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Deflation, Productivity Shocks and Gold: Evidence from the 1880-1914 period

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Introduction

The return to an environment of low inflation in most countries in the past decade has sparked renewed interest in the subject of deflation since its possibility is only a recession away. The recent deflationary experiences of Japan, China, Hong Kong, Switzerland and other countries led to concern in 2003 by policymakers at the Federal Reserve, the ECB and elsewhere that it could happen to them. They feared the possibility of prolonged stagnation as experienced by Japan or even worse a deflationary spiral that would lead to the conditions of the 1930s Great Depression (Bordo and Filardo, 2004).

In this paper we examine the issue from an historical perspective. We focus on the experience of deflation in the late nineteenth century when most of the countries of the world adhered to the classical gold standard. The period 1880-1914 was characterized by two decades of secular deflation followed by two decades of secular inflation.

The price level experience of the pre 1914 period has considerable resonance for today's environment. Several elements are salient.

First deflation pre 1914 was quite low as has been the case recently. In the U.S. the GNP deflator declined by an average of 1% to 1.5 % per year from 1880-1896. In the largest European economies, deflation was slower, but in each of France, the U.K. and Germany, prices declined by a total of 6 to 13% over the same period.

Second, productivity advance was rapid and growth was significant. The emergence of the iron and steel industries, improvements in industrial technologies, particularly in the U.S. and Germany, and productivity gains in transportation—within and between countries, have all been credited with raising aggregate output in the late nineteenth century.

Third, the price level was anchored by a credible nominal anchor—adherence to gold convertibility. Under the gold standard the price level tended to be mean reverting reflecting the operation of market forces according to the classical commodity theory of money. In today's environment, the commitment to low inflation, in some countries institutionalized in inflation targeting (explicit and implicit) and central bank independence, many believe has anchored inflationary expectations in a similar way.

Finally, the late nineteenth century was an earlier era of globalization—the integration of goods and financial markets – similar to today. In the earlier era global shocks dominated price level and overall macroeconomic activity in most countries that were linked together by common adherence to gold (Bordo and Helbling, 2004; Bordo and Murshid, 2003). The dominance of global shocks in explaining the international synchronization of business cycles is also the case today (Stock and Watson, 2004).

We distinguish between good and bad deflations. In the former case falling prices are driven by aggregate supply shocks (likely reflecting productivity advances), which outweigh negative demand shocks such as stagnant gold production and the widespread adoption of the gold standard. In the latter case, negative aggregate demand shocks outpace any expansion in aggregate supply. For example, negative money shocks that are non neutral over a significant period would generate a "bad" deflation. This was the experience in the Great Depression (1929-1933), the recession of 1920-21, and may be the case today in Japan.[1] There is also a third possibility—the Classical case where deflation – for example, caused by negative money shocks—is neutral, when monetary neutrality holds.

We focus on the price level and growth experience of the four dominant countries in the pre 1914 era: the United States, the United Kingdom, France and Germany from 1880-1913. All four countries adhered to the international gold standard, under which the world price level was determined by the demand and supply of monetary gold, and each member followed the rule of maintaining convertibility of its national currency into a

[1] Many people take issue with the term "good" deflation on the view that any departures from price stability are problematic. An alternative set of terms that we could use are "benign" versus "malignant" deflation or "the good, the bad and the ugly" as used by Borio and Filardo (2003). These terms connote: productivity driven deflation as used by us; low deflation and stagnation as has been the case in Japan; and the interwar experience.

fixed weight of gold. This meant that the domestic price level was largely determined by international (exogenous) forces.

We proceed in two stages. We begin by analyzing long run trends in world gold production and their impact on the money supply in the core countries. We then turn to higher frequency behaviour and estimate an empirical Blanchard Quah model which decomposes the behaviour of prices, output and the money stock into the impact of three structural shocks (a world price level shock, a domestic supply shock, and residually defined domestic demand shocks) by imposing long run restrictions on the impact of the shocks on output and prices. We then do a historical decomposition to examine the impact of the shocks on output and the price level. Finally, we consider the effects of changes in monetary gold stocks in the VARs.

Our key finding is that the economies that we examine are essentially classical in the senses that money is neutral and output is largely supply driven. We find that the price level shock is dominated by money supply factors, which in turn are partially explained by gold shocks, but these do not affect output which is largely explained by supply shocks. This leads us to conclude that the deflation observed was ‘good’ rather than “bad” deflation.

The paper begins by briefly describing trends in price level and GDP behaviour in the four countries. We then describe the path of world gold production and how that affected money supplies over the period as a whole. We then describe the methodology used in the short-run analysis, and the following two sections discuss those results. We conclude by summarizing our findings, and discussing their implications for current monetary policy.

Trends in the macroeconomy:

Figure 1 shows the behaviour of the GDP deflator for the four economies that we analyze here (see data appendix for details on sources). The broad picture is of deflation followed by inflation: Prices in the US fell by about 22 per cent from 1880 to 1896, and in the UK, Germany and France by about 10 percent, 6% and 13% respectively. After the mid 1890's the price level in the US, UK, Germany, and France rose by approximately 26 per cent, 16 per cent, 27 percent and 30 percent respectively. This overall pattern is nuanced by cycles within these cycles and by idiosyncratic variation.[2] There is a pause in the deflation in the late 1880s and in the inflation at the turn of the century. The US – whether one relies on the data from Balke and Gordon (1989) or Romer (1989) – experienced the most dramatic deflation and the turnaround was the last to come.

We tested more formally, for the existence of a structural break using the QLR test for a break in the time trend. For each country we found at least one break, with the break occurring between 1893 (Germany) and 1899 (US).[3] In our empirical analysis in the following section we have too few data points to estimate separate break points for each variable, and so we use a Chow test to test whether the data are consistent with assuming that each series has a break point in 1896. The results are shown in Table 1.[4] For each country, at varying levels of significance below 10%, the break cannot be rejected, and the mean inflation rate is negative in the first half of the period, and positive post-1896.

The behaviour of real GDP (Figure 2) shows the dramatic growth of output in the U.S. and Germany (at average annual rates of 3.5% and 2.9% respectively) and the slower growth in France and the U.K (1.7% p.a. in each). Growth rates were somewhat slower in

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[2] We choose the period 1880-1913 because the US did not return to the gold standard until after the Civil War Suspension of Convertibility ended in 1879 and because France had also suspended convertibility in the Cours Force from 1871 to 1878. However it should be noted that world deflation in gold prices actually began in 1873.

[3] The first is by estimating the following model

$$g_t = \alpha + \beta t + \delta_0 D_{st} + \delta_1 D_{st} t + \varepsilon$$

where D_{st} is a dummy variable that takes a value of 1 after period s. The Quandt likelihood ratio approach to finding a break is to calculate the F-test for

$$H_0 : \begin{matrix} \delta_0 = 0 \\ \delta_1 = 0 \end{matrix} \; vrs \;\; H_A : \text{one of them is not } 0$$

We run this model for s=1879…1907. That is we trim the first 15% and last 15% of the sample.

[4] We also tested for a break in the drift of the series, where the date of the break is unknown, using the Quandt Likelihood Ratio test, and found evidence of a structural break in the US and French price series in 1897 and 1898 respectively. The F-stat for the German and UK price series peaked in 1896.

the first half of the period, but from the graph it is not obvious that this was the period of the 'great depression' in the UK, or the 'longue stagnation' in France. All four economies experienced industrial expansion and payoff from the construction of railroads, but the pace of expansion varied enormously. The U.S. economy continued its post-Civil War expansion, but experienced severe cyclical fluctuations, whose depth is frequently attributed to the instability of the monetary and banking systems in that country.

The end of the Franco-Prussian war in 1871 deprived France, and gave to Germany, the benefits of a thriving textile industry and important iron ore deposits in the Alsace-Lorraine. German unification (again in 1871) and tariff policies created a large market and the universal banking structure supported the emergence of an industrial base to exploit the market. In France, agriculture which had boomed in the mid-century saw decline as transportation improvements brought US wheat (cheaply) to European markets, and the wine industry was devastated by pests (phylloxera).[5]

We again conducted formal tests for trend breaks, but found that none of the output series had any strong evidence of a break in trend (see Table 1), although growth rates in countries other than Germany rose after 1896.[6]

Gold and the Money stock

After the surge of gold production following the California gold discoveries of the late 1840s, gold production remained fairly stable until the 1890s. Then the combination of the development of the cyanide process for extracting gold from low-grade ore (1887) and the discovery of low-grade deposits in the Rand in South Africa (1890) – followed by other discoveries in the Klondike - led to a dramatic expansion in gold production (see Figure 2). The generally accepted estimate of the stock of world gold in 1880 is 284 m. fine ounces, of which approximately half was gold coin and bullion. From 1880-1895

[5] E.g. Clapham (1963; ch.8).
[6] Again, we used QLR tests as well, and there was no evidence of a break at any time.

average annual production of gold was 6.1 million fine ounces, which therefore increased the stock by something less than 2% per annum.[7] From 1896 to 1913, the stock grew annually at about 4.0%.

Figures 3a and b show how this increase in world monetary gold was reflected in increases in the monetary gold stock in the four economies we analyze. Clearly, gold flows between countries dwarfed the trends in aggregate production, particularly in the case of the US and the UK.

The impact of the changes in gold stocks on the money stock in each country depended on the particular monetary arrangements in each country. Broadly speaking, in each of the four countries, the money stock comprised gold coin, notes issued by a monetary authority that were convertible into gold, and deposits issued by commercial banks that were convertible into notes or gold. That said, there were idiosyncrasies, particularly in the U.S.

Unlike the European countries there was no central bank in the United States. In the 1880s, the 'notes' circulating included Greenbacks (also called U.S. notes) and National Bank notes. The former were liabilities of the U.S. Treasury, and were convertible (since 1 January 1879) into gold on demand. The Treasury held reserves of gold to make the promise of convertibility credible. National Bank notes were also convertible and were liabilities of the (private) National Banks. The Banks were required to hold 100% (or more) backing for the notes in the form of US government securities. In the 1890s silver certificates and Treasury Notes of 1890 were added to the notes in circulation.

A snapshot of the circulating media (i.e. outside the Treasury but including holdings of banks; excluding all deposits) in the US in 1892 and 1902 shows that gold coin was about 25% of the total in both years. National bank notes were 10% of the total in 1892, and had risen to 15% ten years later, while the share of US notes had fallen from 21% to 15%. Silver and gold certificates represented about 30% of the total.

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[7] Data on the stock of gold are from Cassel, (1923; 77), and for the stock of monetary gold are from (Kitchin, 1923; 83). Data on annual production are taken from Warren and Pearson (1935; 121).

In France, Germany and the U.K. a central bank had monopoly over the note issue, and notes were convertible into gold on demand and were de facto legal tender.[8] In France and Germany, silver coins that had been issued under earlier bimetallic regimes continued to be legal tender, although no more such coins were minted, a system described as a limping gold standard.

In summary, in each country the convertibility requirements tied the stock of money to the quantity of gold; however the ties were not necessarily equally close or constant over time. The ratio of money to gold reflected the monetary asset choices of agents in each country. We would expect the ratio to depend on the 'price of gold' (the interest rate), and the perceived riskiness of notes and deposits – or more specifically, the expectations of convertibility of those assets. In addition, innovation in the monetary sector might generate a secular increase in the ratio, and monetary legislation – reserve ratios, rules concerning the legal tender status of silver – would generate differences across countries and potentially across time.

Figure 4 shows the ratio of the money stock to gold in each of the four countries. There was indeed a secular increase: over the period 1880-1914, the aggregate money stocks in the four countries rose by 300% while the gold stocks rose by 112%. The differences across countries are as conspicuous as the similarities. France had a particularly unintermediated money stock, with a quantity of money somewhat less than twice the stock of gold in 1880 and slightly more than twice in 1913. In Germany and the UK the ratios are similar in 1880 (a multiplier of about 6) and follow similar paths to 1894, but then the increase stops in the UK and continues in Germany, rising to over 10. In the US the ratio remains constant in the early 1880s, and then grew dramatically to 1896 (as the base was augmented by silver) before declining rapidly in the late 1890s (gold replaces silver in the base) and then essentially stabilizing.

[8] Central banks however were not necessarily publicly owned, and notes were not de jure legal tender.

In this section, we have shown that the period of deflation corresponded with slow growth in gold stocks, while the subsequent inflation corresponded to a time of rapid gold production. The gold standard institutions established the quantity of gold as an anchor to the nominal side of the economy. Yet, the anchor line was not rigid. Across countries and across time, factors other than the quantity of gold had major short run influences on the quantity of money.

The short-run: methodology

In this section, we describe a Blanchard-Quah decomposition that we will use to decompose fluctuations in prices, output and the money stock into the effects of: a world price level shock, domestic aggregate supply shocks, and domestic demand shocks. In the following section we show the impulse responses generated by this decomposition, which we argue support our identification assumptions. We then use historical decompositions to demonstrate the impact of each shock by looking at counterfactual worlds where all shocks but one are turned off.

