keynesian open-economy models (e.g. McCallum and Nelson, 2000), despite a lack of empirical evidence for it (Engel, 2013).

Under UIP, a central bank's ability to influence domestic interest rates depends on the exchange-rate regime, as illustrated by the Mundell-Fleming model. If the exchange rate is fixed, domestic interest rates and required returns to long-term assets are simply equal to foreign rates plus exogenous liquidity-default risk-transactions cost premia. Thus, unless the central bank can influence

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[4] New York foreign-exchange dealers held bigger or smaller inventories of London bills depending on the relative return to London bills *versus* New York investments at the same maturity (Goodhart, 1969).

[5] I calculated quarterly average values of Macaulay's monthly series for 90-day time money rates. In a sample from 1890 through 1913, the correlation between quarter-to-quarter changes in the New York commercial paper rate and the time money rate is 0.89, excluding years with financial crises. According to Macaulay (p. A345), fragmentary data indicate term loan rates were also tightly linked to commercial paper rates before 1890.

the level of interest rates in the entire world, it cannot influence domestic interest rates or macroeconomic variables that a central bank would influence *through* interest rates, such as real activity, inflation and quantities of monetary aggregates. It cannot even control the (high-powered) money supply: central bank actions that *tend* to affect the money supply, such as open-market operations in domestic assets, are automatically counteracted by the transactions needed to support the fixed exchange rate. Another well-known result of UIP with fixed exchange rates is that there is no reason for a central bank to buy or sell foreign assets. A central bank's foreign asset transactions are necessarily counteracted by equal changes in the flow of international private investment. They have no effect on anything central bankers might care about.

If the pre-1914 gold standard system was equivalent to fixed exchange rates and UIP held between London and New York, then an American central bank could not have influenced interest rates and macroeconomic conditions, beyond acting as a lender of last resort in crises. Required returns to American assets would have been equal to London interest rates at matching maturities plus premiums outside a central bank's control. A central bank could not insulate American interest rates and the American macroeconomy from changes in European interest rates. It could not adjust American interest rates to stabilize American real activity and inflation in the face of disturbances to spending or inflation. An American central bank might have been able to protect the gold-standard world from seasonal fluctuations in interest rates due to the seasonals in American money demand, by accommodating these with currency. But a European central bank could have done this just as well by accommodating them with its *own* currency: that would increase the world money supply to allow a gold flow to America with no increase in the worldwide interest rate level.

I argue that such conclusions are unwarranted, for two reasons.

First, one should not assume UIP held between New York and London. One must consider the

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[6] There are no comprehensive time series on commercial paper rates outside New York City but there is reason to believe they were closely tied to New York rates. Hinterland banks could and often did buy commercial paper in the New York

possibility of "imperfect international capital mobility." Imperfect capital mobility differs from UIP in that the premium between expected returns on domestic *versus* foreign assets is not exogenous, but rather depends on relative net asset demands of domestic *versus* foreign investors. Essentially, it is the proposition that domestic (foreign) assets are a "preferred habitat" for domestic (foreign) investors. It is similar to the proposition that term or risk premiums across different domestic assets are affected by net demands for particular maturities or for payoffs in particular states of the world, as in the model of Vayanos and Vila (2009). The latter proposition has been the subject of empirical study since the American, British and European economies fell into a liquidity trap in 2008 and central banks attempted to manipulate premiums with "quantitative easing" or "large-scale asset purchases" (LSAPs) (e.g. D'Amico, English, Lopez-Salido and Nelson 2012).

Under imperfect capital mobility, international demand for domestic assets is not perfectly elastic as under UIP, but rather increases with the spread between expected returns to holding domestic assets and expected returns to holding foreign assets, accounting for expected future exchange rates. Imperfect capital mobility is a feature of many "old Keynesian" open-economy models such as Romer (2013). In these models, a central bank can manipulate domestic interest rates even if the exchange rate is fixed. Also, central bank operations in foreign assets are not pointless: they are key to interest-rate control. If the central bank pushes domestic interest rates up to the point that private capital inflow creates a positive balance of payments, authorities must purchase foreign assets. If the central bank pushes the domestic interest rate down, creating a negative balance of payments, authorities must sell reserves of foreign assets. As authorities must eventually run out of foreign assets to sell, a central bank can only temporarily maintain a stance of relatively low interest rates. But a central bank has much more power than under UIP.

Second, *even under UIP*, a gold-standard central bank would have some power to influence domestic interest rates. The connection between domestic and London interest rates was a leash, not a

market. On the commercial paper market and the nature of commercial paper as an asset see James (1978, pp. 102, 174-98).

fixed link. That is because the gold standard did *not* fix exchange rates. In the jargon of modern economics literature, it instead created an exchange-rate "target zone" with "mean-reverting" expectations. An exchange rate could deviate from the gold parity, within the limits determined by the ultimate gold points. At the same time, under normal circumstances the expected value of the exchange rate at some future horizon *was* equal (or close) to gold parity. Thus, the expected future change in the exchange rate at that horizon must have been negatively related to the current deviation of the exchange rate from parity. If the expected exchange rate was equal to parity at a horizon of, say, three months, then a local bill-maturity interest rate could deviate from a London bill rate as much as the current percent deviation of the exchange rate from parity (plus the exogenous liquidity-default risk-transactions cost premium). Keynes (1931) noted that this would give a central bank some control over interest rates under UIP.[7]

Bordo and MacDonald (2005) make the argument in terms of the modern literature on exchange-rate target zones. They examine pre-1914 data on interest rates in London, Berlin and Paris, and exchange rates between these three centers, to judge its practical significance within Europe. They do not examine American data. But the studies of London-New York gold points I cited above suggest that the differential between the current exchange rate and its long-term expected value could be, conservatively, half a percent. Half a percent is negligible relative to other variations in relative goods' prices. But fifty basis points is pretty large relative to other variations in short-term interest rates.

What does all this imply for the powers of a hypothetical central bank in pre-1914 gold-standard America? Assuming UIP held, what possibilities were created by the flexibility of exchange rates within the gold points? Assuming UIP did *not* hold, what further possibilities were created by imperfect international capital mobility?

To answer these questions, in the next section of the paper I lay out a Keynesian open-economy

[7] "a central Bank would be able, by fixing appropriately its forward-exchange rates relative to the spot rates prevailing in the market, to fix in effect different short-term rates of interest for foreign funds and domestic funds" (p. 327).

model with mean-reverting exchange-rate expectations and other specific assumptions to fit the pre-1914 U.S. In the model, the foreign interest rate and the foreign price level are exogenous. Other exogenous factors include shocks to export revenue, to high-powered money demand, to spending (IS shocks) and to international demand for American assets. A potential central bank can engage in open-market purchases of foreign assets or domestic assets, and discounting of domestic assets. The model has two cases: UIP, and imperfect international capital mobility. For each case, I examine the effects of changes in exogenous variables in the *absence* of a central bank; the effects of potential central bank actions; and a central bank's ability to stabilize real activity and inflation in the face of shocks.

To assess the desirability of a possible central-bank action I note its effect on the exchange rate as well as real activity and inflation. All of the actions I consider allow the exchange rate to return to parity eventually, after the dissipation of the exogenous shock that prompted them. Thus, they are all consistent with mean-reverting exchange-rate expectations at a sufficiently long horizon. But actions to stabilize real activity and inflation may have different effects on exchange rates in the short run. Some operate by temporarily pushing the exchange rate *away* from parity. Others tend to push the exchange rate *toward* parity. Other things equal, actions of the second type might be more desirable, because the first type might test the credibility of a country's commitment to the gold standard.

