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Searching for Irving Fisher

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Searching for Irving Fisher

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There is a long-standing debate as to whether the Fisher effect operated during the classical gold standard period. We break new ground on this question by developing a market-based measure of inflation expectations during the gold standard. We derive a measure of silver-gold inflation expectations using the interest-rate differential between Austrian silver and gold perpetuity bonds. Our use of the silver-gold interest rate differential is motivated by the fact that both gold and silver served as numeraires in the pre-WWI period, so that a change in the price of either precious metal would impact the prices of all goods and services. The empirical evidence suggests that silver-gold inflation expectations exhibited significant persistence at the weekly, monthly, and annual frequencies. Further, we find that there is a one-to-one relationship between silver-gold inflation expectations and the interest rate on Austrian perpetuity bonds that were denominated in paper currency. The analysis suggests the operation of a Fisher effect during the classical gold standard period.

Keywords: Fisher effect, inflation expectations, gold standard
JEL Classification Numbers: E4, G1, N2

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Searching for Irving Fisher

The Fisher equation is a stalwart of modern macroeconomics and finance (Gürkaynak, Sack, and Swanson, 2005). Its operation is largely taken for granted even though there are well-known periods, most notably the late nineteenth and early twentieth centuries, when the data on interest rates appear to be inconsistent with its operation.[1] One possible explanation for the failure of the Fisher equation for both short-term and long-term interest rates during the classical gold standard era is that inflation expectations were nearly zero given the low level of persistence in annual measures of *ex post* inflation rates (Capie et. al, 1991; Fisher, 1930; Friedman and Schwartz, 1982). Several studies have found that *ex post* inflation rates are uncorrelated with the level of nominal interest rates during the late nineteenth and early twentieth centuries.[2] Other researchers have suggested that the lack of correlation between nominal interest rates and inflation rates during the classical gold standard period may be due to money illusion or because investors did not understand the quantity theory of money (Summers, 1983; Cagan, 1984; Choudry, 1996; Barsky and Delong, 1991).

The existing literature on the operation of the Fisher effect during the late nineteenth and early twentieth centuries, however, does not directly measure inflation expectations. As a result, it is difficult to rule out that the effect did not hold. One obvious impediment to providing a direct test of the Fisher equation during the gold standard era

[1] For a discussion of inflation expectations during the gold standard period, see Barsky and DeLong (1991). For an analysis of the persistence of inflation during the gold standard period and later, see Burdekin and Siklos (1996). Harley (1977) analyzes prices and interest rates in the UK during the gold standard period to test Gibson's Paradox.

[2] Many studies have found that nominal interest rates during the gold standard are correlated with the price level rather than the rate of inflation. Barsky and Summers (1988) argue that that this positive correlation is a direct result of the fact that the price level in the inverse of the price of gold. Benjamin and Kochin (1984) argue that Gibson's Paradox during this period is a spurious relationship.

or other historical periods is that Treasury Inflation Protected Securities (TIPS) or other inflation-indexed securities did not exist. To break new ground on understanding whether the Fisher effect operated in this earlier period, we derive a new, *market-based* measure of inflation expectations from 1880-1913 that is qualitatively similar in nature to modern-day TIPS. We collect weekly data on gold and silver sovereign bonds and use the difference in their interest rates to measure inflation expectations.[3] Our use of gold and silver bonds is motivated by the fact that both gold and silver served as numeraires during the pre-WWI period. Even after many countries joined the gold standard in the late nineteenth century, silver served as the primary commodity money in China, India (until the late 1890s), Persia, and some areas of South-East Asia.[4] It continued to be used as money for daily transactions in Austria, Mexico, the Balkans, Russia, and many other places. Since these precious metals were given legal tender values in the unit of account, it meant that a change in the price of either gold or silver changed the price of all goods and services in an economy (Barro, 1979; Mills, 1848). An increase in the supply of silver, for example, led the price of gold to rise, making gold and silver endogenous to one another. The reverse would be true with an increase in the supply of gold.

Because most of the world's currencies were backed by silver, gold, or both precious metals during the nineteenth and early twentieth centuries, the silver-gold price

[3] Most previous studies have used econometric techniques to construct inflation expectations (Capie et al., 1991; Perez and Siegler, 2003). Perez and Siegler (2003) find evidence that short-term interest rates adjusted to changes in expected inflation. The response of short-term rates to changes in inflation expectations were not one-to-one, however. An approach similar to ours is Flandreau and Oosterlinck (2010), which examines the extent to which the end of the bimetallism was anticipated; they use the spread between Indian silver and gold bonds to examine if markets believed that the world would shift from a bimetallic to a gold standard.

[4] Maddison estimates that China represented 10 percent of the world's GDP in 1900. http://www.ggdc.net/MADDISON/oriindex.htm

ratio was a particularly important gauge for financial market participants. They used it to form expectations about how currency values and overall price levels in economies changed as a result of a change in the gold-silver price ratio because both precious metals served as numeraires. As early as 1848, J.S. Mill noted how changes in the prices of precious metals used as numeraires changed the overall inflation rate in the economy. Later theoretical work (Barro, 1979) formally showed how sustained increases in the price of gold (or silver) or gold (or silver) discoveries translated into overall increases in prices for countries on metallic standards. Financial publications such as the *Economist* regularly reported data on silver prices so that bond traders could form optimal portfolios.

Given the gold silver-price ratio's central role in price determination during this period and the use of it by traders to speculate on currency movements (Eichengreen 1996), we construct a high frequency, real-time measure of inflation expectations based on it. In particular, we derive a measure of inflation expectations using interest rate data from Austrian sovereign bonds payable in gold or silver. Austria was the only major European country that issued gold and silver perpetuity bonds, which actively traded on the leading financial exchanges of Europe (including London, Paris, Berlin, Amsterdam and Vienna). The nearly identical terms of Austria's silver and gold bonds enables us to interpret the interest-rate spread between them as a measure of silver-gold inflation expectations.

We analyze the persistence of our high frequency, real time measure of inflation expectations, and find that silver-gold inflation expectations were not a white noise process during the gold standard period. This result suggests that inflation expectations were not constant during the classical gold standard period. Constant inflation

expectations are likely to have a small correlation with nominal interest rates that fluctuate over time. We find economically meaningful persistence in silver-gold inflation expectations at the weekly, monthly, and annual frequencies. These results are consistent with studies of inflation expectations in the modern period derived from TIPS as well as from survey data that find significant persistence in inflation expectations (Mankiw et al., 2004).