Our identifying assumptions reflect the gold standard described above, whereby the four economies we are analyzing operated under a highly credible fixed exchange rate.[9] Thus we assume there is a world price level that in the long run is determined by exogenous shocks to world money supply and demand and that each country takes this price level as exogenous. We identify this shock by assuming that no other factors have a permanent impact on prices **(Assumption 1).** We allow this shock to impact individual country output – for example, because of monetary non-neutralities or because it is capturing global technology shocks. Significantly, monetary non-neutralities would imply that a positive shock would raise, prices, the money stock and output, while if global technology shocks were the source of the price behaviour, then a shock that raised prices would lower output and leave money stocks unchanged.

[9] Craig and Fisher (2000) conclude that the gold standard tied together the monetary but not the real side.

We also identify a domestic technology shock, which captures all factors having a permanent impact on output that do not have a permanent impact on prices (**Assumption 2**). We anticipate that a positive technology shock would lower prices and raise money stocks in the short run, and that the impact on the money stock would be permanent.

The third shock is an amalgam of the factors that have a short run impact on prices and output, for example, government spending shocks, or changes in velocity. While we cannot disentangle these influences very far, the differing short run impact of such shocks on prices, money and output may suggest which forces are dominant.

The particular structural vector autoregression (SVAR) we estimate is as follows. Let $x_t = \left(\log\left(p_t\right) \log\left(y_t\right) \log\left(m_t\right)\right)'$ be a vector of log prices, log real output, and log nominal money supply. Then the SVAR that we estimate is

$$\Delta x_t = D_t\alpha + \sum_{j=1}^{p} A_j \Delta x_{t-j} + \varepsilon_t \qquad (1)$$

where D_t is a matrix of deterministic components that could include the constant, time trends or dummy variables, and

$$\varepsilon_t = Cu_t \qquad (2)$$

where u_t is a vector of orthonormal structural shocks. That is, $\text{var}(u_t) = I$ so that $\text{var}\left(\varepsilon_t\right) = CC'$. The structural shocks are identified by imposing restrictions on C that relate to the long-run impact of the structural shocks on the endogenous variables in x.

Let L represent the lag operator defined as $L^j \Delta x_t = \Delta x_{t-j}$. Then (1) can be rewritten as

$$A(L)\Delta x_t = D_t\alpha + \varepsilon_t \qquad (3)$$

where $A(L) = 1 - A_1L - \ldots - A_j L^j$. The vector moving average process associated with (3) is therefore

$$\begin{aligned} \Delta x_t &= A(1)^{-1} D_t\alpha + A(L)^{-1}\varepsilon_t \\ &= \beta_{0t} + \varepsilon_t + B_1\varepsilon_{t-1} + \ldots \end{aligned} \qquad (4)$$

Noting that $\varepsilon_t = Cu_t$ then the cumulative long-run response of x to a one unit shock to u is

$$\begin{aligned}\Psi &= IC + B_1C + B_2C + \dots \\ &= \left(I + B_1 + B_2 + \dots\right)C \\ &= B(1)C\end{aligned} \tag{5}$$

where the (i,j)th element of Ψ is the long run response of the *ith* element of x to a one unit shock to the jth element of u.

The identification strategy is to impose enough zero restrictions on the elements of Ψ so as to allow us to identify and hence estimate the elements of C. Once this is done we can use these estimates to calculate structural impulse functions for each structural shock. The matrix C is calculated using the scoring algorithm described in Amisano and Giannini (1993). **Assumptions 1** and **2** imply that Ψ is lower triangular and, combined with the assumption that the structural disturbances are orthogonal, imply exact identification.

One of the problems with estimating (1) with the data we have is the small sample size. It appears that we need at least two lags in (1) to model the appropriate dynamics of the system.[10] Given that we are first differencing the data we end up with a sample size of 31 observations to estimate each equation of the DVAR. With two lags of each endogenous variable plus the two deterministic variables this means we estimate eight parameters per equation. While this is enough to estimate the parameters we find that the standard errors can be quite large in some cases. This in turn impacts the confidence intervals for the structural impulse functions that we calculate via Monte Carlo methods.

To improve the efficiency of our estimates we estimate all the VARs for each country in one big SUR system. The benefit of doing this is that we can impose some cross-country restrictions on the parameters of the DVAR and we can allow for contemporaneous correlation between the countries and use the standard feasible generalized least squares SUR estimator to improve the efficiency of the estimates.

[10] Information criteria and likelihood ratio tests suggest a lag lengths of 1 and 2 respectively. The estimates of the 2 lag model yields significant coefficients on the second lag of some variables in each equation. Moreover, a 2 lag DVAR produces impulse response functions that are theoretically plausible for all countries in the sample.

Specifically, we assume that the slope coefficients for each equation are equated across countries. This is equivalent to pooling the data across countries and estimating a panel VAR (PVAR).[11] Note that while we assume that the slope coefficients are equated across countries, we do not assume that either the deterministic coefficients or the variance-covariance matrix of the reduced form errors are equal across countries. This allows for each country to have different trends in the data and allows for heteroskedasticity across the countries as well. The impact of allowing each country to have an individual error structure allows each country to have distinct impulse responses to their own structural shocks.

In addition, we take into account any contemporaneous correlation between the endogenous variables across the countries by estimating the system using a feasible GLS estimator. Call this estimator the PVAR-GLS estimator. In order to make the estimator manageable we assume that there is contemporaneous correlation between like variables across countries. That is, the price series in all four countries are contemporaneously correlated as are output and money but there is not contemporaneous correlation between prices and output, prices and money, and output and money. The impact of this is to improve the efficiency of our estimates. Obviously imposing the cross-country restrictions and the SUR structure will have an impact on the estimates for our individual VARs, however, the impact does not appear to be that great. The impulse response functions that are reported here for the PVAR are remarkably similar to the impulse response functions we obtain by estimating each country separately. In fact, the shape and sign of the structural impulse response functions we obtain are quite robust to many different estimation strategies and to the assumptions on lag length. In what follows we report the structural impulse response functions and historical decompositions obtained from the PVAR-GLS estimator.

We begin by pretesting the data for the order of stationarity. It is well known that the presence of a trend break biases the test for a unit root towards the null that the time

[11] The p-value for the Wald test that all slope coefficients are equal across countries is 0.96

series contains a unit root, and the tests reported in Table 1 and footnote 3 suggest that there was a trend break in many series. In table 2 we report results of augmented Dickey-Fuller (ADF) tests for both standard alternative deterministic models as well as under the assumption of a break in trend (Perron (1989)) for the series where the QLR test showed evidence of a possible break.[12]

The results suggest that all series have a unit root. Given our sample size is only 34 observations we must treat these results with caution. However, the results do suggest that we should first difference the data when estimating our VAR. We tested for the presence of cointegration within countries however the tests rejected the presence of a cointegrating relationship so we proceeded to estimate a DVAR, rather than a VECM. In addition, Landon-Lane (2004) shows that trend breaks can cause significant biases in the structural impulse response functions from a VAR, especially when the break is large and occurs in the middle of the sample. Given the results of our trend break tests, but our short data span, we allowed for a trend break in all series in 1896.

The short run: Results.

The impulse responses (shown in Figure 5) describe the decomposition. We begin with the impact of the 'price' shock. The money shock captures all *permanent* influences on the price level, which we think of as potentially coming from world money stock changes or world supply-side changes. The two causes have different implications for the responses of output and money stock: If the price level increases permanently because of a decrease in aggregate supply, the money stock will not be affected and output would permanently decline; if the price level is driven by an increase in the world money stock (or equivalently, a decrease in world money demand), then output would possibly increase in the short run (in the presence of short-run non-neutrality) and the money stock would increase permanently.

[12] The two alternative deterministic components are a constant and a constant plus a trend.

The results show that a positive price impulse is associated with a positive and significant money supply response on impact in all four countries. In the long run, the impact of the price shock is positive and significant in the US and the UK, and positive but insignificant in France and Germany. The impact on output is essentially zero in the European countries, both at impact and in the long run, while it is positive and persistent in the US. We discuss below some explanations for this American particularism, but note here that the results are broadly consistent with the interpretation of the 'price' shock, as a money supply shock.

We turn now to analysis of the 'supply' shock. Here the results are common to all countries. A positive supply shock, causes a temporary decrease in prices as would be predicted by a basic AS/AD model. (Recall that a zero long run impact on prices is imposed.) It also increases the money stock. The income elasticity of the money demand function varies from about 1 in the U.S. to .5 in France, but in all cases the impact is positive and significant.

The 'demand' shock is essentially defined residually, and so we do not have strong priors on the impulse responses. That said, in all four countries, the demand shock causes a large and persistent increase in the money stock and, while its long run impact on prices and output are required to be zero, it has a negative impact on both in the short run. Thus, the impulse responses are consistent with a country-specific increase in money demand (ceteris paribus – alternatively described as a decrease in velocity) or equivalently, a country specific decrease in money supply that is met by gold flows or a change in the money multiplier.

The estimated structural disturbances are shown in Figure 6. The identifying assumptions, combined with our small open economy model, imply that the money shocks should be highly correlated across countries, while the supply and demand shocks are essentially country specific. Our results are consistent with this interpretation, as shown by the correlation coefficients reported in Table 3. The broad brush shows that all four countries experienced a series of negative money shocks (1883-7), followed by a run of positive shocks (1888-93) followed by another sequence of negative shocks (1893-96). The experience is mixed from 1897-1904, but this is followed by largely common shocks: positive from 1905 to 1912, with the exception of the sharp negative shock in1908.

Historical decompositions combine the information in the estimated errors and the impulse responses, and show the effect on each variable of the current and past realizations of specific structural disturbances. Our results are shown in Figures 7-15. In each figure there are three panes. Each pane shows the actual behaviour of a variable's growth rate, and the contribution of deterministic factors to that growth rate. For example, Figure 7 shows the historical decomposition of US prices. Each pane shows the actual path of inflation (the solid line) and the contribution of deterministic components - essentially the trend – (the dashed line). In addition, each pane has a line (solid plus large dots) showing the impact of a particular shock. For example, the solid-plus-dots line in the first pane shows what the inflation rate would have been if the supply and demand shocks were zero at each point in time, and the money shock took on its historical value.

At the extremes, if the shock line lies on top of the actual it means that this shock accounts for all of the observed behaviour of the variable, while if the shock line lies on the baseline it means that the shock accounts for none of the observed behaviour. By construction, the sum of the shock lines must equal the actual.

The results for the European countries are remarkably similar. The price level is driven by the 'money' shock, output is driven by the supply shock, and the money stock is driven by all three, except in France where the demand shock accounts for most of the fluctuations in the money stock. What does this mean?[13] The 'money' shock is capturing international factors that drive the long run price level, whether supply or demand. The impulse response results suggest that these are primarily money supply. Output in the European countries was primarily driven by country specific supply-side factors. Consistent with our overview model, these country specific factors do not have a

[13] Statistically it reflects the fact that the reduced form residuals are close to orthogonal.

permanent impact on prices, but they do have an impact on the money stock. Note that the high volatility of the growth rate of monetary gold discussed earlier in part reflects these idiosyncratic shocks to aggregate supply, and therefore money demand.

The results for the US are more complex, largely as a result of the observed non-neutrality of money shocks shown in the impulse response functions. Overall, the picture is the same: the money shock drives the price level, and the supply shock drives output. However, there are 'money' shocks in the early 1880s, in the mid 1890s, and in 1908 that have significant impacts on output. These dates correspond to periods of financial turmoil, and we suspect that such events would have had a persistent impact on US output.

Empirical Results with Gold Stocks explicitly included:

The importance of gold as the foundation of the monetary system in our four countries suggests that it be included in the VAR analysis. However, changes in world gold production were low frequency events whose impact is unlikely to show up in a VAR based on annual data.

We re-estimated the model incorporating changes in gold stocks in two alternative ways. Firstly, we estimated the model including world gold production as an exogenous variable in each equation, and secondly we incorporated changes in monetary gold in country *i*, as an exogenous variable in the model for country *i*. This latter captures the fact that country specific gold stocks were far more volatile than the aggregate, but on the other hand the exogeneity is hard to defend since they may reflect gold flows driven by shocks to output and prices.

The impact of the gold shock on the historical decompositions is potentially twofold: the baseline now includes the impact of the exogenous gold shock, and so may explain more of the behaviour of the variable; and the inclusion of world gold production (or domestic monetary gold stocks in our second set of estimates) as an exogenous shock naturally changes the definition of the ‘money’ shock since it is now purged of the influence of gold shocks, and captures the other shocks to the world price level.

Figures 19 and 20 show the new historical decompositions for output in the US and UK. (the results for other variables and for Germany and France are not included for brevity’s sake - they are available on the author’s web site). The ‘baseline + gold shock’ lines show the impact of gold shocks, and the volatility of that line shows that world gold shocks did affect output in each country. However, there is considerable distance between ‘baseline + gold shock’ and ‘actual’, showing the role of other shocks. Particularly in the UK, but also for the US, the supply shock continues to account for the majority of the fluctuations in output.

Figures 21 and 22 repeat this exercise using (changes in) country specific monetary gold stocks. Again, we focus on the historical decompositions for output in the US and UK, which show some effect of domestic gold stocks, but it is still supply shocks that drive the behaviour of output. (The historical decompositions for money stocks show a larger impact of domestic gold stocks.)