To preview, under UIP a central bank aiming to stabilize real activity and employment can deal with money-demand shocks of any size. The same actions that stabilize the domestic interest rate, real activity and inflation also stabilize exchange rates. A central bank has some ability to insulate the domestic economy from changes in the foreign interest rate, and to adjust domestic interest rates to counteract effects of spending shocks on real activity and inflation. But its ability here is limited - it can counteract only relatively small shocks - and it can do so only with actions that tend to drive the exchange rate away from parity. However, just as in a Mundell-Fleming model, central-bank purchases of foreign assets are pointless. They have no effect on the exchange rate, the domestic interest rate or macroeconomic conditions.

Under imperfect capital mobility, as one would expect, a central bank has more power. It can deal with changes in the foreign interest rate and spending shocks of any size, as well as counteract all money-demand shocks. Also, central-bank purchases of foreign assets are not pointless: they affect the exchange rate and macroeconomic conditions.

Two points are especially important for my argument later on. First, in the absence of a central bank, export-revenue shocks affect the interest rate, real activity and inflation *only under imperfect capital mobility*. Second, under imperfect capital mobility there is a correspondence between central bank actions that stabilize real activity and inflation, and central bank actions that stabilize the exchange rate. *Central bank actions that stabilize real activity and inflation tend to stabilize the exchange rate, and vice-versa.*

2) Model

2.1) Assumptions

The model consists of a balance-of-payments equation; a negative relation between the current account and the relative price of domestic value-added; a money-demand function; an open-economy IS equation (real activity depends on the relative price of domestic value-added as well as the domestic real interest rate); and a Phillips curve. To fit the pre-1914 U.S., expected future inflation is always close to zero and, in the absence of a central bank, the money supply is affected by the balance of payments through international flows of monetary gold. It is an "old Keynesian" model in that the IS equation and Phillips curve are not explicitly forward-looking. But these equations are consistent with a conventional open-economy New Keynesian model, if agents forecast future real activity based on current real activity as an AR(1).[8]

[8] For an example see Hanes (2013). This assumption about expectations is unconventional but more realistic than conventional rational expectations. Of course, much standard New Keynesian microstructure is a bad fit for the pre-1914 economy, such as capital markets that allow households to borrow against future labor income and insure against idiosyncratic income shocks. So I do not think there is much to be gained by going further down this road.

Under the gold standard, the international inflow of monetary gold to a country through private channels was equal to the balance of payments *less* official purchases of gold or financial assets in foreign markets. The balance of payments is equal to the sum of the country's net exports, international capital inflow, foreign investment income and a few other items (such as foreign remittances). Gold inflow through private channels automatically affected a country's money supply unless it was sterilized by an offsetting change in the supply of nongold currency and central-bank balances. To describe this, the change in the real money supply from one period to the next is:

$$(1) \qquad \Delta(m - p) = g + z - \Delta p$$

where g is the international inflow of monetary gold through private channels. z represents the effects of other money-supply factors. Both variables are expressed as a fraction of the previous period's high-powered money supply. The relation between g and the balance of payments is:

$$(2) \qquad g = ka + ca - rg$$

where ka and ca are real values of net capital inflow and the current account, scaled by the average magnitude of their fluctuations relative to trend money growth. rg is the increase in authorities' stocks of foreign financial assets or gold purchased in foreign markets, scaled in the same way.

Most potential actions of a central bank can be described by z and rg. An open-market purchase of domestic assets paid for with gold or currency from central bank vaults, or with a write-up of reserve balances, is an increase in z. So is a change in the terms of central bank discounting, such as a decrease in the discount rate, that boosts the volume of discounting at a given market interest rate.[9] A central-bank purchase of foreign exchange, foreign financial assets or gold in foreign markets corresponds to an increase in rg. If the purchase is unsterilized, the increase in rg is accompanied by an

[9] Changes in the terms of central bank discounting can also affect demand for high-powered money, for example by affecting banks' incentive to hold extra reserve balances to avoid unpredictable shortfalls (overdrafts or failure to meet reserve requirements) in their reserve accounts. The nature of the relationship between discounting terms and reserve demand depends on rules governing reserve accounts and central bank discounting. I ignore this, though it should be clear that it would have similar effects to z.

increase in z. For simplicity, I assume that z and rg are zero in the absence of a central bank.

To describe the exchange rate, e is the percent deviation from parity of the exchange rate on London (the dollar price in New York of a claim to a pound in London). I assume the international supply of gold to (from) the U.S. is perfectly elastic when e is at its lower (upper) bound. Between the ultimate bounds there is a negative relationship between e and g. For simplicity this relationship between e and g is linear and the range around parity is symmetric. x is the maximum range around parity as a percent of parity, somewhere between fifty basis points and one percent. Thus:

$$(3) \qquad e = -\sigma g \quad \text{for} \quad -\sigma/x \leq g \leq \sigma/x$$

$$e = -x \quad \text{for} \quad \sigma/x \leq g$$

$$e = x \quad \text{for} \quad g \leq -\sigma/x$$

All gold-standard central banks made occasional use of strategems to manipulate gold points called "gold devices," such as providing interest-free loans to gold shippers or making it hard to get gold from the central bank in exchange for currency or reserve balances. Gold devices affect x. Though everyone used them, they were considered vaguely indecent by pre-1914 central bankers and financiers. I assume the gentlemen running an American central bank would be above the use of such things.

$E\Delta e$ is the expected future change in the exchange rate over the maturity of a London bill. To describe mean-reverting expectations,

$$(4) \qquad E\Delta e = -\rho e + \varepsilon^{SR} \quad \text{where } 0 < \rho \leq 1$$

ρ is financial market participants' guess at the serial correlation in the deviation of the exchange rate from parity. If they believe deviations from parity dissipate within the maturity of a bill, $\rho = 1$. If they believe deviations from parity can persist a long time ρ is closer to zero. If financial market participants have rational expectations, the value of ρ must be consistent with the *realized* behavior of the exchange rate. I will return to this point later. ε^{SR} allows for other factors affecting exchange-rate expectations. In the pre-1914 U.S., one such factor was "silver risk" - a perceived probability the U.S. would link the dollar to silver and float against gold. I will not say any more about silver risk in this section, as my hypothetical central bank operates in an environment without it. But it will be important to account for later on.

The current account is net exports *less* the net outflow of factor payments and transfers. Net exports might be affected by fluctuations in real activity through demand for imports, and by the relative price of foreign goods. The latter depends on the domestic nonagricultural price level, the foreign price level, and the exchange rate. I ignore the last factor on the assumption that brief exchange-rate fluctuations between half a percent and one percent were not large enough to make a substantial difference to the relative price of foreign goods. I describe deviation from trend in the current account as:

$$(5) \qquad ca = -\alpha y - \varphi(p - p^*) + \varepsilon^{CA}$$

where y is deviation from trend in nonagricultural real activity, p is the price level of domestically-produced final output and p^* is the price level of final output produced abroad. ε^{CA} represents other factors affecting net exports. One such factor would be fluctuations in foreign real activity which affect demand for American exports. Another would be exogenous factors affecting the domestic supply or world price of American export goods.

Demand for money (recall I mean high-powered money specifically) is related to short-term nominal interest rates and real activity in the usual way:

$$(6) \qquad m - p = \mu y - v i + \varepsilon^{md}$$

where $(m-p)$ is deviation from trend in real balances and i is deviation from trend in the short-term rate that is banks' opportunity cost of holding money, indicated by commercial paper or time money rates. ε^{md}, the money-demand shock, represents all other factors affecting money demand, including events in the agricultural sector.