We then test whether the Fisher equation held during the late nineteenth and early twentieth centuries by examining the relationship between the silver-gold interest rate differential and the interest rate on Austrian *paper* bonds. The empirical exercise is motivated by the fact that Austria shadowed metallic monetary systems during this period. Austria followed the silver standard from 1878 to July 1892 and then shadowed the gold standard (August 1892 to 1913) during our sample period by keeping its currency close to the mint par ratio. Given the use of both metals as numeraires, it is a nearly ideal country for basing a measure of inflation expectations the silver-gold price differential.

Our empirical results provide evidence of a long-run cointegrating relationship between our measure of inflation expectations and Austrian paper interest rates. Moreover, we cannot reject the restriction of a one-to-one relationship between the silver gold interest differential and paper interest rates over the period 1880-1913. We interpret our findings as evidence of the operation of a Fisher effect during the classical gold standard period.

The next section of the paper discusses our data. Section III analyzes the time series properties of inflation expectations during our sample period in Austria and Section

IV tests for a long-run Fisher effect. The last section discusses our findings and their implications.

II. Austria and the Gold Standard

To derive a market-based measure of inflation expectations and to test for the presence of a Fisher effect during the gold standard period, we hand-collected weekly bond price quotations of Austrian sovereign debt issues payable in gold and silver, over the period 1880-1913, from the *Economist*. Austria tapped international capital markets on a significant scale following the passage of the Law of March 16, 1876, which authorized a 16 million, florin gold bond issue that was exempt from Austrian taxes. These sovereign bonds paid interest every half-year in gold in Vienna or other European cities at the following rates: at the Amsterdam and Frankfurt exchanges it paid 20.25 marks per 10 florin and at the Brussels, Amsterdam, and Paris exchanges it paid 25 francs per 10 florin. Morys (2008) estimates that foreigners held approximately 80 percent of the debt issue. In 1910, the *Stock Exchange Official Intelligence* reported that there were more than 490 million Austrian crowns of gold bonds that were unredeemed and that traded on markets throughout Europe; that equaled approximately five percent of Austrian GDP in 1910.

Austria sold sovereign bonds denominated in silver bonds on the leading European exchanges. Issued in 1868, the silver bonds were perpetuity obligations and subject to a 16 percent income tax. The coupon payments on the five percent silver bonds were payable in silver half-yearly on February or August 1st or on May 1st and November 1st (*Stock Exchange Official Intelligence*, various issues). Approximately 519 million

crowns of silver bonds were outstanding in 1910, roughly 2.9 percent of Austrian GDP (Schulz, 2000).

The Austrian gold and silver bonds series represent the senior debt obligations of the Austrian government (Morys, 2008; Official Market Intelligence, 1910) and Austria faithfully repaid all its sovereign debt obligations between 1880 and 1913.[5] Moreover, since the silver and gold bonds were widely held by foreign investors, Austria could not differentially default on the silver bonds without damaging its reputation in international capital markets.

For the purpose of considering Austria's level of financial development (and later for our test of the Fisher equation), it should also be noted that Austria issued large amounts of government debt throughout Europe payable in its own currency. The market value of unredeemed "paper" or home-currency bonds exceeded more than 886 million crowns. Morys (2008) finds that approximately 20 percent of the paper bonds were held by foreign investors. Only the UK, France, Germany, Netherlands, and the United States were also able to sell large bond issues in their home currency on several European markets during the classical gold standard period.

Some scholars have characterized nineteenth-century Austria as a financially underdeveloped, agriculturally-oriented economy, suggesting that it belonged to the periphery rather than to the core of European gold standard countries like the United Kingdom, France, or Germany. However, the fact that Austria was able to issue paper debt successfully throughout Europe suggests that it may have more closely resembled core gold standard countries. In contrast to countries on the periphery, Austria suffered

[5] Additional evidence suggests that UIP held for Austrian gold and silver bonds during the period when the countries was a de facto member of the gold standard or shadowed the gold standard.

"original sin" only to the extent that its debt was denominated in gold, silver, and paper florin (Eichengreen and Hausmann, 1999; Bordo, Meissner, and Redish, 2005). A depreciation in the paper florin, for example, would require Austrian authorities to collect more tax revenues (in paper florin) to service its debt denominated in gold florin.[6]

In addition, Austria's GDP per capita prior to World War I compares favorably to other core gold standard countries, such as France and Germany (see Figure 1). Further, Austria was one of the leading European military powers of the late nineteenth century and its financial markets appear to have been well developed and integrated (Good, 1977). An integrated network of joint stock banks with an extensive branching system (including the important Viennese banks) emerged in the 19th century to lend to businesses throughout the Austrian empire. Further, Austria borrowed from the German model of universal banking in forming institutions such as the Creditanstalt fur Handel und Gewerbe (1855), and it created a central bank in 1816, modeled after the Bank of France, which had the exclusive right to issue notes.

The issuance of sovereign debt denominated in gold and silver is partly a function of its monetary history. Austria was on the silver standard for much of the nineteenth century, but like many other countries, it went onto the gold standard towards the end of the century (de facto beginning in 1892). The Compromise of 1867 between Austria and Hungary gave constitutional foundations for a monetary union with the silver florin as the monetary standard and a central bank with no authority to print new currency issues. Despite this agreement, Austria and Hungary disagreed over the management of

[6] This was true even after Austria joined the gold standard. As shown in the *Amsterdamsch Effectenblad,* after Austria joined the gold standard, the coupons for paper bonds often traded at a discount to the coupons for gold bonds.

monetary policy. In addition to a monetary union, Hungary wanted overdraft facilities and a central bank office in Budapest. In July 1878, Austria and Hungary renewed the "Compromise of 1867" for ten years, but changed the name of the central bank from the Austrian National Bank to the Austro-Hungarian Bank. This new agreement created central bank offices in Budapest and Vienna with both German and Hungarian as the official languages of the monetary institution.

After 1879, the florin was no longer convertible into silver. The silver florin deviated by as much as seven percent from the mint par ratio and, as shown in Figure 2, exchange rates exhibited significant fluctuations in the 1880s. Austria formally cut the link to silver in August 1892 after renewing the "Compromise" with Hungary for a second time. It established the crown as its new currency and introduced a new parity. The crown's value was fixed in terms of gold and complete control of the money supply was given to the central bank; the value was initially determined based on the average exchange rate of the florin in the past (Flandreau and Komlos, 2001). The consensus view in the literature is that Austria was on a de facto gold standard or shadowed the gold standard as of this date. Flandreau and Komlos (2001) show that, even though it did not establish unrestricted convertibility, the central bank successfully stabilized the currency such that it traded in a very narrow band after 1896 – slender enough to conform to the bands that would have been required by strict convertibility.[7] This led markets to view Austria as on gold.