Conclusions:

Inflation rates around the globe have fallen from historically high levels in the 1970s and 1980s to numbers close to zero as the 20th century ended. Indeed some countries have experienced actual deflation. Yet output growth rates remain positive. Not since the turn of the 19th century, have economies experienced such low inflation associated with non-negative growth, and it seems natural to turn to that period to learn about macro behaviour in low inflation or possibly deflationary environments.

Deflation can reflect the impact of positive aggregate supply shocks (in the absence of offsetting positive demand shocks) or negative demand shocks. In the latter case, if the aggregate supply curve is non-vertical, the deflation will be ‘bad’ in that it will be accompanied by negative output effects.

Our results show that the deflation in the late nineteenth century gold standard era in the four core countries reflected both positive aggregate supply and negative money supply shocks. Yet the negative money shock had only a minor effect on output. This we posit is because the aggregate supply curve was very steep in the short run. Thus our evidence suggests that deflation in the late nineteenth century was primarily good.

The price experience of the late nineteenth century has great resonance for today's environment. One key lesson is on the stabilizing role of a credible nominal anchor. Adherence to the gold standard meant that market agents had strong expectations that the price level would be anchored and hence deflationary shocks would be only temporary (Bordo and Filardo (2004), Borio and Filardo (2003)). The gold standard also drove the money supply process and in turn the price level of each adherent. For an open economy, although international price levels were closely linked through commodity arbitrage and gold movements, we find that the transmission mechanism of price level shocks worked through the money supply in a very classical quantity theory way as described by Irving Fisher (Bordo 1984 page 52).

> "The price level in an outside community is an influence outside the equation of exchange of that community, and operates by affecting its money in circulation and not by directly affecting its price level." (Fisher {1922} 1965, p 172.)

Although important issues for today's environment arise from our findings. We need to be clear about what was different between the late nineteenth century environment and that of the twentieth and twenty first centuries. First, the historical era we analyze was the classical gold standard regime under which all four countries were linked together via common adherence to the gold standard convertibility rule and all faced a common money shock – the vagaries of the gold standard.

Second, aggregate supply seems to have been an important source of the shocks that we identify. This is likely in contrast to the other major deflationary episodes of the the twentieth century including: 1920-21, 1929-33, and Japan in the 1990s, which many observers posit reflected the consequences of severe monetary contraction.[14] Today's environment in the US, Canada and the EU may indeed be closer to the pre-1914 era than the earlier twentieth century episodes.

Third the short run aggregate supply seems to have been very steep pre-1913. This meant that negative demand shocks did not have much of a contractionary bite. This result is in sharp contrast to the experience of 1929-33. Many attribute the catastrophic declines of output in the face of monetary contraction then to the presence of nominal rigidities, in particular sticky wages (Bordo, Erceg and Evans, 2000).

Our analysis does not deal with many important issues that resonate in today's policy debate over what to do about the spectre of deflation. These include the zero nominal bound problem -- that very low inflation by reducing nominal interest rates makes it difficult to conduct monetary policy by conventional means (Orphanides, 2001). In contrast to today, in the pre-1914 era, little emphasis was placed by the policy makers in countries, like the UK and Germany, which had central banks, in using monetary policy to stimulate the real economy. Hence the zero nominal bound was not viewed as a problem.

We also do not explicitly distinguish between the effects of actual versus expected price level changes. It is unexpected deflation that produces negative consequences. However the steep slope of the aggregate supply curve revealed in our work suggests that price level changes were large anticipated. We also do not consider the efficiency aspects of deflation. According to Friedman (1969), the optimum holding of money would occur at a rate of deflation equal to the long run growth rate of real output.

Finally, although we find that pre-1914 deflation was primarily of the good variety, it doesn't mean that people *felt* good about it. The common perception of the 1880s and 1890s in all three countries was that deflation *was* depressing. This in turn may reflect the fact that deflation was largely unanticipated. It may also have reflected money

[14] For a contrary view see Kehoe and Prescott (2002).

illusion.[15] This was reflected in labor strife and political turbulence. This perception can be seen in the views of US farmers who believed that the terms of trade had turned against them and workers in all three countries who did not view falling money wages as being compensated by even more rapidly falling commodity prices. It is doubtful if a sustained deflation today would be any less unpopular.

[15] Friedman and Schwartz (1963; 41-2) compare the U.S. experience of the 1870s when money growth exceeded the growth of the labor force but not the growth of real output so that nominal wages were rising, with the 1880s when money growth was less than the growth of the labor force and of real growth and money wages declined. They then relate these facts to the increase in labor unrest and agitation over the monetary standard.

Data appendix

U.S.: Data on money, prices and GDP all from Balke and Gordon (1986). The money series is M2 (in billions of dollars) and they describe it as an average of quarterly data. Money stock and RGDP are converted from local currency units to British pounds using the exchange rate between the local currency and the pound for each year of the sample. Data on gold from NBER Historical data series 14076.

UK: the GDP deflator is the ratio of Constant (1900 prices) to current prices GDP from Mitchell (2003; Table J1) rebased to 1913=100. Money is M3 (in millions of pounds sterling) annual average data from Capie and Weber (1985;76). Real GDP are from Mitchell (2003; Table J1), based on the estimates of Feinstein. Gold is the sum of Bank of England reserves from Jones and Obstfeld (NBER data) and gold outside the Bank of England is from Capie and Webber (1985, 198) col. IV.

Germany: the GDP deflator is the ratio of Constant (1900 prices) to current prices GDP from Mitchell (2003; Table J1) rebased to 1913=100. GDP is the sum of NNP + CF from Mitchell (2003; Table J1), who in turn took the data from Hoffman (1965). Money stock is M2 (in millions of marks) from Tilly (1973; 347), with a correction for his typo in 1907. Money stock and RGDP are converted from local currency units to British pounds using the exchange rate between the local currency and the pound for each year of the sample. Gold reserves from Deutshce Bundesbank (1976; 36) "Geld in barren und munzen" Table 1.01; Gold in circulation from Deutsche Bundesbank (1976; 14) "Goldmunzen" Table 1.01.

France: the GDP deflator is the ratio of Constant (1900 prices) to current prices GDP from Mitchell (2003; Table J1) rebased to 1913=100. GDP is the sum of NNP + CF from Mitchell (2003; Table J1), based on Toutain (1987). The money stock is computed as the sum of notes in circulation and sight deposits (from St. Marc (1983; 37)) and an interpolated series of specie in circulation. This latter is derived by interpolating between Sicsic's data points (1878,1885,1891,1897,1903,1909) using Pupin's annual estimates of the coin in circulation. Specie in circulation comprised two-thirds of the money stock in 1880 and one third in 1913. Gold: Sicsic (1989) data on gold coin, interpolated with Dunuc's data plus Gold in the Bank of France from Jones and Obstfeld's NBER data.

World: Stock of gold from Cassel (1930) Appendix 1; stock of monetary gold from Kitchin (1930) Table B.

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Table 1: Summary of Chow Tests for a Break in 1896

Variable	μ *(before) (%)	μ(after) (%)	p-value (Chow test)
Price(US)	-1.08	1.28	0.019
Price(UK)	-0.65	0.84	0.053
Price(Germany)	-0.32	1.25	0.085
Price(France)	-0.89	1.49	0.003
Output(US)	2.66	4.26	0.260
Output(UK)	1.64	1.74	0.329
Output(Germany)	3.24	2.66	0.337
Output(France)	1.66	1.72	0.768
Money(US)	4.60	7.55	0.533
Money(UK)	2.26	1.84	0.418
Money(Germany)	4.53	6.22	0.277
Money(France)	0.30	3.75	0.022

* μ represents average growth rate (in per cent) of the variable before or after the break date

Table 2: Unit Root Tests

	ADF(1)		ADF(2)		Perron	
Variable	Statistic	Crit. value	Statistic	Crit. value	Statistic	Crit. value
Prices						
US	-0.58	-2.95	-1.24	-3.55	-3.31	-4.24
UK	-0.57	-2.95	-3.00	-3.55	-3.41	-4.24
Germany	-0.37	-2.95	-2.61	-3.55	-4.01	-4.24
France	-0.24	-2.95	-0.85	-3.55	-2.73	-4.24
Output						
US			-2.13	-3.55		
UK			-1.92	-3.55		
Germany			-2.90	-3.55		
France			-2.82	-3.55		
Money						
US			-1.98	-3.55		
UK			-2.08	-3.55		
Germany			-1.92	-3.55	-2.78	-4.24
France			-1.50	-3.55	-2.08	-4.24

ADF(1) refers to ADF test with only a constant in alternative, ADF(2) refers to ADF test with constant and trend in alternative. The critical value reported is the 5% critical value for the ADF and the 5% critical value for the Perron test for a break that occurs in the middle of the sample.

Table 3
Correlations across Countries: Money Shock

Country	Correlation			
	US	UK	Germany	France
US	1	0.1902	0.4095	0.4252
UK	0.1902	1	0.4576	0.1643
Germany	0.4095	0.4576	1	0.4109
France	0.4252	0.1643	0.4109	1

Correlations across Countries: Supply Shock

Country	Correlation			
	US	UK	Germany	France
US	1	0.5191	0.0408	-0.0617
UK	0.5191	1	-0.0247	0.2252
Germany	0.0408	-0.0247	1	0.1117
France	-0.0617	0.2252	0.1117	1

Correlations across Countries: Demand Shock

Country	Correlation			
	US	UK	Germany	France
US	1	-0.1634	-0.0066	-0.0643
UK	-0.1634	1	-0.052	-0.2777
Germany	-0.0066	-0.052	1	-0.029
France	-0.0643	-0.2777	-0.029	1