The relationship between interest rates, real activity and inflation is governed by a constraint on long-run trend inflation imposed by the gold standard. In the long run, the gold-standard world price level was determined by the balance between world gold production, growth in real output and financial innovations that affected the relation between output and demand for monetary gold. The price level trended slighty downward over the 1880s and slightly upward after the mid-1890s, but there was little, if any serial correlation in inflation from year to year. Judging from the behavior of interest rates, expected inflation at both long and short horizons was always close to zero and remarkably unresponsive to economic events (Barsky, 1987; Barsky and Delong, 1991; Bordo and Dewald, 2001). In terms of standard macroeconomic models, the expected long-run steady state rate of wage and price inflation was always close to zero.

Under these conditions, a shock to nominal interest rates meant a shock to real interest rates. Thus:

$$(7) \qquad y = -\tau i - \eta (p - p^*) + \varepsilon^{IS}$$

Matching (5) I allow for an effect of the relative American price level on the volume of spending directed to domestic output (and foreign demand for American exports). ε^{IS} accounts for exceptions to the usual pattern for expected inflation, which would affect the relation between the nominal and real interest rates. It also accounts for "IS shocks" such as extraordinary disturbances to the operation of financial intermediaries, which would affect the supply of credit to potential borrowers (Woodford, 2010).

With long-run expected inflation always close to zero, an expectations-augmented Phillips curve of either the old-Keynesian or New-Keynesian variety implies a positive relation between inflation and output along the lines of the original Phillips curve (Alogoskoufis and Smith, 1991, Hanes 2013), which is in fact observed in empirical studies of American wage and price inflation in the pre-1914 era (Gordon, 1990, Hanes, 1999). Thus:

$$(8) \qquad \Delta p = \xi y$$

For simplicity, I do not allow for a disturbance term in the Phillips curve - a "supply shock" - but it should be obvious that adding one would not affect my argument.

International investors and American borrowers compare short-term interest rates in New York, or expected short-term returns to holding long-term American securities, with the sum of the London bill rate and the expected increase in the exchange rate (dollars per pound) over the bill's maturity. The London bill rate is the sum of a long-run steady-state value and a deviation i^* (matching the definition of i as deviation from trend in the domestic rate). International investors compare i with $(i^* + E\Delta e)$.

Under UIP demand for American assets is perfectly elastic at a required expected return, in sterling, equal to i^* *plus* a premium ε^{diff} that compensates for differences in liquidity, default risk and/or transactions costs between London bills and commercial paper or time money. Thus:

$$(9) \quad i = i^* + E\Delta e + \varepsilon^{diff}$$

Net capital inflow *ka* can take any value subject to (9).

Under imperfect capital mobility demand for American assets is elastic but not perfectly so. The interest-rate premium between American and European assets depends on relative net asset demands of Americans *versus* Europeans. Thus:

$$(10) \quad ka = \gamma\Delta\,(i - i^* - E\Delta e - \varepsilon^{diff})$$

i^*, ε^{SR}, ε^{CA}, ε^{md}, ε^{IS} and ε^{diff} are all exogenous variables. Each evolves with a degree of serial correlation and a long-run steady-state value of zero. Given *z, rg* and a value for ρ, expressions (1)-(8) along with either (9) or (10) determine the endogenous variables, including the exchange rate. Because the long-run expected value of all exogenous variables is zero, in the absence of a central bank it is generally true that the expected value of *e* is zero at some sufficiently long horizon. That confirms an expectation that the exchange rate reverts to parity.

With a central bank, the realized behavior of the exchange rate will be affected by the behavior of *z* and *rg*. Thus, ρ is not invariant across different central bank practices. However, as all of the actions I consider allow the exchange rate to return to parity in the long run, they are all consistent with a positive value for ρ , which is all that matters for my purposes.

2.2) Outcomes and potential central bank powers

To simplify the expressions below, I take the foreign inflation rate Δp^* to be exogenous and equal to zero, and assume all other variables were at their trend values in the prior period (that is I set $(p - p^*)_{-1}$, y_{-1} , i_{-1} and $(m-p)_{-1}$ at zero).

Under UIP or imperfect capital mobility, given the domestic interest rate i , output and inflation are:

$$(11) \quad y = - \beta_1 i + (\beta_1 / \tau) \varepsilon^{IS} \text{ where } \beta_1 = \tau /(1+ \gamma\xi)$$

$$(12) \quad \Delta p = - \beta_2 i + (\beta_2 /\tau) \varepsilon^{IS} \text{ where } \beta_2 = (\tau\xi) / (1 + \gamma \xi)$$

the current account is:

$$(13) \quad ca = \beta_3 i - (\beta_3 / \tau) \varepsilon^{IS} + \varepsilon^{CA} \text{ where } \beta_3 = (\alpha + \varphi \xi) \beta_1$$

high-powered money growth is:

$$(14) \quad \Delta m = - \beta_4 i + (\xi + \mu)(\beta_1 /\tau)\varepsilon^{IS} + \Delta\varepsilon^{md} \text{ where } \beta_4 = \beta_1 (\xi + \mu) + \nu$$

gold inflow is:

$$(15) \quad g = \Delta m - z$$

the exchange rate is:

$$(16) \quad e = - \sigma(\Delta m - z) \quad \text{for} \quad -\sigma/x \leq \Delta m - z \leq \sigma/x$$

$$e = -x \quad \text{for} \quad \sigma/x \leq \Delta m - z$$

$$e = x \quad \text{for} \quad \Delta m - z \leq - \sigma/x$$

and international capital inflow must be:

$$(17) \quad ka = g - ca + rg$$

A central bank can stabilize output and employment to the degree that it can manipulate the interest rate i through z and/or rg. In response to spending shocks ε^{IS} , a central bank should adjust i

enough to counteract the effect of ε^{IS} on y. In response to all other shocks, the policymaker must be able to hold the interest rate steady - to counteract the effect of the shock on i.

Before I examine the two cases of interest, to show I have nothing up my sleeve I point out that the model gives standard Mundell-Fleming results under UIP and a fixed exchange rate. With $E\Delta e=0$,

$$(18) \quad i = i^* + \varepsilon^{diff} + \varepsilon^{SR}$$

The central bank cannot influence the domestic interest rate with z and rg. Substituting (18) into (11)-(16), one sees that the export-revenue shock ε^{CA} and the money-demand shock ε^{md} do not enter into the determination of y or Δp. ε^{md} affects only money growth, gold inflow and capital inflow. ε^{CA} affects only the current account and capital inflow. z affects only gold inflow and capital inflow. rg affects only capital inflow. All central bank operations are pointless.