[7] Tullio and Wolters (2007) show that the Austrian exchange rate vis-à-vis other major gold standard countries (England, France, and Germany) fluctuated within a range of about 15 percent between 1876 and 1891 and just eight percent between 1892 and 1895. The share of metallic-backed notes to paper notes issued by the central bank increased from an average of 53 percent over the period 1876-1895 to an average of nearly 75 percent over the period 1896-1914 (Tullio and Wolters, 2007). After 1896, the exchange rate

The credibility of Austria's gold standard was further buttressed in 1899 when Hungary was granted full parity with Austria in the management of the central bank. As a result, the two parts of the Habsburg Empire were no longer quarreling over who would make monetary policy. Investors reacted favorably to this new power-sharing arrangement and the end of monetary debates: large capital inflows from the leading European financial centers including London, Paris, and Berlin occurred in response (Tullio and Wolters, 2007). Figure 2 confirms that Austrian exchange rates were remarkably stable after 1892. Financial markets thus seem to have considered Austria as shadowing the gold standard or on a de facto gold standard from 1892 (the point at which it introduced the crown) until the outbreak of World War I. Austria's commitment to the gold standard is shown by the fact that the correlation coefficient of the consumer price index between the Central European country and UK, France, and Germany was 72, 89, and 80 percent, respectively after 1892. Prior to shadowing the gold standard, however, the correlation of Austria's price level with UK, France, and Germany was 31, 51, and -90 percent from 1884 until 1892.[8] Based on the behavior of the exchange rate, Flandreau and Komlos (2001) conclude that Austria was a country that was neither a core nor a peripheral member of the gold standard, but rather somewhere in between.

for the Austrian crown relative to other gold standard countries fluctuated only two percent and +/- 0.4 percent from mint par (Flandreau and Komlos, 2001; Tullio and Wolters, 2007).

[8] The consumer price indices used to construct these correlation coefficients were assembled after the gold standard period.

III. Estimating Silver-Gold Inflation Expectations

A. Model and Empirical Findings

The Fisher equation states that the nominal interest rate is equal to the real interest rate plus the expected rate of inflation. The nominal interest rate for Austrian silver bonds (i.e., payable in units of silver coin) can therefore be written as:

(1) $i_t^S = r_t + \pi_t^{e,S}$,

where r_t is the real interest rate and $\pi_t^{e,S}$ is the expected rate of silver inflation. Likewise, the Fisher equation for Austrian gold bonds (i.e., payable in units of gold coin) is:

(2) $i_t^G = r_t + \pi_t^{e,G}$,

Inflation expectations for the gold bond are denoted by $\pi_t^{e,G}$. The silver-gold interest-rate differential can be obtained by subtracting equation (2) from equation (1), which yields:

(3) $i_t^S - i_t^G = \pi_t^{e,S} - \pi_t^{e,G}$.

Equation (3) states that the silver-gold interest rate spread is equal to the expected rate of inflation in the silver-gold price ratio.[9]

This silver-gold interest rate spread is particularly relevant for measuring inflation expectations during for our sample period because silver and gold functioned as numeraires for most countries in the world. Hence, when the price of either gold or silver changed, it affected the overall price level of the economy (Barro, 1979). As a result, the gold-silver price ratio acted as a coordinating signal for financial market participants to form beliefs about the general movement of prices. Financial market participants of the gold standard era understood the implications of David Hume's price-specie flow model,

[9] Perez and Siegler (2003) use econometric approaches suggested by Mishkin (1981) and Cecchetti (1992) to extract inflationary expectations.

which emphasized the adjustment of prices via flows of precious metals, and recognized that prices would adjust whenever there were shocks or endogenous economic responses that changed the relative demand and supply of metallic currencies. Hence, the silver-gold price ratio was widely followed in the financial press as an important indicator of inflation. Consider the following excerpt from a manufacturer to the Editor of the *Economist*:

> The great event of the last few weeks has been the rise in silver [price of gold]. It is the supposed cause of a considerable rise in the prices of many commodities, and if the predictions of bi-metallists are worth anything, it ought to have greatly improved the position of the cotton spinner and manufacturer. (*Economist*, May 24, 1890, p. 665)

Prof. J.S. Nicholson (quoted in the *Economist*) noted "that the fall in the gold price of silver has coincided almost exactly with the fall of the gold prices of commodities in general" (*Economist*, February 10, 1894, p.171). Since consumer or wholesale price indexes were not yet widely available to investors and market participants, they relied on information from the silver price of gold to form expectations about the broader movements in prices.

To carry out the empirical analysis, we make two assumptions. First, we assume that the real interest rate is the same in both equations (1) and (2). It is represented by the interest rate on the British Consol, which was widely considered to be the risk-free benchmark security of the gold standard era.[10] Second, we assume that the silver and gold bonds had about the same degree of market liquidity. Without this assumption, an additional term would be included in equation (3), reflecting the difference in liquidity between the two bond issues. The fact that Austria's silver and gold bonds were very

[10] No capital controls existed between Austria and England.

large issues that traded on several different European markets provides support for this assumption; however, to make sure this is a valid claim, we collected data on bid-ask spreads of the Austrian gold and silver perpetuity bonds so we could explicitly compare their liquidity. The average bid-ask spread for the gold bond is 52 basis points, with a standard deviation of 8 basis points, while the average bid-ask spread for the silver bond is 63 basis points, with a standard deviation of 15 basis points. The small difference in the bid-ask spreads between the two bonds suggests that they had very similar liquidity profiles.

Figure 3 plots current yields on a weekly basis for the Austrian gold and silver bonds from 1880-1913. The two series tend to move together, with the gold bond having the lower interest rate over the sample period. As shown in Table 1, the average interest rate for the gold bonds during the gold standard period is about 430 basis points, with a standard deviation of 38 basis points. The interest rate on the silver-denominated bonds averaged approximately 555 basis points, with a standard deviation of 59 basis points. Bond yields were highest during the silver standard period. Following the adoption of the gold standard, the average yield fell by approximately 57 basis points for the gold bonds and by more than 100 basis points for the silver bonds.

Figure 4 plots our weekly measure of silver-gold inflation expectations, $\pi_t^{e,S} - \pi_t^{e,G}$ derived from Austrian silver and gold bonds. Inflation expectations over the entire sample period averaged 1.25 percent (125 basis points). Since inflation expectations were relatively stable (the standard deviation is slightly more than three percent), the empirical evidence also indicates that movements in real interest

rates were probably more important than inflation expectations in driving fluctuations in Austrian nominal interest rates.