Figure 1 : Prices, Output, and Money Stocks

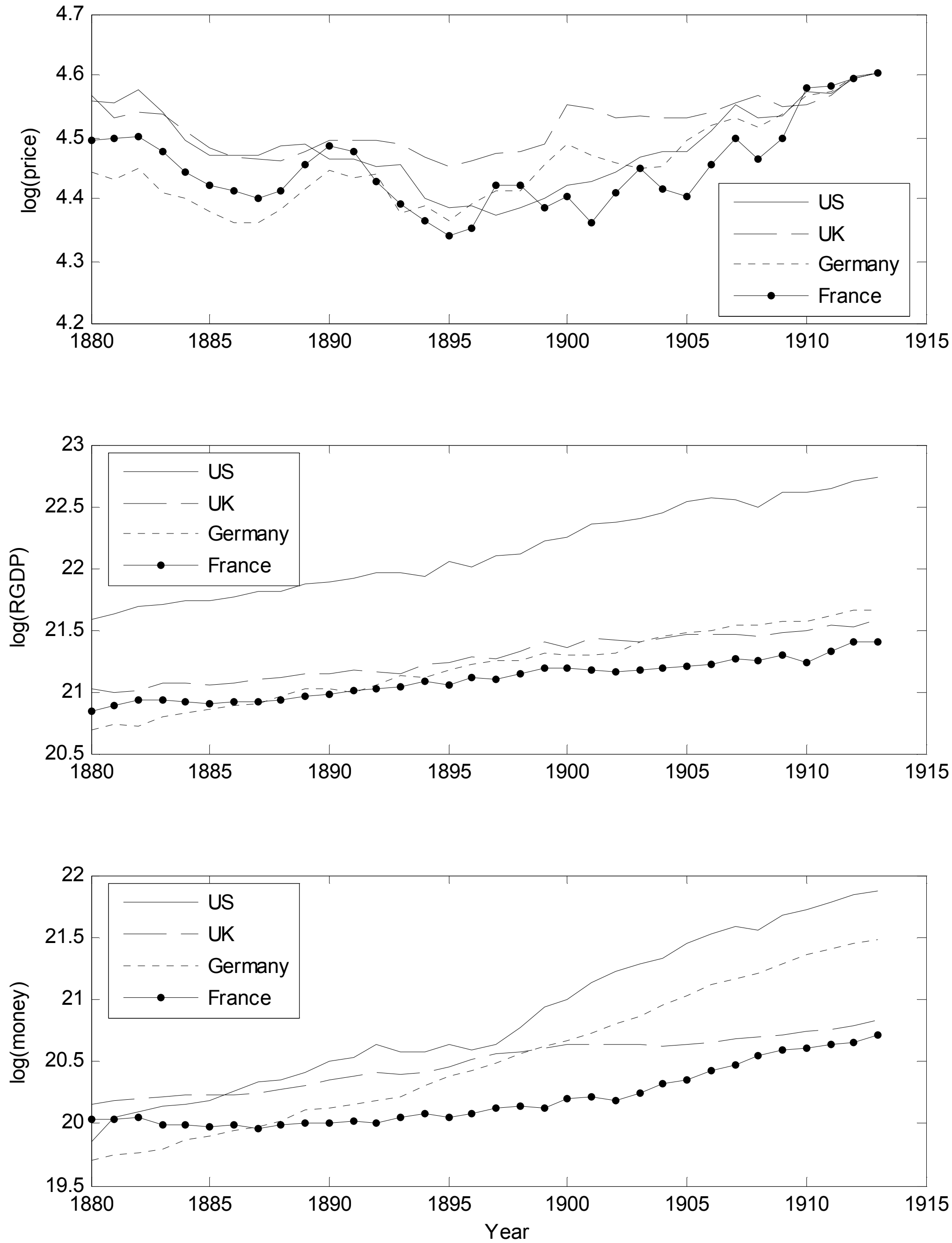


Figure 2: Stocks of Gold

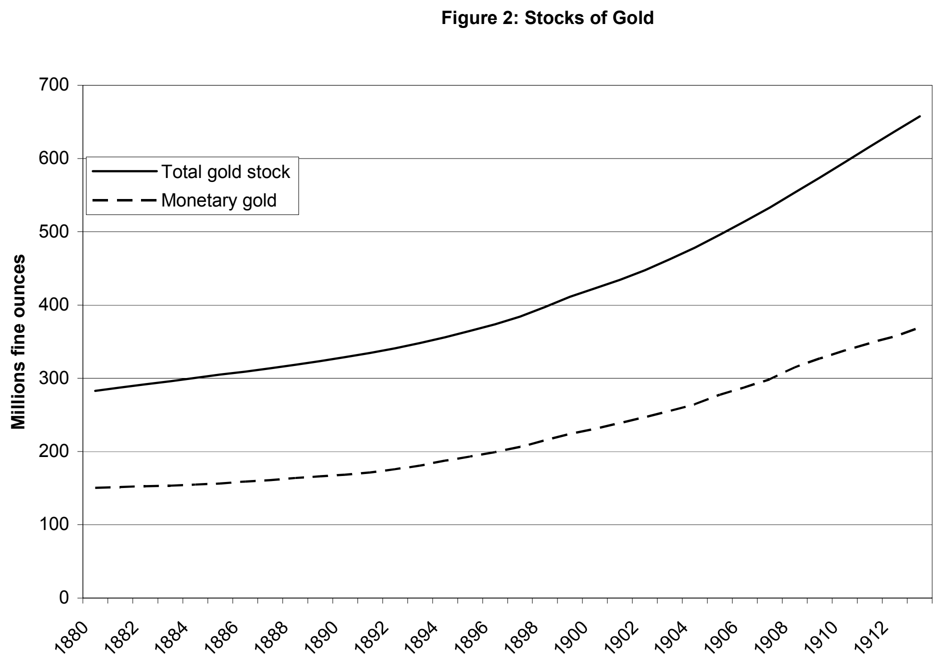


Figure 3a: Growth rates of Monetary Gold Stocks

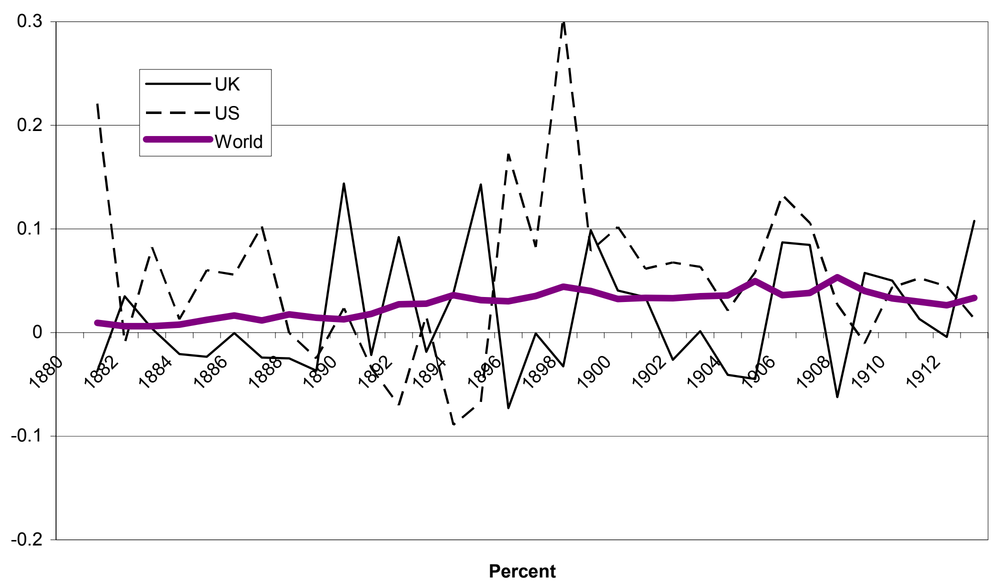


Figure 3b: Growth rates of Monetary Gold stocks

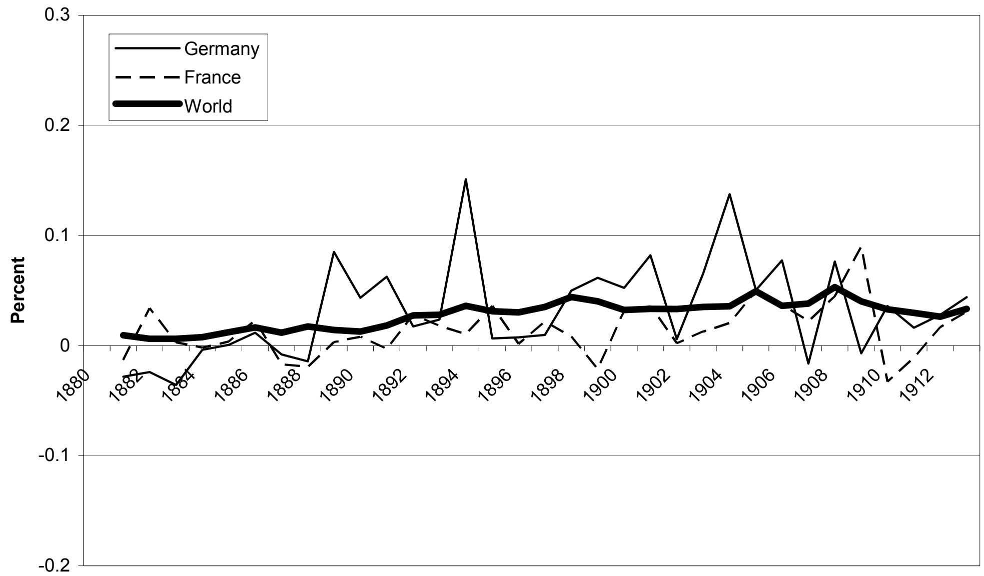


Figure 4: Money stock to Monetary Gold Ratio

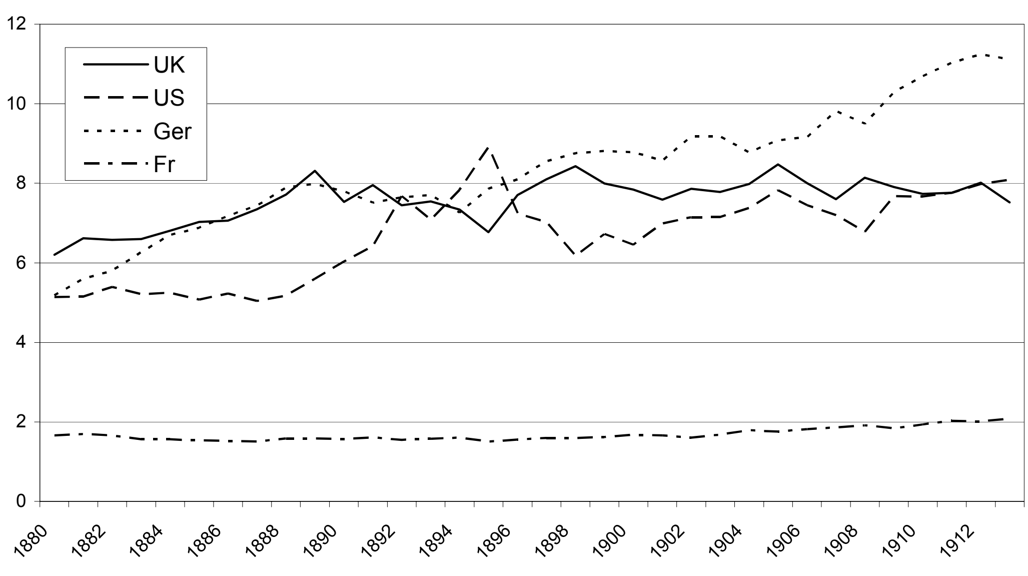
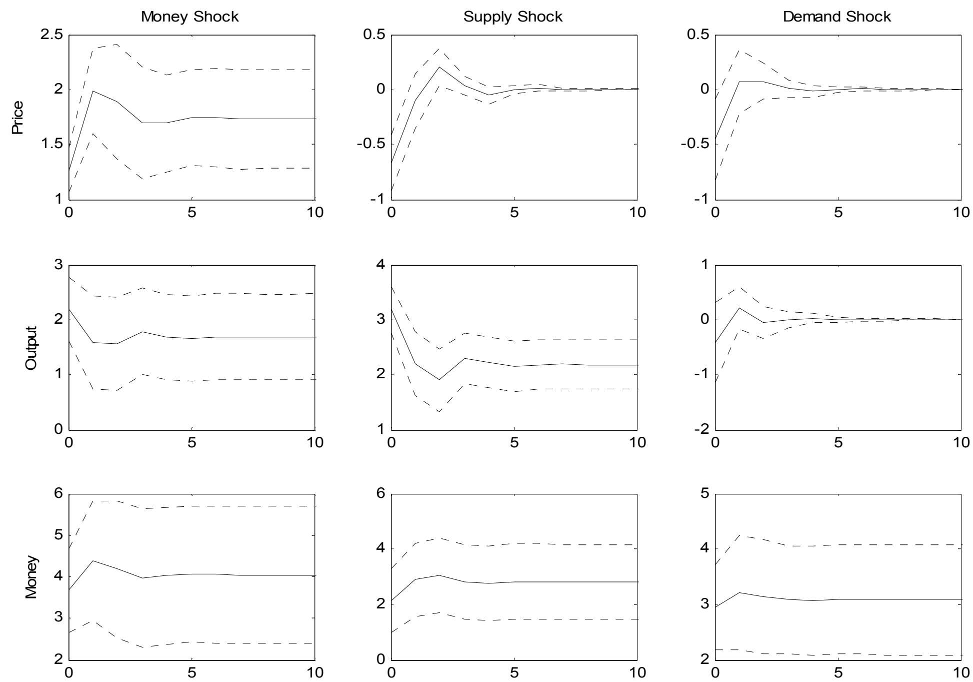
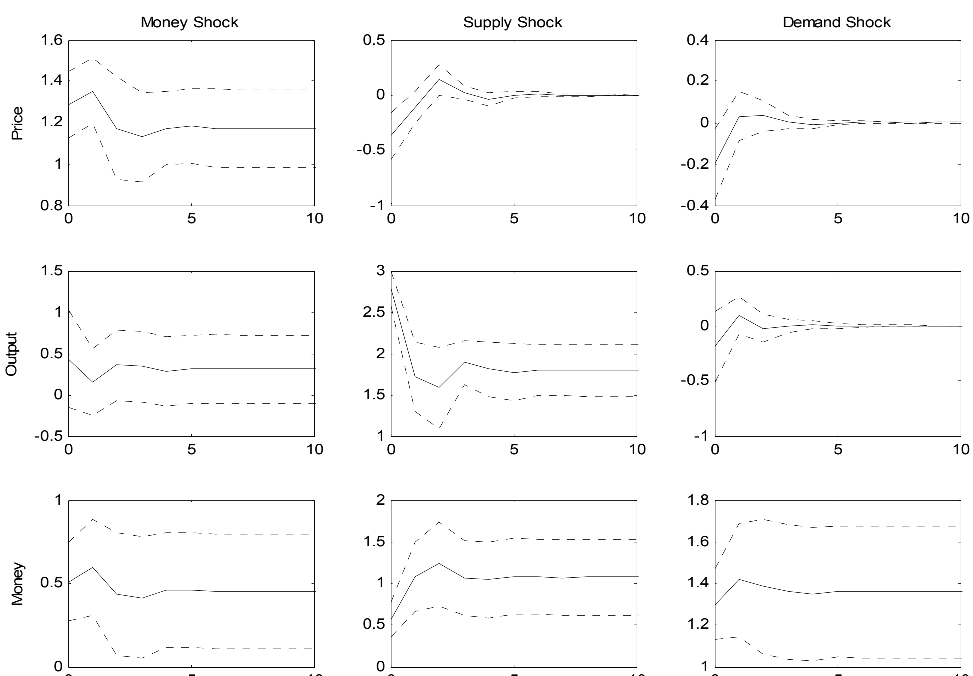


Figure 5:

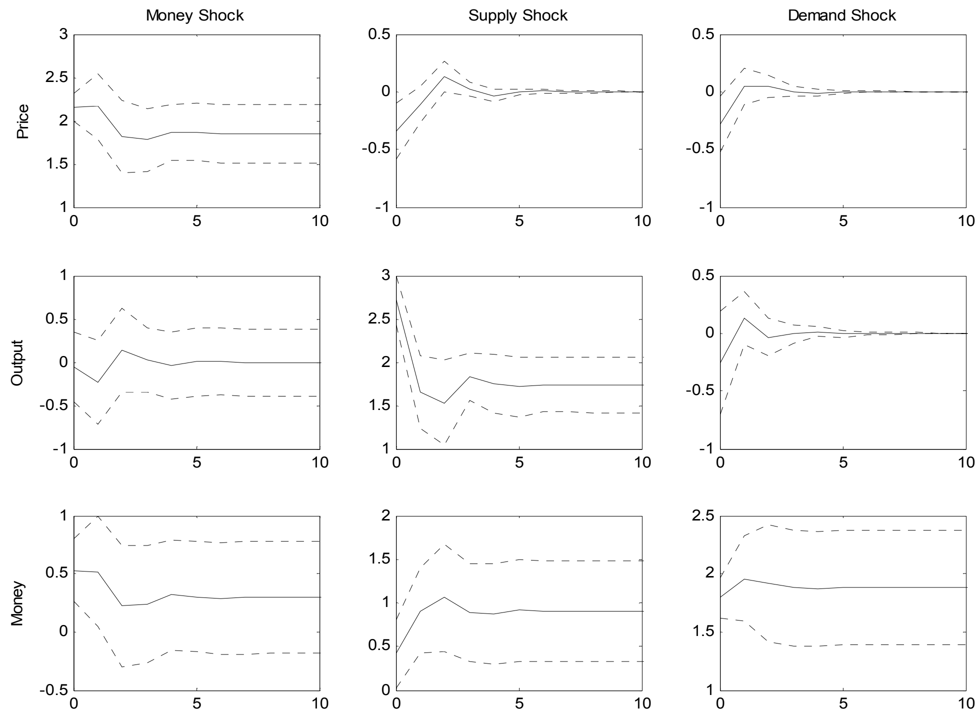
Structural IRF: US



Structural IRF: UK



Structural IRF: Germany



Structural IRF: France

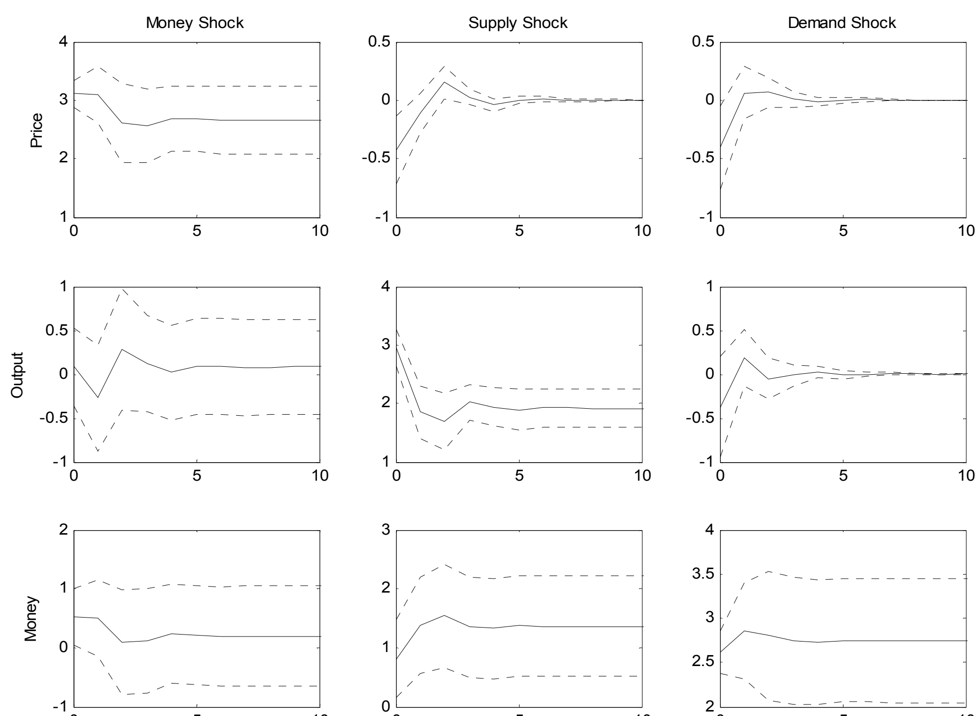
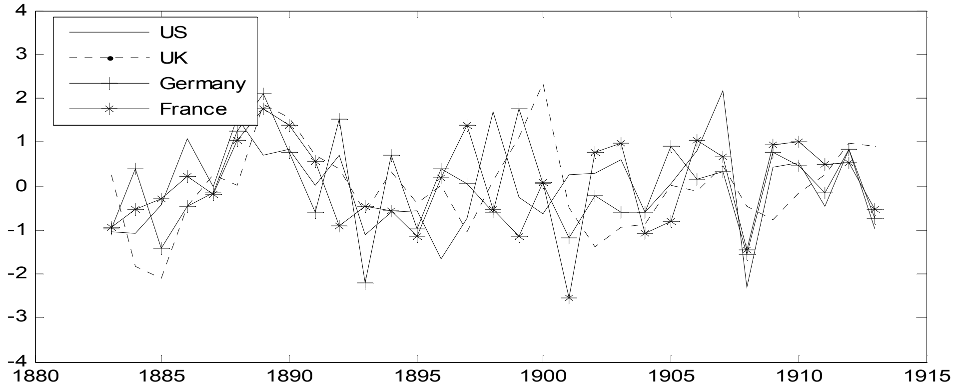
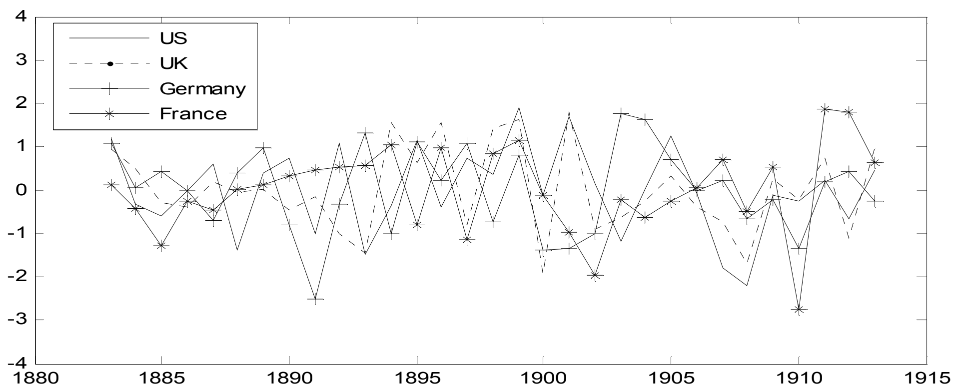


Figure 6:

Money Shock



Supply Shock



Demand Shock

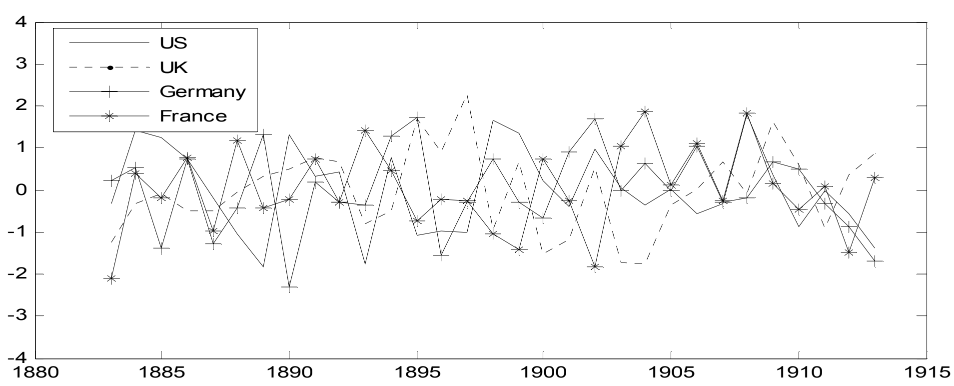


Figure 7: Historical Decomposition for Prices: US

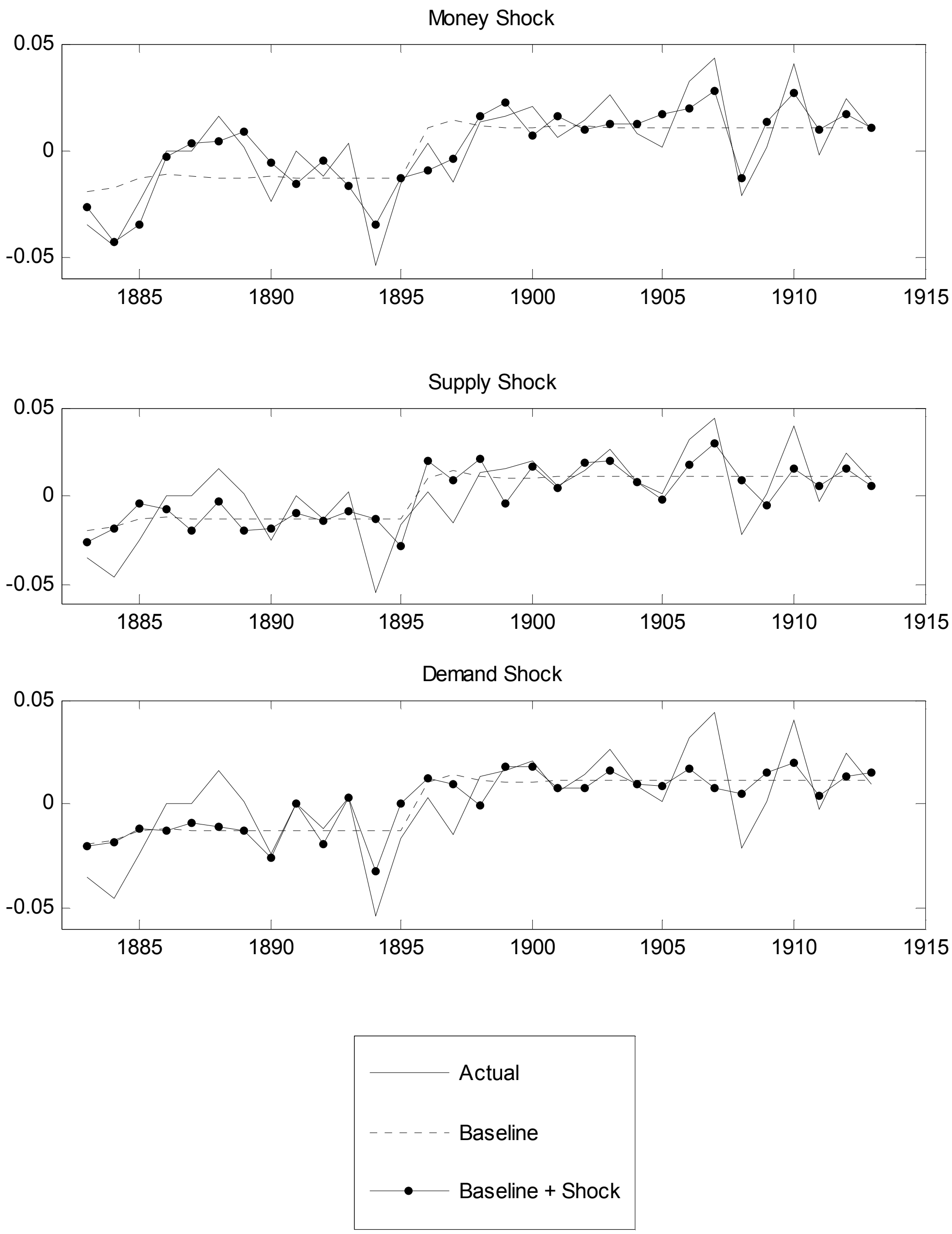


Figure 8: Historical Decomposition for Output: US

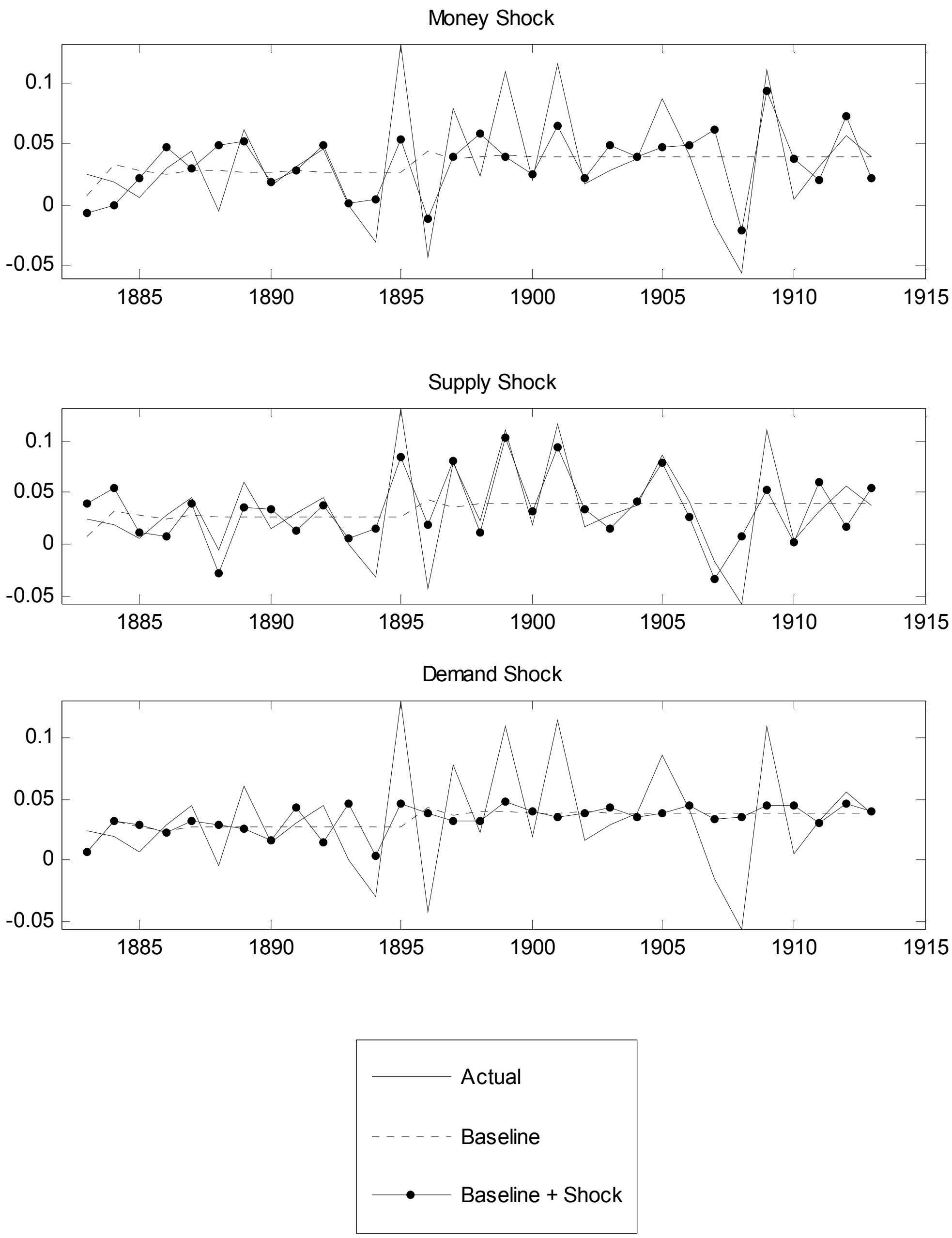


Figure 9: Historical Decomposition for Money: US

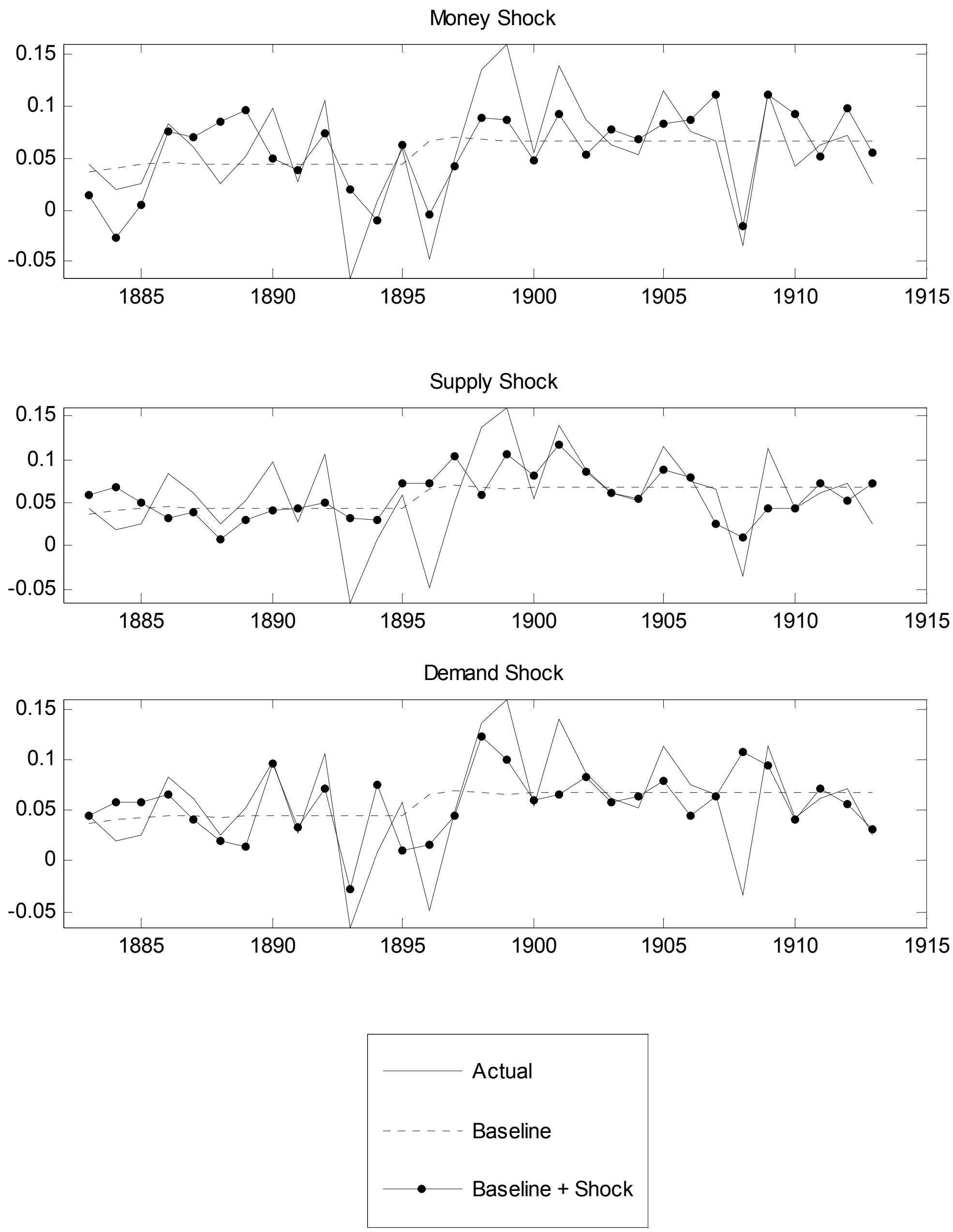


Figure 10: Historical Decomposition for Prices: UK

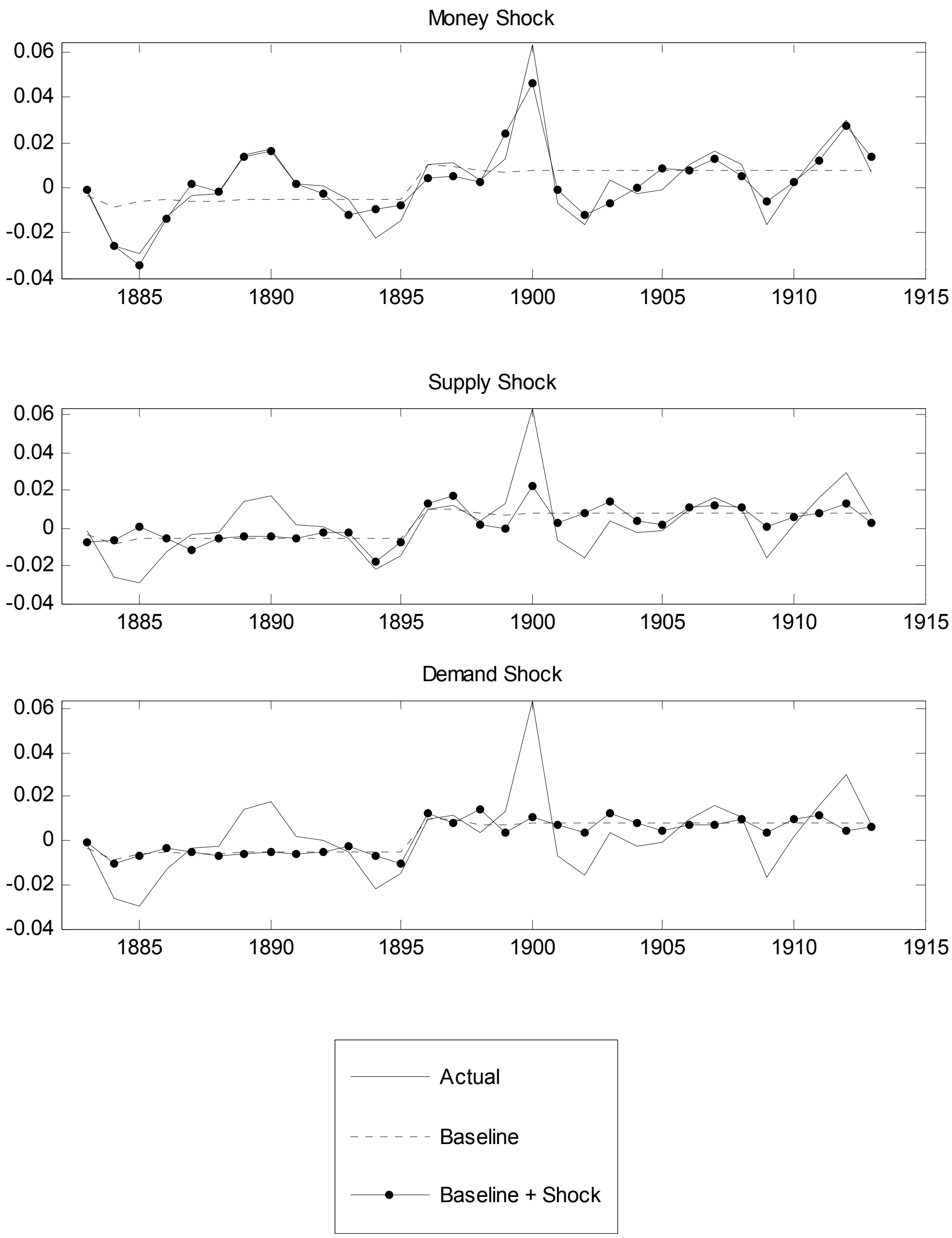