Under UIP

Now suppose UIP holds but the exchange rate varies within its bounds and exchange-rate expectations are mean-reverting as described by (4). Then:

$$(19) \quad i = i^* - \rho e + \varepsilon^{diff} + \varepsilon^{SR}$$

This means the domestic interest rate is held within a range around the foreign interest rate:

$$(20) \quad i^* + \varepsilon^{SR} + \varepsilon^{diff} - \rho x \leq i \leq i^* + \varepsilon^{SR} + \varepsilon^{diff} + \rho x$$

The span of the range reflects the maximum possible exchange-rate deviation from parity and the rate at which the exchange rate is expected to revert to parity. Within the range, the interest rate and exchange rate are:

$$(21) \quad i = \beta_5 [(1/\rho\sigma) (i^* + \varepsilon^{diff} + \varepsilon^{SR}) + \Delta\varepsilon^{md} - z + (\xi + \mu)(\beta_1 /\tau)\varepsilon^{IS}]$$

$$(22) \quad e = -\sigma g = (\beta_5 / \rho) [\beta_4((i^* + \varepsilon^{diff} + \varepsilon^{SR}) - \Delta\varepsilon^{md} + z - (\xi + \mu)(\beta_1 /\tau)\varepsilon^{IS}]$$

$$\text{where} \quad \beta_5 = \rho\sigma /(1 + \rho\sigma\beta_4)$$

Given (21), expressions (11)-(17) determine output, inflation, the current account and the money supply. Note that ε^{CA} does not enter (21) or (22). That means export-revenue shocks have no effect on the exchange rate, interest rate, output or inflation. *rg* is also absent from (21) and (22): sterilized central bank purchases of foreign assets are pointless. They do not affect any variable of interest. This is all the same as under UIP with fixed exchange rates.

$\Delta\varepsilon^{md}$ and ε^{IS} *do* enter (21) and (22). That is unlike UIP with fixed exchange rates. In the absence of a central bank, a positive realization of either shock raises the interest rate and lowers *e*. That is because both shocks increase the quantity of money demanded, causing gold inflow. Gold inflow is associated with appreciation of the dollar toward the gold import point. Because the dollar has appreciated, financial market participants expect future depreciation. That is what allows the domestic interest rate to rise.

z also enters (21) and (22). Thus, central bank discounting or open-market operations in domestic assets affect the interest rate, the exchange rate and the macroeconomy. Through *z* a central bank can push the interest rate to the top or bottom of the range given by (20), or hold the interest rate at a desired point within this range.

A central bank that aims to stabilize output and inflation can *entirely* counteract money-demand shocks by setting $z = \Delta\varepsilon^{md}$, that is, by accommodating the money demand shock with open-market operations or discounting. In doing so, it forestalls the international gold flow that would otherwise occur to accommodate domestic money demand. By forestalling gold flow, it also stabilizes the exchange rate. Thus, there is no conflict between counteracting this shock and the gold-standard commitment to parity.

The central bank has only limited ability to counteract other types of shocks: changes in the foreign interest rate i^*, the rate-of-return premium on American assets ε^{diff} and spending shocks ε^{IS}. In the face of spending shocks the value of the interest rate needed to hit the desired levels of real activity and inflation might fall outside the range in (20). In the face of big shocks to ε^{diff} or i^*, it may be impossible to hold i fixed. Also, the actions a central bank would take to stabilize real activity and inflation in the face of these shocks would tend to push the exchange rate away from parity, which may be undesirable.

An increase in i^* or ε^{diff} tends to raise both i and e. (Because the dollar depreciates, appreciation is expected so the increase in i is smaller than the increase in i^*.) To stabilize i the central bank would set $z > 0$. But (22) shows that raises e even further. To keep the domestic interest rate from increasing at all, the central bank must generate more expected future appreciation: to do that it must push the exchange rate even higher (more depreciation) today. Thus, this action pushes the exchange rate even further from parity.

A positive spending shock ε^{IS} tends to raise the domestic interest rate and lower e. (Because the dollar appreciates, depreciation is expected so i can rise relative to i^*.) To stabilize real activity and inflation a central bank would want to further raise the domestic interest rate by setting z less than zero. Looking at (22), one can see that a negative value of z tends to lower e even further. Again, this pushes the exchange rate further from parity.

Under imperfect capital mobility

Finally, suppose international capital mobility is imperfect as described by (16). While the exchange rate is still held within the gold-point bounds, the domestic interest rate is no longer held within a range around the foreign interest rate. But the determination of the interest rate is different depending on whether the exchange rate is at a bound. If the exchange rate is not at a bound, the interest rate and exchange rate are:

$$(23)\quad i = \beta_6 \beta_7 [\, \gamma\, (i^* + \varepsilon^{diff} + \varepsilon^{SR}) + rg - \varepsilon^{CA}] + \beta_7 [\, \Delta\varepsilon^{md} - z + \beta_8\, \varepsilon^{IS}]$$

$$(24)\quad e = -\sigma g = \sigma \beta_4 \beta_6 \beta_7 [\, \gamma\, (i^* + \varepsilon^{diff} + \varepsilon^{SR}) + rg - \varepsilon^{CA}] + \sigma\beta_{10} [- \Delta\varepsilon^{md} + z] + \sigma \beta_{11}\, \varepsilon^{IS}$$

where $\beta_6 = 1 / (1 + \gamma\rho\sigma)$ $\beta_7 = 1 / [(\gamma + \beta_3)\beta_6 + \beta_4]$

$\beta_8 = (\xi + \mu)(\beta_1 /\tau) + \beta_6 (\beta_3 / \tau)$ $\beta_9 = (1 - \mu\gamma)(\beta_1 /\tau) + \beta_6 (\varphi - \alpha\gamma)(\beta_1 /\tau)$

$\beta_{10} = [(\gamma + \beta_3)\beta_6] / [(\gamma + \beta_3)\beta_6 + \beta_4]$ $\beta_{11} = (\xi + \mu)(\beta_1 /\tau) - \beta_4 \beta_7 \beta_8$

If the exchange rate has been driven to one of its bounds, the domestic interest rate is:

$$(25) \quad i = \beta_{12} [\gamma (i^* + \varepsilon^{diff} + \varepsilon^{SR} +(-)\rho x) - z + \Delta\varepsilon^{md} + rg - \varepsilon^{CA} + \beta_8 \varepsilon^{IS} + \beta_9 \varepsilon^{p}]$$

where $\beta_{12} = 1 / [(\gamma + \beta_3 + \beta_4]$

Given (23) or (25), (8)-(11) determine output, inflation, the current account and the money supply.

$\Delta\varepsilon^{md}$ and z enter (23) and (25): again, money-demand shocks affect macroeconomic variables and the central bank can entirely counteract them by setting $z = \Delta\varepsilon^{md}$. (24) shows that in doing so the central bank also stabilizes the exchange rate.

Unlike the UIP case, ε^{CA} and rg also enter (23) and (25). Thus, export-revenue shocks affect the interest rate and exchange rate. Sterilized purchases of foreign assets or gold in foreign markets are not pointless; they affect the domestic interest rate, output and inflation as well as the exchange rate.

In the absence of a central bank, a positive shock to export revenue (increase in ε^{CA}) decreases the interest rate, decreases e (appreciate the dollar) and causes gold inflow. Through the decrease in i, the export-revenue shock boosts real activity and inflation. The central bank can counteract these effects by $rg>0$ (sterilized purchases of foreign assets or gold in foreign markets). Comparing (23) and (24), one can see that the value of rg that stabilizes i also stabilizes e.

An increase in i^* or ε^{diff} tends to raise both i and e. To stabilize i the central bank can set $rg < 0$ (sterilized sales of foreign assets or gold in foreign markets). Again, comparing (23) and (24) one sees that the value of rg that stabilizes i also stabilizes e.

A positive spending shock ε^{IS} tends to raise the domestic interest rate and lower e. To stabilize real activity and inflation a central bank would want to further raise the domestic interest rate. It can do so by $rg>0$ (sterilized purchases of foreign assets or gold in foreign markets). Looking at (24), one can see that $rg>0$ tends to push e back toward zero. To put it another way, if the central bank uses rg to stabilize e in the face of ε^{IS} , it will also be acting to raise the domestic interest rate to stabilize real activity and inflation.