B. Persistence of Silver-Gold Inflation Expectations

We first examine the extent to which changes in inflation expectations were persistent and forecastable using univariate ARIMA models. If we find evidence that inflation expectations were a white noise process and therefore constant, it would imply that there is likely to be a small correlation between nominal interest rates and expected inflation. However, it instead seems likely that inflation expectations exhibited persistence because information transmission in markets was far less perfect in comparison to today. Indeed, a typical reason given for the high persistence of inflation expectations in modern financial markets is the fast flow of information.[11] Any lags in information would lead to serial correlation in economic data generating process.

To measure the persistence of silver-gold inflation expectations, we estimated ARIMA models for the entire sample period as well as for the periods when Austria shadowed the silver and gold standards. As shown in Table 2, over the entire sample period, inflation expectations in Austria are best characterized by an AR(2) process.[12] The sum of the autoregressive coefficients is over 98 percent, suggesting a high degree of persistence in inflation expectations. The constant indicates that investors expected inflation expectations of approximately 1.23 percent per year. For the period 1880-July

[11] To examine the time-series properties of long-run silver-gold inflation expectations during the classical gold standard period, we first test for a unit root using the Augmented Dickey-Fuller-GLS test. The results of the unit root test are mixed depending on the lag length chosen for the analysis.

[12] Perez and Siegler (2003) construct "crude" estimates of inflationary expectations derived from a multivariate econometric model as well as from ARIMA models by subtracting a one-step ahead forecast residual from actual inflation. Capie, Mills, and Wood (1991) use VAR econometrics to estimate the impact of a shock to inflation expectations on interest rates.

1892 when Austria shadowed the silver standard, we also find a high degree of persistence. Inflation expectations are best characterized during the silver standard by an AR(2) process and the sum of the autoregressive coefficients is nearly 98 percent. The coefficient on the constant term in the ARIMA model suggests that financial market participants expected inflation to average approximately 1.52 percent per year.

For the gold standard period, we estimate ARIMA models from August 1892 through 1913, and find that the best model for inflation expectations is an AR(2) model. Table 2 shows that the level of inflation persistence drops to about 94 percent. Although we observe a slightly lower level of persistence in inflation expectations after Austria joined the gold standard, there is a marked reduction in the average level of inflation expectations from 1.51 percent to 1.07 percent. These findings suggest that there was significant persistence in inflation expectations, and that joining gold reduced the average level of inflation expectations by roughly 30 percent.

C. Sensitivity Tests

One possible critique of the analysis thus far is that the large persistence in silver-gold inflation expectations may be driven by the use of high frequency data in the estimation process. We therefore re-estimated the baseline empirical results using data from the end of each month. The ARIMA models of monthly inflation expectations are presented in Table 3. The results are similar to those employing the weekly data. Inflation expectations follow an AR(1) process when the country adhered to the silver standard and inflation persistence is approximately 95 percent and significant at the one-percent level. For the gold standard period, inflation expectations are best modeled as an AR(1)

process. Although inflation expectations are once again not a white noise process, the coefficient on the autoregressive term falls by roughly 12 percent, from 94 to 85 percent.

Using annual data, we find similar results for the persistence of inflation expectations. The constant term shown in Table 4 indicates that annual inflation expectations averaged more than one percent over the full sample period. Again, we find that there is significant persistence in inflation expectations: the sum of the two autoregressive terms is nearly 92 percent. Hence, using weekly, monthly, or annual data, we find substantial persistence in silver-gold inflation expectations during the gold standard period.

Another possible critique of our analysis is that Austria's commitment to gold might have been perceived as less credible than other western European countries, and hence the analysis of silver-gold inflation expectations we derive for it may not be very representative of gold standard countries. That is, inflation expectations for non-credible members of the gold standard may be much larger than for countries that strictly adhered to the monetary rule (Bordo and Rockoff, 1996). While Austria was a newer member of the gold standard in comparison to France, Germany, and the UK, it does not appear that market participants viewed its commitment to gold as substantially less credible than these countries. Mitchener and Weidenmier (2008) provide evidence that Austria was one of the most credible gold standard monetary regimes during the period 1870-1913: market participants expected the Austrian crown to depreciate approximately three percent after the country joined the gold standard based on the premium of paper over gold bonds. The level of expected depreciation is considerably smaller than several other gold standard countries including the United States, Argentina, Brazil, Chile, India,

Mexico, and Russia. We therefore interpret our results as providing a lower bound on the size and persistence of inflation expectations for the average core country during the classical gold standard period.

IV. Testing for a Fisher Effect

Having established that inflation expectations exhibited significant persistence during the classical gold standard period, we now provide a straightforward test of whether the Fisher effect operated during the classical gold standard era using the Johansen Maximum Likelihood Test for Cointegration. We test for the presence of a long-run Fisher effect using the Austrian government's paper bonds as the nominal interest rate. The long-run test for a Fisher effect is motivated by Friedman and Schwartz's (1982) comment that market participants only gradually "learned their Fisher" before World War I and Barsky and DeLong's (1991) view that investors did not understand the quantity theory of money. Austrian paper interest rates and our silver-gold measure of inflation expectations enable us to examine whether there was a long-run relationship between nominal interest rates and expected inflation.

The paper bonds were also perpetuities and had nearly identical terms to the Austrian gold and silver bonds. The coupons were payable in paper currency in Vienna half-yearly: on February 1st and August 1st or on May 1st and November 1st. They paper bonds were subject to a 16 percent deduction for income tax. The paper interest rate averaged 559 basis points with a standard deviation of nearly 62 basis points over the entire sample period, 1880-1913.

Figure 5 shows silver-gold inflation expectations along with the paper currency bonds. The two series move together over the entire sample, suggesting a strong positive link between nominal interest rates and expected inflation. The correlation coefficient between the silver-gold interest rate differential and paper interest rates is 84 percent.

We test for the presence of a long-run cointegrating relationship between paper interest rates and silver-gold inflation expectations using vector autoregressions. To do so, we first check whether there is a unit root in Austrian paper interest rates using the DF-GLS unit root test. The null hypothesis of a unit root cannot be rejected at the 5 or 10-percent level of significance with any lag length between 1 and 26. We then use the Johansen procedure to test for the presence of a long-run cointegrating relationship between inflation expectations and the interest rate on the paper bonds. Enders (1996) points out that that there may still exist a stationary, long-run equilibrium relationship between two variables even if, as in our case, only one of the variables appears to have a unit root. We select a lag length of 26 weeks on the basis of the Akaike Information Criteria (AIC) for the cointegration test. The null hypothesis of no cointegration can be rejected at the 5-percent level of significance with a λ_{TRACE} statistic of 16.717.