Figure 11: Historical Decomposition for Output: UK

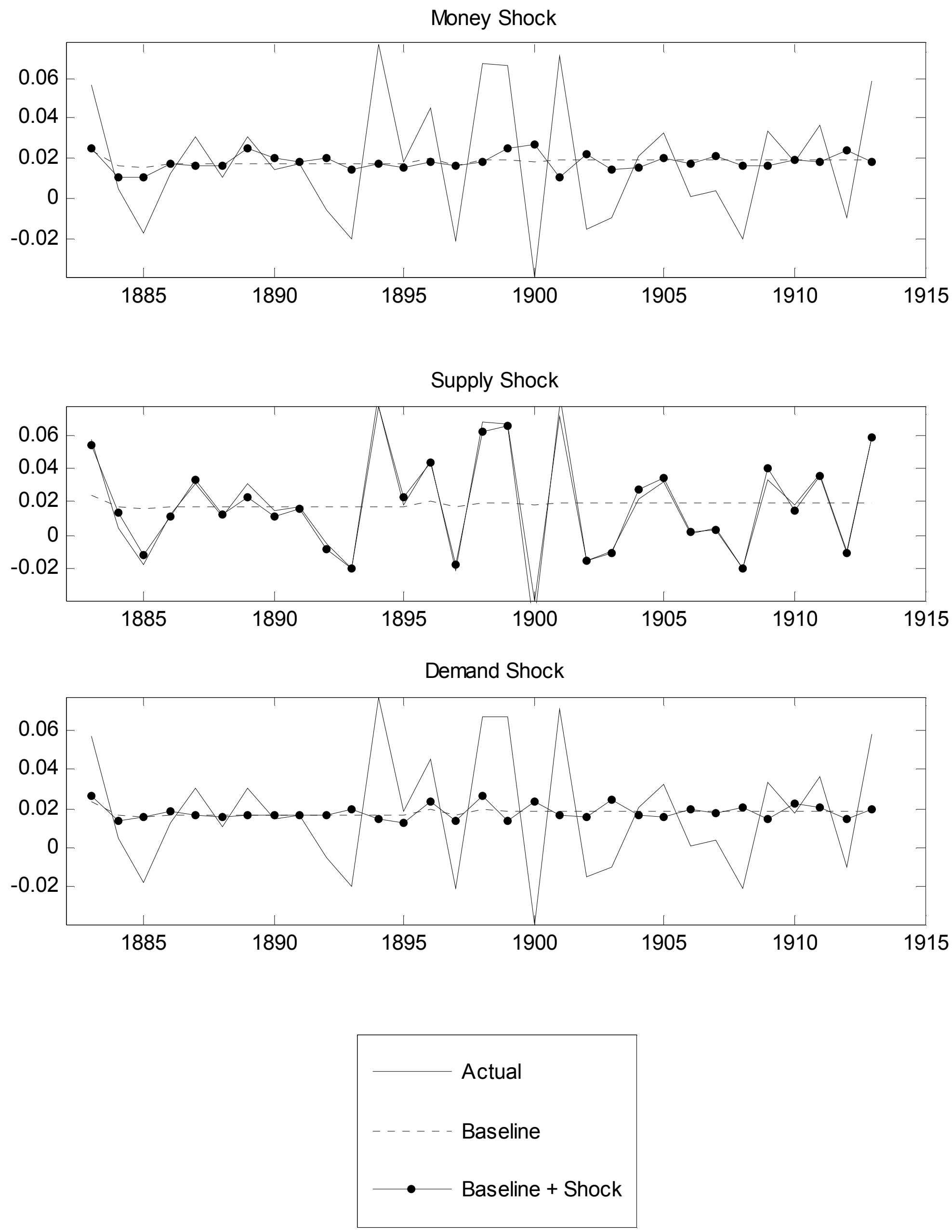


Figure 12: Historical Decomposition for Money: UK

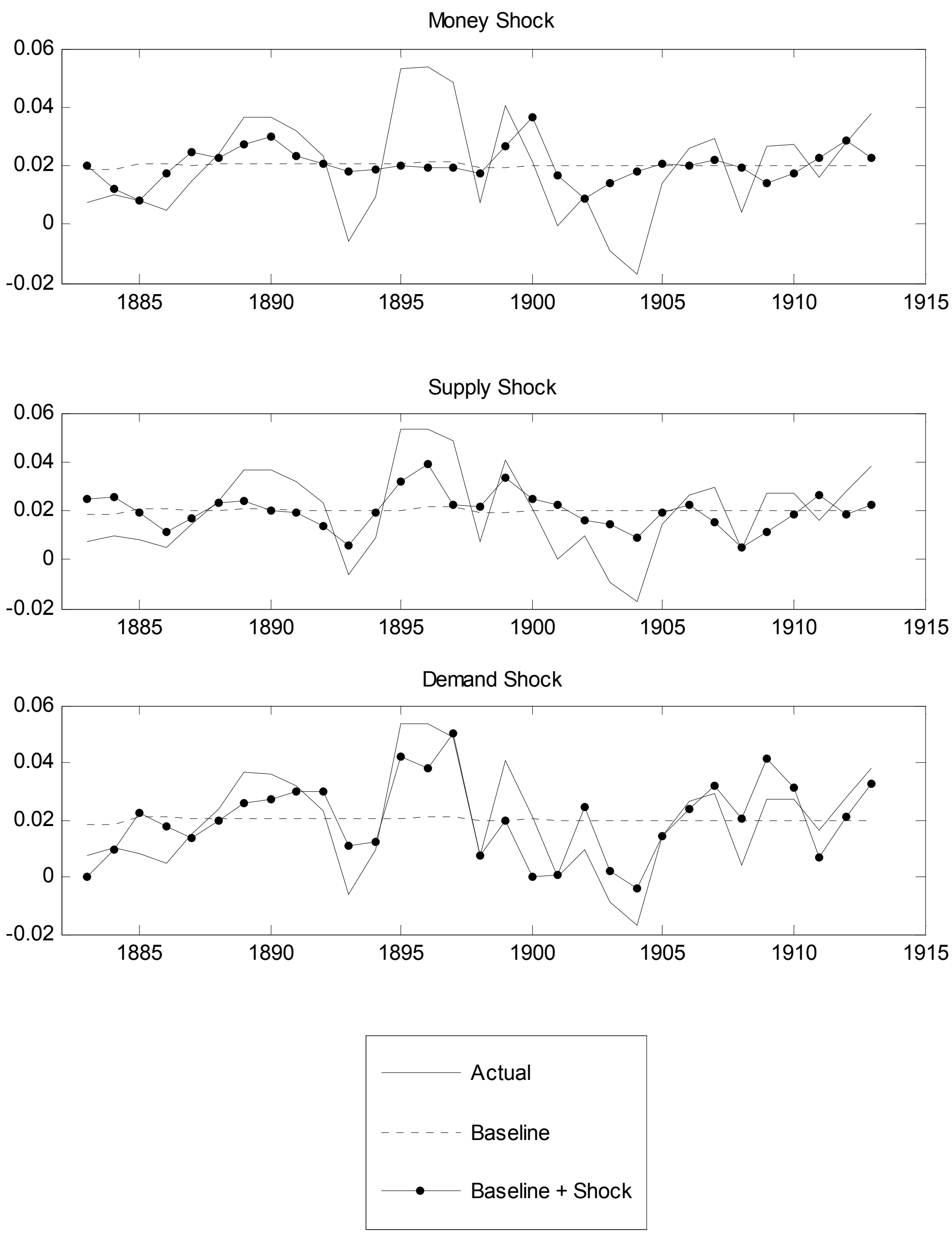


Figure 13: Historical Decomposition for prices: Germany

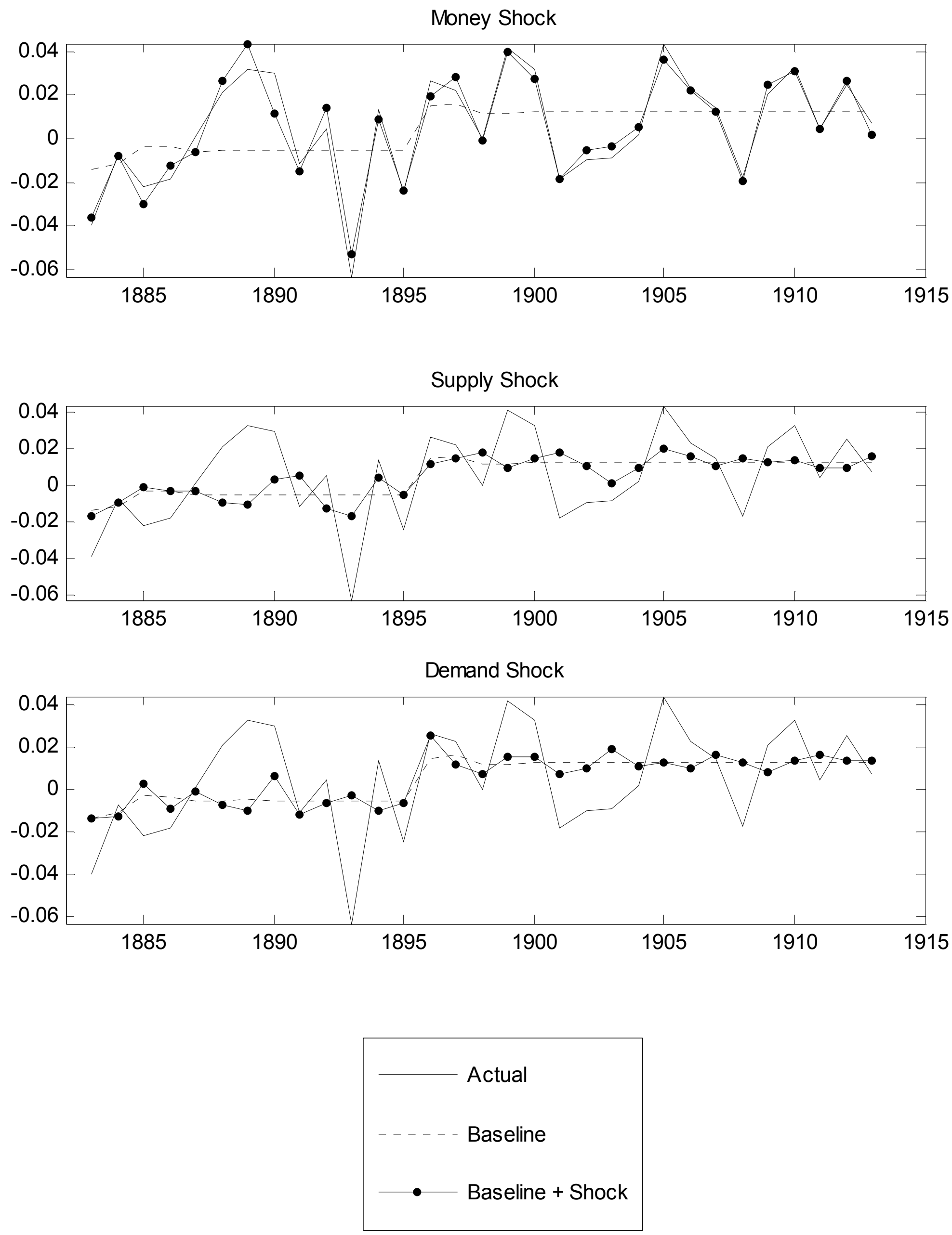


Figure 14: Historical Decomposition for Output: Germany

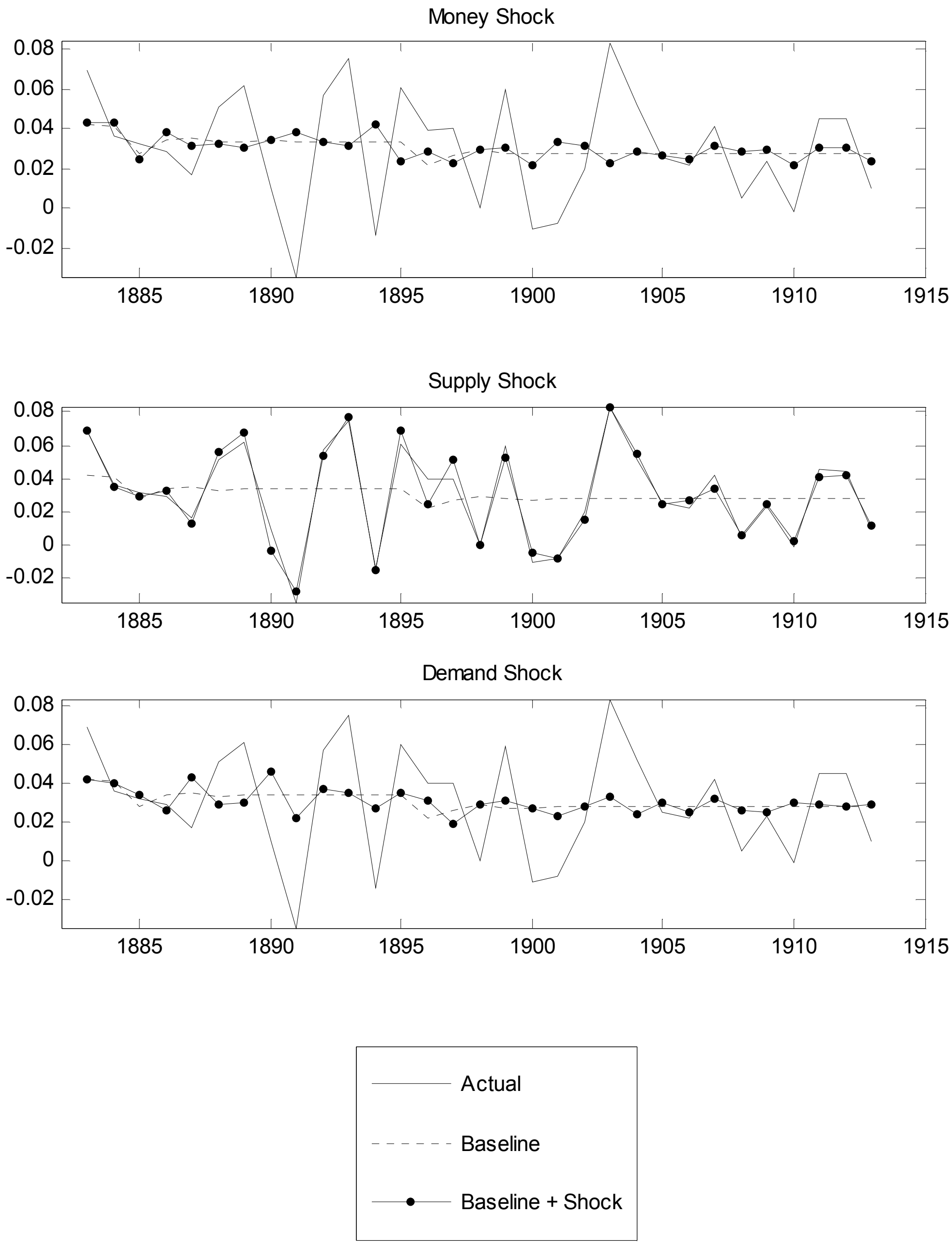


Figure 15: Historical Decomposition for Money: Germany