To summarize, under imperfect capital mobility there is no conflict between stabilization of real activity and inflation and the commitment to gold parity, even in the short run. By using both its tools - z and rg - the central bank can counteract all types of shocks while simultaneously stabilizing the exchange rate.

In response to money-demand shocks $\Delta\varepsilon^{md}$, the central bank can use z (discounting, open-market operations or domestic lending) to accommodate money demand. This forestalls the international gold flow that would otherwise occur to accommodate domestic money demand. By forestalling gold flow, it also stabilizes the exchange rate.

In response to all the other shocks, the central bank can use rg (sterilized transactions in foreign assets or gold in foreign markets) to forestall the international gold flow that would otherwise occur in response to these shocks. This stabilizes the exchange rate. It also fixes the domestic money supply, which completely insulates the domestic economy from shocks to the foreign interest rate or demand for American assets, and tends to stabilize the macroeconomy in the face of spending shocks (as in Poole, 1970).

Of course, the use of rg may be constrained by the central bank's stock of foreign assets. The value of rg can be negative only until the central bank runs out of foreign assets or gold to sell in foreign markets.

3) Existing evidence on international capital mobility in the pre-1914 U.S.

So far, I have shown that the tools and powers of a gold-standard central bank would have been greater under imperfect international capital mobility than under UIP. Which case prevailed in the pre-1914 U.S.? In this section I review some previous work on the issue.

3.1) Interest-rate spreads and the gold points

One way to test UIP is to examine data on interest rates and exchange rates, and see if changes in interest-rate differentials between locations can be plausibly accounted for by changes in expected future exchange rates. A number of studies have examined differentials between London bill rates and New York commercial paper or time money rates in the pre-1914 era. UIP implies a differential could not exceed the sum of three factors: first, the risk-liquidity-transactions-cost premium; second, possible future movement in the exchange rate within the ultimate gold points; third, the probability and magnitude of possible future dollar devalution. As I noted above, through much of the pre-1914 era financial market participants believed there was a chance the U.S. would link the dollar to silver and float against gold - "silver risk." It is hard to account for the possible effects of silver risk. It was created by two more-or-less exogenous political events, the 1878 Bland-Allison Act and the 1890 Sherman Silver Purchase Act, but it varied a lot over time and may have been related to macroeconomic conditions.[10] However, silver risk appears to have become negligible after the 1896 presidential election (Friedman and Schwartz, 1982, pp. 513-517).

Studies have shown that London-New York interest-rate differentials far exceeded the possible future movement of the exchange rate within any reasonable estimate of gold points (Morgenstern, 1959; Officer, 1986; Giovannini 1993, pp. 133-136). Silver risk alone cannot account for this, because variations in the differential remained very large long after 1896. Remarkably, a number of studies have found substantial variations in the *covered* interest-rate differential between New York and London (that is, for arbitrage covered by forward exchange-rate contracts or other means that eliminate exchange-rate risk altogether) (Calomiris and Hubbard, 1996; Obstfeld and Taylor 1998, pp. 361-363;

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[10] Sprague (1910, pp. 109-110), Fels (1959, pp. 130-131) and Friedman and Schwartz (1963, pp. 100-101) all argue that an increase in perceived silver risk caused foreign sales of U.S. assets in 1884, but that the increase in perceived risk was triggered by a prior cyclical downturn. Sprague (1910, pp. 162, 165, 168, 179) concluded that silver risk was important in 1893 but it came into play after the financial crisis was already underway. Fels (1959, pp. 184-187) describes silver risk as

Juhl, Miles and Weidenmier, 2005). Thus, the behavior of London and New York interest rates does not give evidence in favor of UIP. At the same time, it does not constitute definitive evidence *against* UIP: unaccounted-for variation in the interest-rate differential could be due to variations in the risk-liquidity-etc. premium.

Foster (1994) finds clearer evidence against UIP in seasonal patterns. Over 1880-1913 there were a number of regular seasonal patterns in exchange rates the London-New York interest differential, which were well-known to contemporary financial market participants. Foster shows that seasonal movements in the interest differential did not match up to seasonal movements in exchange rates as predicted by UIP. For example, the spread between New York commercial paper or time-money rates and London bill rates was highest in the summer, while the exchange rate regularly fell (the dollar appreciated) from summer to fall. Overall, "seasonal exchange rate movements were not working to offset seasonal interest rate differentials" (p. 149).

3.2) Effects of harvest fluctuations

Positive evidence *for* imperfect capital mobility can be found in Davis, Hanes and Rhode (2009) and Hanes and Rhode (2013). These studies examine the response of American financial and macroeconomic variables to year-to-year fluctuations in harvests of America's three main crops, cotton, wheat and corn, in the gold-standard era. Cotton and wheat harvest fluctuations caused variations in American export revenue and money demand. At least some harvest fluctuations, those due to measurable weather events, were fundamentally exogenous. Thus, cotton and wheat harvest fluctuations, especially those due to weather, demonstrate effects of export-revenue and money-demand shocks on the American economy.

Cotton and wheat were export crops. Their harvest fluctuations were positively related to export revenue because world prices were not too sensitive to American production. Their harvest fluctuations may also have been positively related to American money demand, for some of the same

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a factor that interacted with the cyclical downturn, but did not cause it.

reasons American money demand spiked in the harvest season - farmers and farm laborers held crop sale income in cash hoards to cover expenses over the following year. Corn was the most important crop by production value, but relatively little was exported or even sold off the farm where it was grown (it was used as animal feed). So corn harvest fluctuations were unrelated to export revenue and perhaps unrelated to money demand.

If UIP held, the money demand shocks associated with cotton and wheat harvest fluctuations should have created positive correlations between harvests, money-supply growth and gold inflow, negative correlations with the New York-London exchange rate, and positive correlations with the spread between New York interest rates and London rates. (Gold inflow to accommodate money demand would be associated with dollar appreciation. The resulting expected future depreciation would raise American interest rates relative to London rates.) But the export-revenue shocks would not matter.

Under imperfect capital mobility, the effects of money-demand shocks would be more or less the same as under UIP, but export-revenue shocks would matter too. They would tend to reenforce the effects of the money demand shock on money-supply growth, gold inflow and the exchange rate. But export-revenue shocks would tend to create a negative correlation between harvest fluctuations and the interest-rate spread. If the export-revenue effect dominated, the interest rate spread would be negatively correlated with exogenous harvest fluctuations. If the two effects cancelled out, harvest fluctuations would be uncorrelated with the interest-rate spread.

Davis, Hanes and Rhode (2009) find that corn harvest fluctuations were unrelated to any of these variables. Wheat harvest fluctuations were positively related to money growth and gold inflow, and negatively related to the exchange rate and unrelated to the interest-rate spread. Cotton harvest fluctuations were positively related to money growth and gold inflow, negatively related to the exchange rate, and negatively related with the interest-rate spread. These patterns hold for harvest fluctuations in general and also for fluctuations specifically due to weather (that is, using weather variables as instruments for harvest fluctuation in 2SLS). Imperfect capital mobility can account for all of these patterns. Cotton harvest fluctuations were negatively related to the the interest-rate spread because their effect on money demand was small relative to their effect on export revenue. For wheat, money-demand effects were stronger relative to export-revenue effects, so there was no net effect on the interest-rate spread. UIP cannot possibly account for the negative effect of cotton harvest fluctuations on the interest-rate spread.