We next test for the presence of a Fisher effect by imposing a one-to-one relationship between paper interest rates and the silver-gold inflation rate. The long-run equilibrium relationship can be written as follows:

$$(4) \quad Paper_t = 366.653 + 1.499 SilverGoldInf_t$$
$$(0.289)$$

The restriction that there is a one-to-one relationship between paper interest rates and silver gold inflation expectations over the period 1880-1913 cannot be rejected at the

five-percent level of significance. The 95-percent confidence interval for silver-gold inflation expectations ranges from 0.92 to 2.05. The empirical evidence suggests the operation of a long-run Fisher effect during the late nineteenth and early twentieth centuries.

V. Conclusion

Researchers have long searched for the operation of Irving Fisher's eponymous effect during the classical gold standard period in order to justify its use in modern macroeconomics and finance. We show that Fisher's effect may be lurking in the silver-gold inflation expectations of Austrian sovereign debt issues of the 19th century. We compute the first high-frequency market-based measures of inflation expectations for the classical gold standard period so that we can test for its existence during this era. The interest rate differential between silver and gold bonds provides a direct approach for studying the behavior of expectations during the gold standard period. Our measure is motivated by the fact that both gold and silver were used as numeraires before World War I. Innovations in the price of gold and silver impacted the price of all goods and services. As a result, the silver-gold price ratio was widely followed by contemporary market participants as an important indicator of future prices. In addition, and in contrast to previous studies, our measure of inflation expectations does not have to be derived from econometric assumptions. This is important since market participants would have had neither the theory nor the tools to derive such measures.

Our analysis of silver-gold inflation expectations suggests several conclusions. First, we find considerable persistence in long-run inflation expectations at the weekly,

monthly, and annual frequencies, suggesting that expected inflation varied over time and was non-constant. The correlation of expected inflation and nominal interest rates is much higher than previously believed.

We show that silver-gold inflation expectations had a long-run, one-to-one, cointegrating relationship with Austrian paper interest rates, suggesting that the Fisher effect held during the late nineteenth and early twentieth century. Market participants updated nominal interest rates following a change in silver-gold inflation expectations. Investors required an inflation premium that was built into nominal interest rates. We also find that, with respect to monetary regimes, adoption of the gold standard reduced the average level of inflation expectations in Austria. Joining the gold standard led to a 30 percent drop in inflation expectations, from 1.5 percent to 1.1 percent, as measured by decisions made in financial markets.

References

Barro, Robert J. (1979). "Money and the Price Level under the Gold Standard." *Economic Journal* 89: 13-33.

Barsky, Robert B. and J. Bradford Delong. (1991). "Forecasting Pre-World War I Inflation: The Fisher Effect and the Gold Standard." *Quarterly Journal of Economics* 106(3): 815-36.

Barsky, Robert B. and Lawrence H. Summers. (1988). "Gibson's Paradox and the Gold Standard." *Journal of Political Economy* 96(3): 518-80.

Benjamin, Daniel and Levis Kochin. (1984). "War, Prices, and Interest Rates: A Martial Solution to Gibson's Paradox." in, *A Restrospective on the Classical Gold Standard, 1821-1931* (Michael Bordo and Anna Schwartz, eds.), 587-604.

Bordo, Michael and Finn Kydland. (1995). "The Gold Standard as a Rule: An Essay in Exploration." *Explorations in Economic History* 32(4): 423-64.

Bordo, Michael, Christopher Meissner, and Angela Redish. (2005). "How 'Original Sin' was Overcome: The Evolution of External Debt Denominated in Domestic Currencies in the United States and the British Dominions 1800-2000." In *Other People's Money: Debt Denomination and Financial Instability in Emerging Market Economies*, Barry Eichengreen and Ricardo Hausmann (eds.), Chicago: University of Chicago Press, pp. 122-153.

Bordo, Michael and Hugh Rockoff. (1996). "The Gold Standard as a Good Housekeeping Seal of Approval." *Journal of Economic History* 56: 389-428.

Burdekin, Richard C.K. and Pierre Siklos. (1996). "Exchange Rate Regimes and Shifts in Inflation Persistence: Does Nothing Else Matter?" *Journal of Money, Credit, and Banking* 31(2): 235-47.

Cagan, Philip. (1984). "Mr. Gibson's Paradox: Was It There?" *A Restrospective on the Classical Gold Standard, 1821-1931* (Michael Bordo and Anna Schwartz, eds.), 604-610.

Capie, Forrest H., Terrence C. Mills, and Geoffrey E. Wood. (1991). "Money, Interest rates, and the Great Depression: Britain from 1870 to 1913," in *New Perspectives on the late Victorian Economy* (James Foreman-Peck, ed.), 251-284.

Choudry, Tafiq. (1996). "The Fisher Effect and the Gold Standard: Evidence from the USA." *Applied Economic Letters* 3(8): 553-555.

Economist, various issues.

Eichengreen, Barry. (2008). *Globalizing Capital: A History of the International Monetary System*. Princeton: Princeton University Press.

Eichengreen, Barry and Ricardo Hausmann. (1999). "Exchange Rates and Financial Fragility." NBER Working Paper 7418.

Fisher, Irving (1930). *The Theory of Interest*. New York, NY: Macmillan.

Flandreau, Marc, Galimard, Christophe, Jobst, Clemens, and Pilar Nogues-Marco. (2009) "The Bell Jar: Commercial Interest Rates between Two Revolutions, 1688-1789." In *The Origin and Development of Financial Markets and Institutions*. Edited by Jeremy Atack and Larry Neal. Cambridge: Cambridge University Press.

Flandreau, Marc and John Komlos (2001). "Core or Periphery? The Credibility of the Austro-Hungarian Currency." CEPR Working Paper.

Flandreau, Marc and Kim Oosterlinck. (2011). "Was the Emergence of the International Gold Standard Expected? Melodramatic Evidence from Indian Government Securities." Graduate Institute of International and Development Studies Working Paper.

Flandreau, Marc and Frederic Zumer (2004). *The Making of Global Finance*. Paris: OECD.

Friedman, Milton and Anna J. Schwartz. (1982). *Monetary Trends in the United States and the United Kingdom, Their Relation to Income, Prices, and Interest Rates, 1867-1975*. Chicago, IL: University of Chicago Press.

Good, David F. (1977). "Financial Integration in Late Nineteenth Century Austria." *Journal of Economic History*. 37(4): 890-1910.