4) New evidence for imperfect capital mobility

In this section I present new evidence on the nature of capital mobility in the pre-1914 U.S. I examine the effects of American harvest fluctuations, and one type of exogenous shock to the London bill rate, on the *ex post* spread between the New York commercial paper rate and the dollar return to holding London bills. This is the spread accounting for the *realized* change in the exchange rate over the life of the bill. I argue that imperfect capital mobility implies the ex post spread is negatively correlated with exogenous shocks to export revenue; positively correlated with exogenous shocks to money demand; and negatively correlated with exogenous shocks to the London bill rate. UIP implies the ex-post spread is uncorrelated with any of these factors, unless the factor is correlated with the liquidity-default risk-transactions cost differential or with an unrealized devaluation risk - a "peso problem" - such as silver risk.

I assume cotton harvest fluctuations created exogenous shocks to export revenue and relatively small shocks to money demand; wheat harvest fluctuations created shocks to export revenue accompanied by relatively large money-demand shocks; and corn harvests affected neither. Thus, I take imperfect capital mobility to imply fluctuations in the harvest of cotton, but not wheat or corn, should be negatively correlated with the *ex post* spread. My shock to the London bill rate is, following Barro (1987), deviation from trend in British military spending, which was positively correlated with London bill rates and also presumably exogenous to American economic conditions. Thus, I take imperfect capital mobility to imply British military spending is negatively correlated with the ex post spread.

I find that the ex post spread was in fact negatively related to cotton harvest fluctuations, unrelated to wheat or corn harvest fluctuations, and negatively related to British military spending. This is consistent with imperfect capital mobility. To account for these results under UIP, one could perhaps argue that cotton harvest fluctuations were correlated with silver risk and/or the liquidity-etc. premium through the harvest's effect on American macroeconomic conditions. But I do not see how one could argue these factors were affected by British military spending.

4.1) Predictions of UIP versus Imperfect Capital Mobility for the ex post spread

The ex post spread is equal to the ex ante, expected spread minus the error in financial market participants' expected value for the change in the exchange rate over the relevant maturity:

(26) $$i - i^* - \Delta e = i - i^* - E\Delta e - (\Delta e - E\Delta e)$$

Within a historical sample, the error must be uncorrelated with information available to financial market participants - variables observable at the time - if expectations are rational *and* the distribution of realized changes in the exchange rate spans the distribution of possibilities that were rationally considered *ex ante*. Because of silver risk, the latter condition does not hold in a sample that includes years prior to 1897. Sticking provisionally with rational expectations, I describe the error as:

(27) $$\Delta e - E\Delta e = -\varepsilon^{SR} + \varepsilon^{Ee}$$

ε^{SR} may be correlated with observable variables, even if the remaining component ε^{Ee} is not.

Under UIP the ex ante spread satisfies (9) so the ex post spread is:

(28) $$i - i^* - \Delta e = \varepsilon^{diff} + \varepsilon^{SR} + \varepsilon^{Ee}$$

An observable variable should be correlated with the ex post spread only if it is correlated with ε^{diff} or ε^{SR}.

Under imperfect capital mobility, the ex ante spread, and hence the ex post spread, can be affected by many more variables. In the pre-1914 U.S., with money supply growth tied to the balance of payments, a positive export-revenue shock would tend to decrease the spread; a positive money-demand shock would increase the spread; an increase in the foreign interest rate would decease the spread. In the model presented above, when the exchange rate is between the bounds:

(29) $-1 < \partial(i - i^* - E\Delta e)/\partial i^* = -(\beta_3 + \beta_4)\beta_6\beta_7 < 0$

(30) $\partial(i - i^* - E\Delta e)/\partial\varepsilon^{CA} = -(1/\gamma)[1 - (\beta_3 + \beta_4)\beta_6\beta_7] < 0$

(31) $0 < \partial(i - i^* - E\Delta e)/\partial\varepsilon^{md} = (1/\gamma)[1 - (\beta_3 + \beta_4)\beta_7]$

The effects are only stronger when the exchange rate is at one of its bounds.

4.2) Data

I calculate the ex post spread from the standard monthly series on New York commercial paper (Macaulay,1938) and the standard monthly series for London open-market bill rates (averages of from weekly data in the *Economist*). I take the exchange rate from Neal and Weidenmier (2003). Appendix 2 gives details.

A "harvest fluctuation" is the deviation from a quadratic trend 1866-1913 of the log of the year's crop production (the harvest that comes in the autumn of the year), as described in Davis, Hanes and Rhode (2009).

"British military spending" is the deviation of annual Army, Navy and Ordnance spending (Mitchell, 1988, p. 588), as a share of the year's annual British nominal GNP (Feinstein's estimates taken from Mitchell, 1988, p. 828), from a quadratic trend over 1880-1913.

4.3) Specification and results

The British military spending series is annual. Harvests were of course fundamentally annual events. The harvest season began in July. My main LHS variable is the ex post spread averaged over the twelve months from the beginning of the harvest season through the month prior to the beginning of the following harvest season, that is from July through June of the following year. My main RHS variables are cotton harvest fluctuations and the British military spending deviation-from-trend. The military spending variable is for years ending in March; I match the interest-rate average ending in June of a year to military spending ending in March of the same year. As Friedman and Schwartz

(1982) show, there was a large decrease in the average level of American interest rates relative to British rates around 1896. It is tempting, but not necessarily correct, to explain this as a consequence of a decrease in silver risk.[11] Whatever the reason for it, I include a dummy variable that takes the value one beginning with the twelve months ending in June 1897.

I examine one sample that includes all years beginning with the harvest of 1879 (the first harvest under the gold standard) through June 1914 (harvest of 1913) to avoid the financial disruptions associated with the outbreak of the First World War. To make sure that my results are not due to specific factors associated with financial panics, which could obviously be associated with fluctuations in silver risk ε^{SR} and the liquidity etc. premium ε^{diff}, I also examine a sample that excludes the July-to-June spans containing the months of New York financial panics. On the standard definition (general runs on New York city banks, as indicated by issuance of loan certificates by the New York Clearinghouse) these were in May 1884, November 1890, May or June 1893, and October 1907 (Wicker, 2000). Calomiris and Gorton (1991) additionally classify as a panic October 1896 (when the Clearing House authorized ceriticates but did not issue any).

Before I examine the ex post spread, I make sure that my British military spending variable was indeed related to the London bill rate within my sample. Table 1, columns (1) and (2) show results of regressing the bill rate, July through June average, on the spending variable, with and without quadratic time trends. Either way the coefficient on spending is positive and significantly different from zero at the one percent level.

The remaining columns of the table show results for the ex post spread. In both samples, the coefficient on British military spending is negative and significant at the one percent level; the cotton harvest is negative and significant at the three percent level or better.