Gürkaynak, Refet, Sack, Brian, and Eric Swanson. (2005). "The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models." *American Economic Review* 95(1): 425-36.

Harley, C. Knick. (1977). "The Interest Rate and Prices in Britain, 1873-1913: A Study of the Gibson Paradox." *Explorations in Economic History* 14(January): 69-89.

Mankiw, N. Gregory, Reis, Ricardo, and Justin Wolfers. (2004). "Disagreement about Inflation Expectations." In NBER Macroeconomics Annual, Edited by Mark Gertler and Kenneth Rogoff. Boston: MIT Press, pp. 209-248.

Mill, J.S. (1848). *Principles of Political Economy*. Vol 2. Boston: Little, Brown.

Mitchener, Kris and Marc D. Weidenmier (2008). "Are Hard Pegs Ever Credible in Emerging Markets?" NBER Working Paper #15401.

Morys, Matthias. (2008). "The Classical Gold Standard in the European Periphery: A Case Study of Austria-Hungary and Italy, 1870-1913." Unpublished Doctoral Dissertation, London School of Economics and Political Science.

Official Market Intelligence, 1910. London: .

Perez, Stephen and Mark Siegler. (2003). "Inflationary Expectations and the Fisher Effect prior to World War I." *Journal of Money, Credit, and Banking* 35(6): 947-65.

Schulz, Max Stephan. (2000). "Patterns of Growth and Stagnation in the Late Nineteenth Century Habsburg Economy." *European Review of Economic History* 4: 311-40.

Shiller, Robert and Jeremy Siegel. (1977). "The Gibson Paradox and Historical Movements in Real Interest Rates." *Journal of Political Economy* 85(5): 891-8.

Stock Exchange Official Intelligence, Various Issues.

Summers, Lawrence H. (1983). "The Nonadjustment of Nominal Interest Rates." In *Macroeconomics, Prices, and Quantities*, edited by James Tobin. Washington, DC: Brookings Institute, pp. 201-41.

The Times of London, various issues.

Tullio, Giusseppe and Jurgen Wolters. (2007). "Monetary Policy in Austria-Hungary, 1876-1913: An Econometric Analysis of the Determinants of the Central Bank's Discount Rate and the Liquidity Ratio." *Open Economies Review* 18 (October): 521-37.

Table 1. Mean Austrian Interest Rates, 1880-1913

	Entire Sample Period (Std. Deviation)	Shadow Gold Standard Period Only (Std. Deviation)	Shadow Silver Standard Period Only (Std. Deviation)
Gold	430.475 (37.502)	409.129 (15.296)	466.767 (36.168)
Silver	554.996 (59.148)	516.865 (20.395)	619.826 (45.416)

Table 2. ARIMA Models of Inflation Expectations (Weekly Data)

	Entire Sample Period	Shadow Silver Standard Period Only	Shadow Gold Standard Period Only
Constant	122.790*** (9.685)	151.817*** (12.050)	107.472*** (1.832)
AR(1)	0.819*** (0.023)	0.799*** (0.038)	0.823*** (0.030)
AR(2)	0.169*** (0.023)	0.180*** (0.029)	0.117*** (0.030)
Observations	1,771	655	1,117

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3. ARIMA Models of Inflation Expectations (Monthly Data)

	Entire Sample Period	Shadow Silver Standard Period Only	Shadow Gold Standard Period Only
Constant	121.523*** (11.684)	149.483*** (15.557)	107.436*** (2.187)
AR(1)	0.969*** (0.012)	0.948*** (0.028)	0.852*** (0.033)
Observations	407	148	257

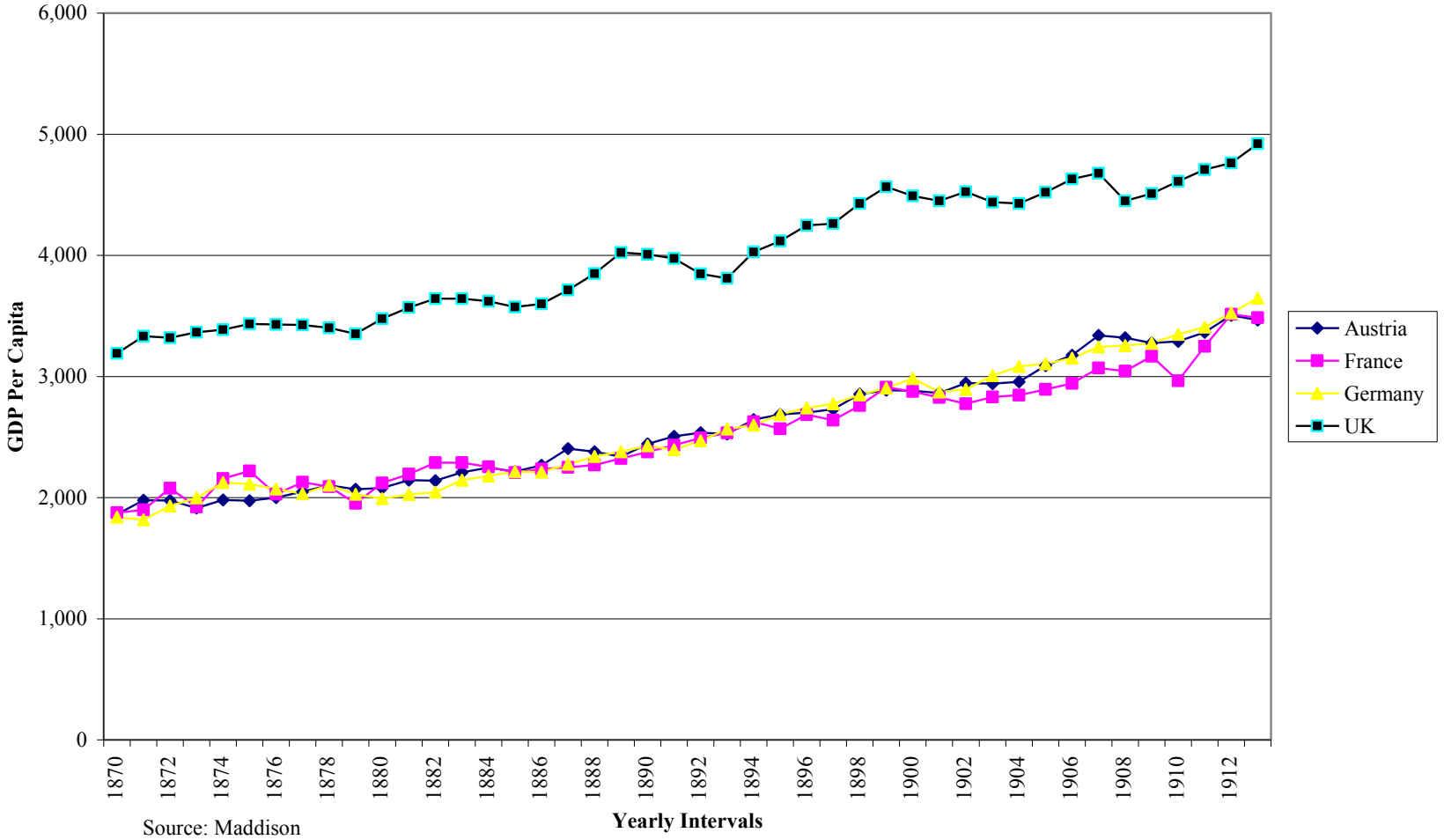
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4. ARIMA Models of Inflation Expectations
(Annual Data)