5) The potential role of an American central bank

[11] If the change in the interest rate differential were due to a decline in silver risk, one might expect to observe an increase in net capital inflow to the U.S. around the same time. In fact, the opposite occurred. Prior to the mid-1890s the U.S. was a net capital importer most years. Starting around 1896 the U.S. was a net capital exporter most years. Under imperfect

I have shown the pre-1914 American economy was subject to imperfect international capital mobility. I have argued that means a central bank would have had great power to stabilize real activity and inflation. It could do so through actions that would also tend to push the exchange rate toward parity, so there was no conflict with the fixed gold rate even in the short run. In response to money-demand shocks ($\Delta\varepsilon^{md}$), the right action was accommodation with money from central bank vaults or creation of reserve balances through discounting, domestic lending or open-market operations in domestic assets ($z = \Delta\varepsilon^{md}$). In response to transient shocks of other types (spending or IS shocks, export revenue, foreign interest rates, or international demand for American assets - ε^{IS}, ε^{CA} , i^*, ε^{diff}) the right action was transactions in foreign assets or gold in foreign markets (*rg*) to forestall international private gold flows and hence stabilize the money supply. I say "transient" because sales of foreign assets or gold ($rg < 0$) were constrained by the size of reserves of foreign assets or free gold (gold in excess of requirements to cover central bank liabilities). A central bank could not do any good in the face of a *persistent* increase in the London interest rate (i^*), decrease in foreign demand for American assets (hike in ε^{diff}) or decrease in export revenue (decrease in ε^{CA}).

In this section, I examine the shocks that caused the era's major American depressions, and actual practices of the era's central banks. I argue that most American depressions were caused by transient shocks to export revenue and money demand. I observe that pre-1914 central banks acted to accommodate domestic money-demand shocks. Except for the Bank of England, they also used reserves of free gold and foreign assets to stabilize exchange rates and forestall private gold flows. Thus, an American central bank would have prevented most depressions if it had merely followed the examples of other central banks.

5.1) Causes of American business cycles in the 1879-1914 era

capital mobility, such a change in the balance of capital flow, if due to exogenous factors, could cause a decrease in the American interest-rate spread.

There were seven or eight major depressions between 1879 and 1914. According to the NBER's business cycle chronology for the pre-1914 era and modern studies of industrial production data (Romer, 1994; Davis, 2006), major downturns occurred in 1884, 1893, 1896, 1904, 1907, 1910 and 1914. The NBER chronology identifies another major downturn in 1890 but annual IP shows a growth slowdown rather than absolute decline. The downturns of 1884, 1893, 1896 and 1907 were associated with New York bank panics, which can best be understood as consequences rather than independent causes of the downturns (Calomiris and Gorton, 1991; Hanes and Rhode, 2013).

The downturns of 1907 and 1914 and the slowdown of 1890 were due mainly to exogenous hikes in foreign interest rates (i^*), perhaps accompanied by increases in the premium Europeans demanded to invest in American assets (ε^{diff}). In all three cases the foreign financial disturbances persisted for many months, so an American central bank could not have done much about them. 1890 was the year of the Barings Crisis in London. In 1914, the outbreak of the First World War was associated with increases in European interest rates as well as unprecedented disruptions to financial institutions (such as the closure of the New York Stock Exchange for more than four months). 1907 followed sharp hikes in European interest rates due to tightening by the Bank of England and other European central banks. Accounts generally agree that European central banks took these actions in response to persistent gold outflows starting in the second half of 1906. Odell and Weidenmier (2004) argue that these gold outflows from Europe were due to international financial transactions associated with payments by European insurance companies liable for damage from the San Francisco earthquake of April 1906.

But four downturns - 1884, 1893, 1896 and 1910 - were caused by poor cotton harvests, which were fundamentally transient events. Davis, Hanes and Rhode (2009) show that cotton harvest fluctuations were negatively related to New York commercial paper rates, as well as to the spread of commercial papers rates against London bills, because London bill rates were unrelated to American harvest fluctuations. Hanes and Rhode (2013) show that this was just part of a general effect on required returns to American assets: cotton harvests also affected long-term bond yields and stock prices. With a lag of about six months, cotton harvest fluctuations affected real activity. Cotton harvests and cotton export revenues were extremely poor in the autumns of 1888, 1892, 1896 and 1910, due to weather conditions and/or pest depredations. The timing of the subsequent downturns is consistent with the general macroeconomic effects of cotton harvests and the usual time-lag between disturbances to interest rates and declines in real activity.

5.2) What pre-1914 central banks actually did

Pre-1914 financiers and central bankers often described central bank policy in terms of "internal drains" and "external drains." An internal drain was a situation when domestic banks were bringing lots of bills to the discount window and withdrawing reserve balances into currency, but there was no drain of gold to abroad through private channels - the exchange rate was not being pushed to the gold export point - and no extraordinary demand of gold from the central bank in exchange for currency or reserve balances. In the model presented above, under imperfect capital mobility *or* UIP, these conditions result from a positive shock to money demand (an increase in ε^{md}).

It was generally agreed that a central bank should respond to an internal drain by holding its discount rate fixed and accommodating the increase in money demand with a release of currency and/or gold from its vaults into domestic circulation - actions corresponding to an increase in z. This is what American proponents of a central bank meant by the provision of an "elastic currency." They expected an American central bank to respond in this way to agricultural money-demand shocks. Paul Warburg (1908, pp. 126-27) of Kuhn, Loeb, an important central bank proponent, attempted to explain how European central banks accomplished this through discounting, in his contribution to a pro-central bank lecture series at Columbia University in 1907-08:

> It is one of the main duties and privileges of the government banks [that is, central banks] to buy legitimate commercial paper, with bankers' acceptances or bankers' endorsements. As the government banks buy this paper, the circulation of the notes which they issue in payment increases, and on the other hand, as they collect this paper upon maturity and reduce their discounts, their outstanding

circulation decreases.

After noting that there were times when a central bank should respond to an increase in discounting by raising its rate, he said:

A distinction is, however, carefully to be drawn between the abnormal crisis and what we may call the normal emergency which arises regularly in consequence of certain economic developments, like crop movements or particular requirements for special industries at fixed periods, and which, as experience has shown, subside after a time as regularly as they occur. When these normal emergencies arise, the [central] banks do not unduly raise their rates, but, for the time being, meet all the requirements at a given rate, and allow their circulation to increase, while the reserves go down.

It is reasonable to suppose that a pre-1914 American central bank would have held its discount rate fixed in the autumn to accommodate the seasonal increase in money demand, as the Federal Reserve banks in fact did after 1914. Importantly, this would mean that the central bank would also accommodate year-to-year variations in harvest-related money demand due to harvest fluctuations.

An external drain was a drain of gold abroad through private channels as the exchange rate was pushed to the gold export point, accompanied by extraordinary demand for gold from the central bank in exchange for currency or reserve balances. In the model presented above, under imperfect capital mobility or UIP, these conditions result from an increase in foreign interest rates (an increase in i^*) or an exogenous increase in the premium on domestic assets (ε^{diff}). Under imperfect capital mobility only, they could also result from a negative shock to export revenue (a decrease in $\varepsilon^{C.A.}$)

European central banks differed in their response to external drains. The Bank of England held no reserves of foreign assets and very small free reserves of gold. In response to a gold drain, it generally allowed the domestic interest rate to rise and hiked its discount rate (Bloomfield, 1959, p. 17). From the British point of view, these were the gold standard's "rules of the game." The Bank followed these rules even when it came to the regular, predictably temporary "autumnal drain" of gold to America and other agricultural countries (Hawtrey, 1938, p. 120-121; Keynes, 1930, p. 230). An American central bank following the example of the Bank of England would not have acted to counteract the effects of shocks to export revenue or foreign interest rates.

But there were better examples to follow. Continental central banks held reserves of foreign assets and free gold that were large relative to fluctuations in the balance of payments. Frequently, they used them to stabilize exchange rates (Patron, 1909, pp. 134-35; 145; United States National Monetary Commission, 1910, pp. 165-72). At least sometimes, their explicit goal was to stabilize domestic interest rates.