	Entire Sample Period
Constant	118.420***
	(24.913)
AR(1)	0.918***
	(0.070)
Observations	33

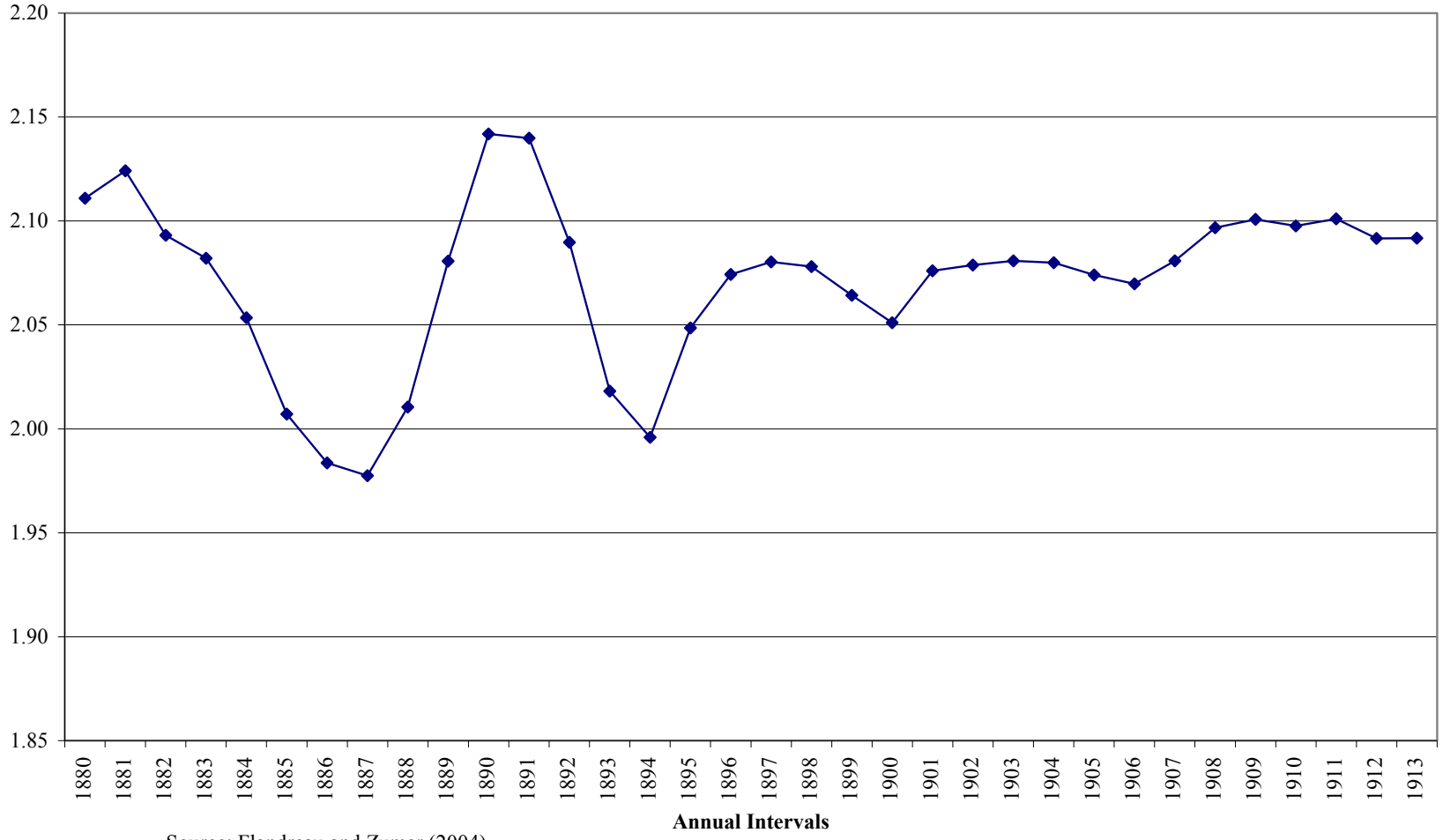
* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1
GDP Per Capita, 1870-1913



Source: Maddison

Figure 2
Franco-Austrian Exchange Rate 1880-1913



Source: Flandreau and Zumer (2004)

Figure 3
Austrian Gold and Silver Bonds, 1880-1913
(Basis Points)

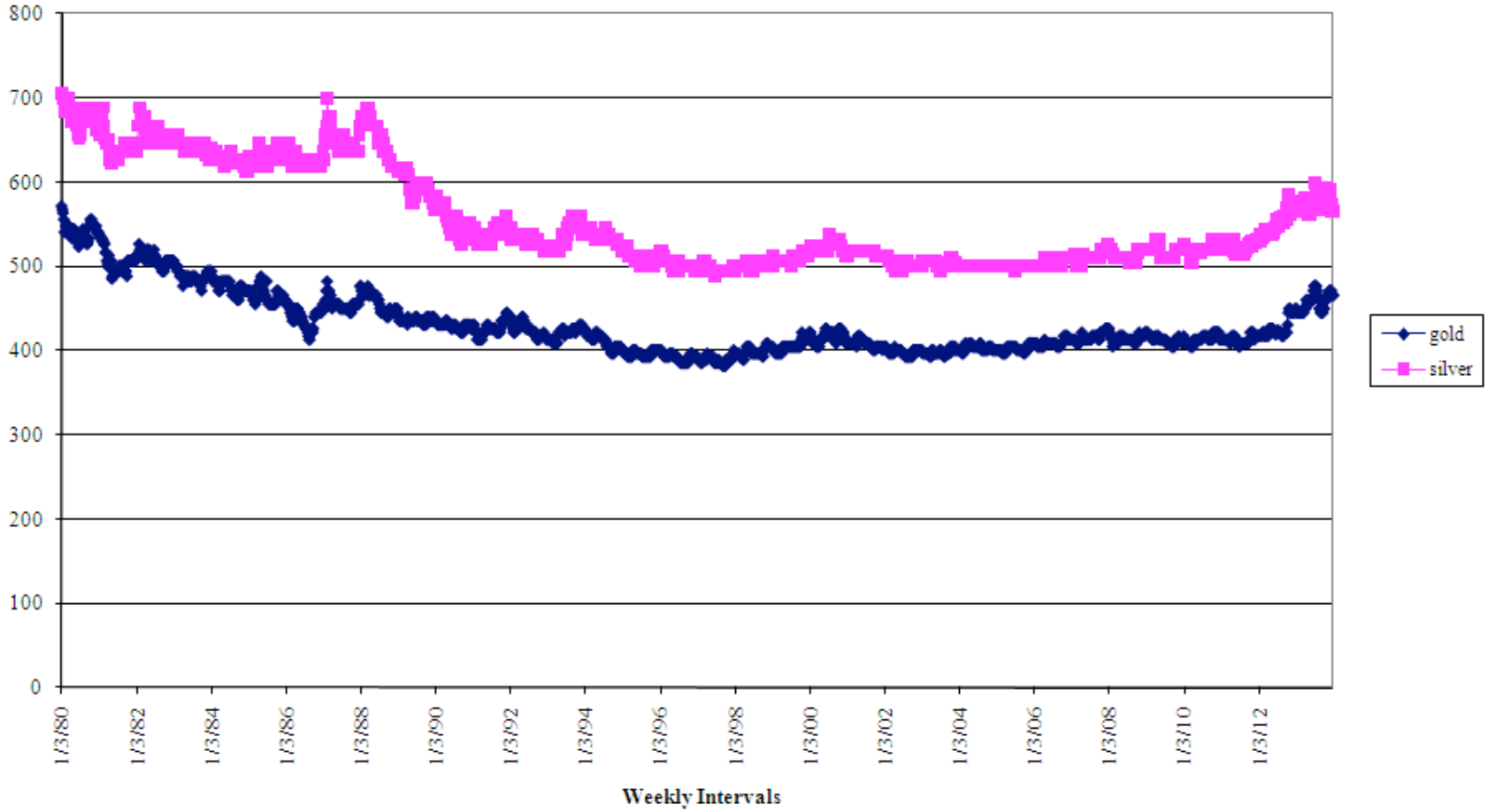


Figure 4
Austrian Silver-Gold Inflation Expectations, 1880-1913
(Basis Points)

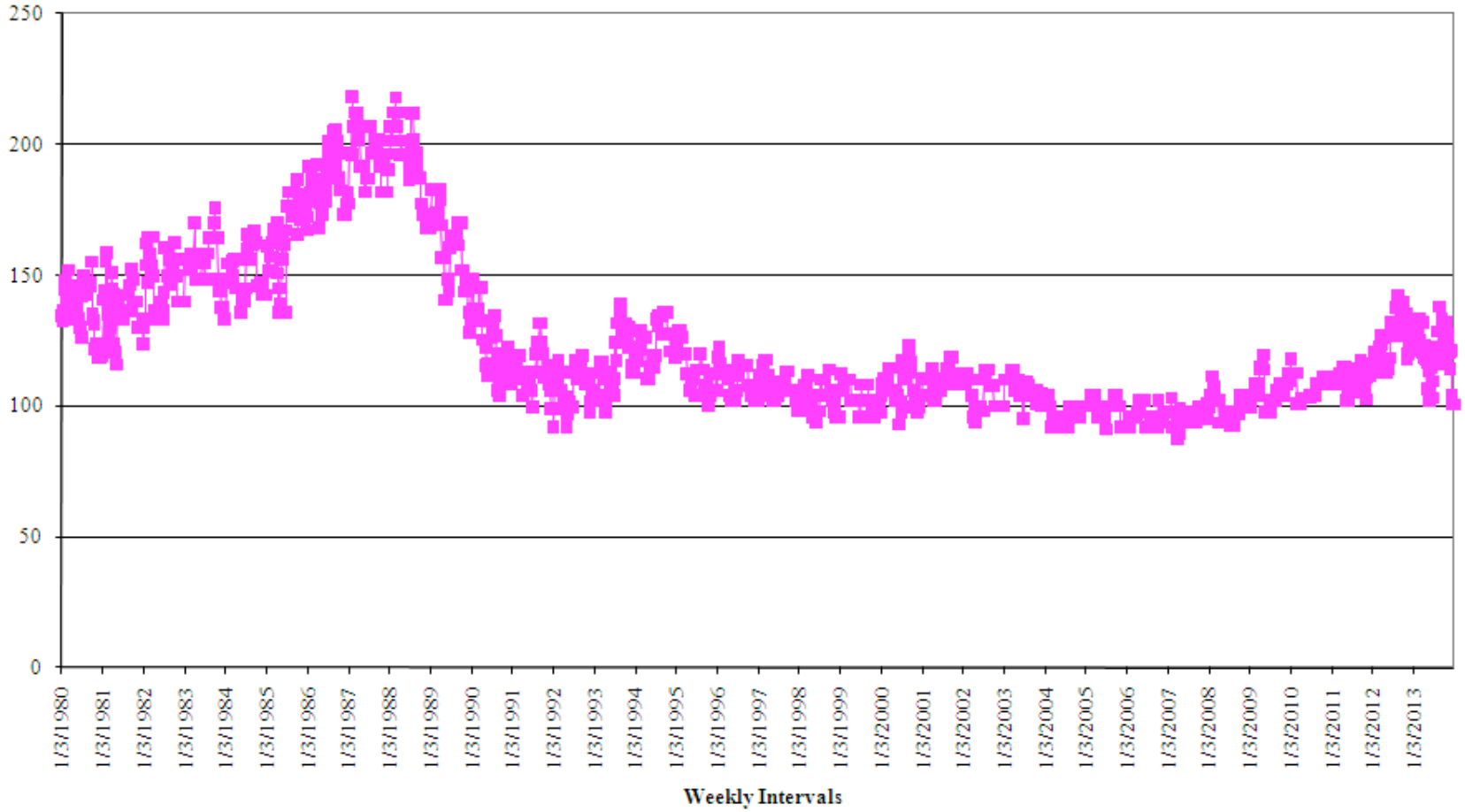


Figure 5
Austrian Silver-Gold Inflation Expectations and Paper Interest Rates, 1880-1913 (Basis Points)