In a study of the pre-1914 Reichsbank, McGouldrick (1984) concludes that its proximate goal was the stabilization of the mark exchange rate on London, and it often used all of its tools to this end. The Reichsbank sometimes held its discount rate fixed in the face of gold drains due to increases in London bill rates, because it believed London bill rates would soon come down again. In late 1889, in the run-up to the Barings crisis, the Reichsbank was faced with a gold drain and high demand from its discount window. It was "urged to follow the example of the Bank of England, which in the last days of the year had raised its discount rate to 6 per cent...The officials of the Reichsbank believed, however, that, with the relief to be expected in the first weeks of the new year, they would be able to spare the business world such an unusual increase of its interest rate", and continued to supply funds at an unchanged discount rate (United States National Monetary Commission, 1910, p. 254).

The Bank of France did not set quite so good an example. It was maniacally devoted to holding its discount rate fixed and perversely held the mass of its foreign reserves in gold rather than interest-earning foreign assets. It was, however, ingenous in using its massive gold reserve to stabilize the exchange rate on London by forestalling private gold flows. A demand for gold anywhere in the world eventually drained gold from London. Ordinarily, that forced the Bank of England, which held little free gold reserve, to tighten and raise London bill rates. An increase in London bill rates would in turn draw gold from France by depreciating the franc to the export point, and put pressure on the Bank of France to raise its discount rate. The Bank of France could short-circuit this process by lending gold to the Bank of England, and it did so on a number of occasions. In 1907, the Bank of England was tightening due to gold drains mainly to the U.S. The Bank of France ingenously found a way to sell gold *directly to the U.S.* despite the absence of an American central bank to be the counterparty. It gave gold to American counterparties in exchange for French-currency assets held by Americans (trade bills on Paris that had paid for American cotton exports to France) (Conant, 1927, p.716; Rodgers and Payne, forthcoming).

I do not claim that continental countries were subject to important export-revenue shocks or necessarily subject to imperfect international capital mobility, like the U.S. But an American central bank with tools and goals similar to those of continental central banks could have easily forestalled the effects of export-revenue shocks on exchange rates and gold flows, and thereby prevent their effects on real activity and inflation.

6) Conclusion

America suffered horribly from its lack of a central bank in the pre-1914 gold standard era. An American central bank that accommodated internal drains and forestalled external drains to stabilize exchange rates, like the Bank of France and the Reichsbank, would have blocked the effects of harvest-related export-revenue and money-demand shocks on American interest rates. That would have prevented most of the era's worst depressions. The crux was imperfect capital mobility between New York and London. That was why export-revenue shocks had devastating effects on American macroeconomic conditions in the absence of a central bank. It was also what would have given a central bank the tools to deal with export-revenue shocks: unsterilized operations in foreign assets or gold in foreign markets.

To be sure, none of this means the international gold standard was a good monetary framework. The same mechanisms that would have allowed an American central bank to deal with transient export-revenue shocks before 1914 made for trouble in the reconstituted gold standard of the 1920s. They allowed a central bank to maintain domestic interest rates at a persistently high level, through continued sterilized purchases of foreign assets and gold from abroad. The new Federal Reserve system's leaders followed such a policy over much of the decade in order to stabilize American inflation (Meltzer, 2003; Orphanides, 2003). The Bank of France followed a similar policy. The pile-up of gold in these two countries tended to reduce the volume of money and nominal demand across the gold-standard world, which became awkward after 1929 (Eichengreen, 1992).

Appendix 1: Data sources

General note: "NBER" refers to the National Bureau of Economic Research Macro History database (http://www.nber.org/databases/macrohistory/)

Commercial paper rate. NBER 13002, from Macaulay (1938, appendix Table 10).

New York – London exchange rate: Neal and Weidenmier (2003) collected weekly-frequency New York bid and ask prices for London exchange from the New York *Commercial and Financial Chronicle*. Weidenmier kindly provided these data (at the time of this writing, available on his website ebutts05.tripod.com/nealweidenmiergsd). I calculate monthly averages of the bid-ask mean, for sight exchange. For most weeks, the *Commercial and Financial Chronicle* gave exchange rates as dollar prices per pound sterling. For some weeks in January 1881, exchange rates were given as percent of par value, during a short-lived effort by foreign-exchange dealers to shift the market to quotations on that basis (Myers 1931, p. 347). For these weeks, we assumed a par value of $4.8665. We corrected the *Commercial and Financial Chronicle* quote for January 8, 1881, faithfully reproduced in the Neal-Weidenmier database. This was the first week that exchange dealers gave quotes as percent of par, and the *Chronicle* wrongly recorded the percent figures as dollar figures. (Converted to dollars, the values for this week are bid 4.8242, ask 4.83.) For months prior to January 1880, sight exchange rates taken from Schneider, Schwarzer and Zellfelder (1991, p. 330).

London bill rate: From weekly data in The Economist, taken from NBER series 13016.

Cotton, wheat and corn production: Carter et. al. (2006), series Da696, Da718, Da756.

Appendix 2: calculation of ex post spread

I calculated the ex post spread at a monthly frequency as d_{us} - d_{uk} , where d_{us} is MacAulay's monthly average commercial paper rate and d_{uk} is the return in dollars to holding London bills over the same maturity, converted at the sight exchange rate. MacAulay's series is an average of commercial paper rates as quoted in American markets and recorded in commercial publications. These are discount rates on a 360-day year, as is conventional in the U.S. If the payoff on the bill at maturity is *F*, the market price is *P*, and the number of days on the bill is *t*, this discount rate is:

$$d = (Y/t)\,[1 - (\$P/\$F)]$$

with Y = 360. To get d_{uk} , I applied the same formula to an estimate of the dollar price/payoff ratio for the hypothetical London bill investment: $(\$P/\$F)_{UK} = (£P/£F)\,(e/e_{+90})$

(£P/£F) is the sterling price/payoff (e/e_{+90}) is the ratio of the exchange rate to the realized exchange rate ninety days hence. London bill rates in the standard *Economist* series are discount rates on 365-day year (as is the practice in London), so I calculated *(£P/£F)* using the above formula but setting Y=365. To get a monthly number for (e/e_{+90}), I took *weekly* data for the exchange rate, calculated (e/e_{+90}) on a weekly frequence, and took the monthly average.

Table 1: Ex post interest-rate spreads, American harvests and British military spending

Coefficient
[robust (White) standard error]
p-value

LHS variable	i^*		$i - i^* - \Delta e$ Full sample		Excluding panics	
	(1)	(2)	(3)	(4)	(5)	(6)
British military spending	31.91 [8.27] *0.00*	32.08 [8.28] *0.00*	-29.17 [6.22] *0.00*	-32.22 [6.08] *0.00*	-29.37 [6.66] *0.00*	-32.51 [6.53] *0.00*
Cotton harvest			-2.65 [1.00] *0.01*	-2.88 [1.04] *0.01*	-2.58 [1.10] *0.03*	-2.93 [1.18] *0.02*
Wheat harvest				1.00 [0.94] *0.29*		1.22 [1.04] *0.25*
Corn harvest				0.34 [0.81] *0.68*		0.41 [0.87] *0.64*
Post-1896 dummy			-0.92 [0.20] *0.00*	-0.92 [0.20] *0.00*	-0.91 [0.23] *0.00*	-0.89 [0.22] *0.00*
Time		-0.071 [0.055] *0.21*				
$Time^2$		0.003 [0.002] *0.09*				
R2	*0.16*	*0.31*	*0.62*	*0.65*	*0.61*	*0.64*

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