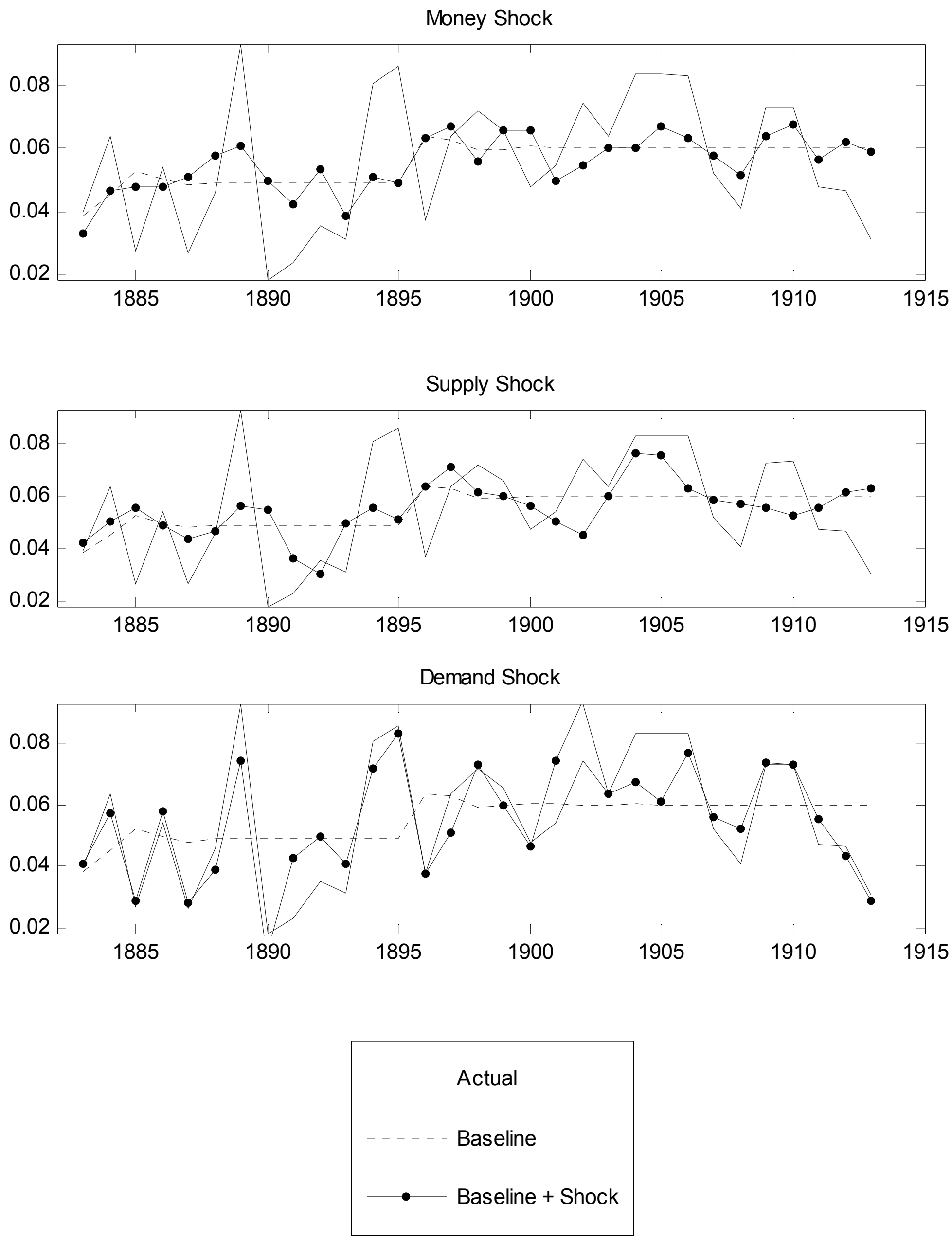


Figure 16: Historical Decomposition for Prices: France

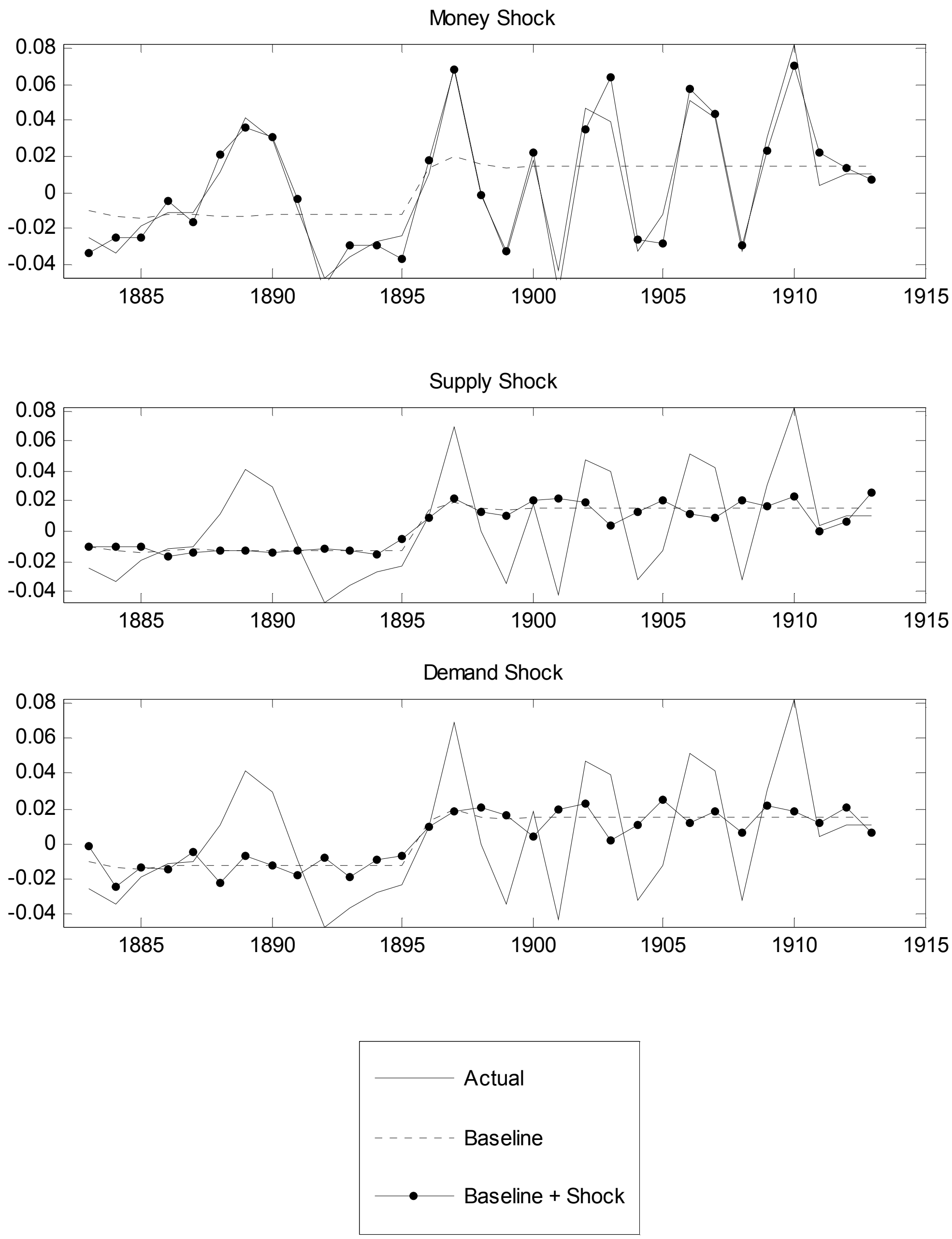


Figure 17: Historical Decomposition for Output: France

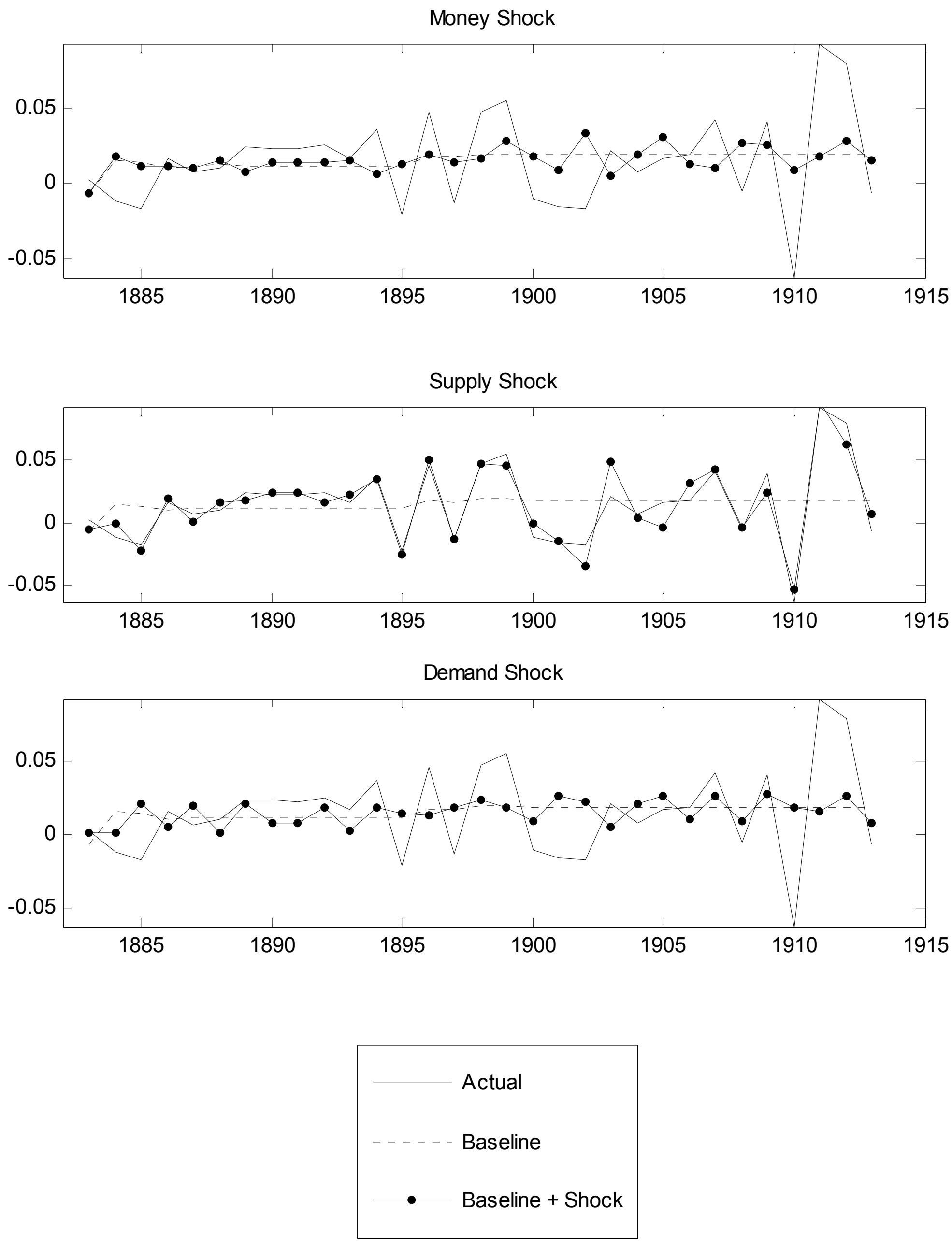


Figure 18: Historical Decomposition for Money: France

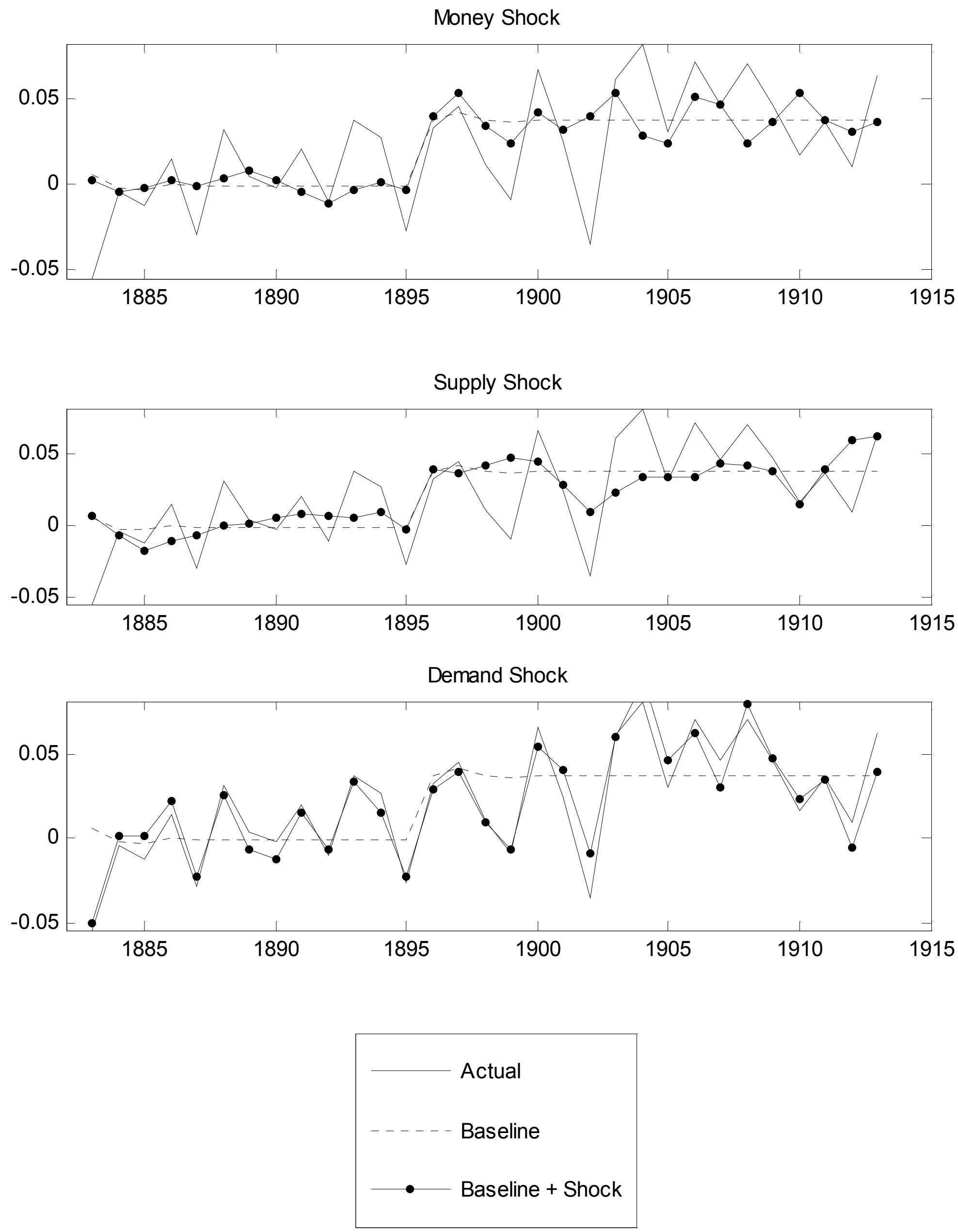


Figure 19: Historical decomposition for output (including world gold production): U.S.

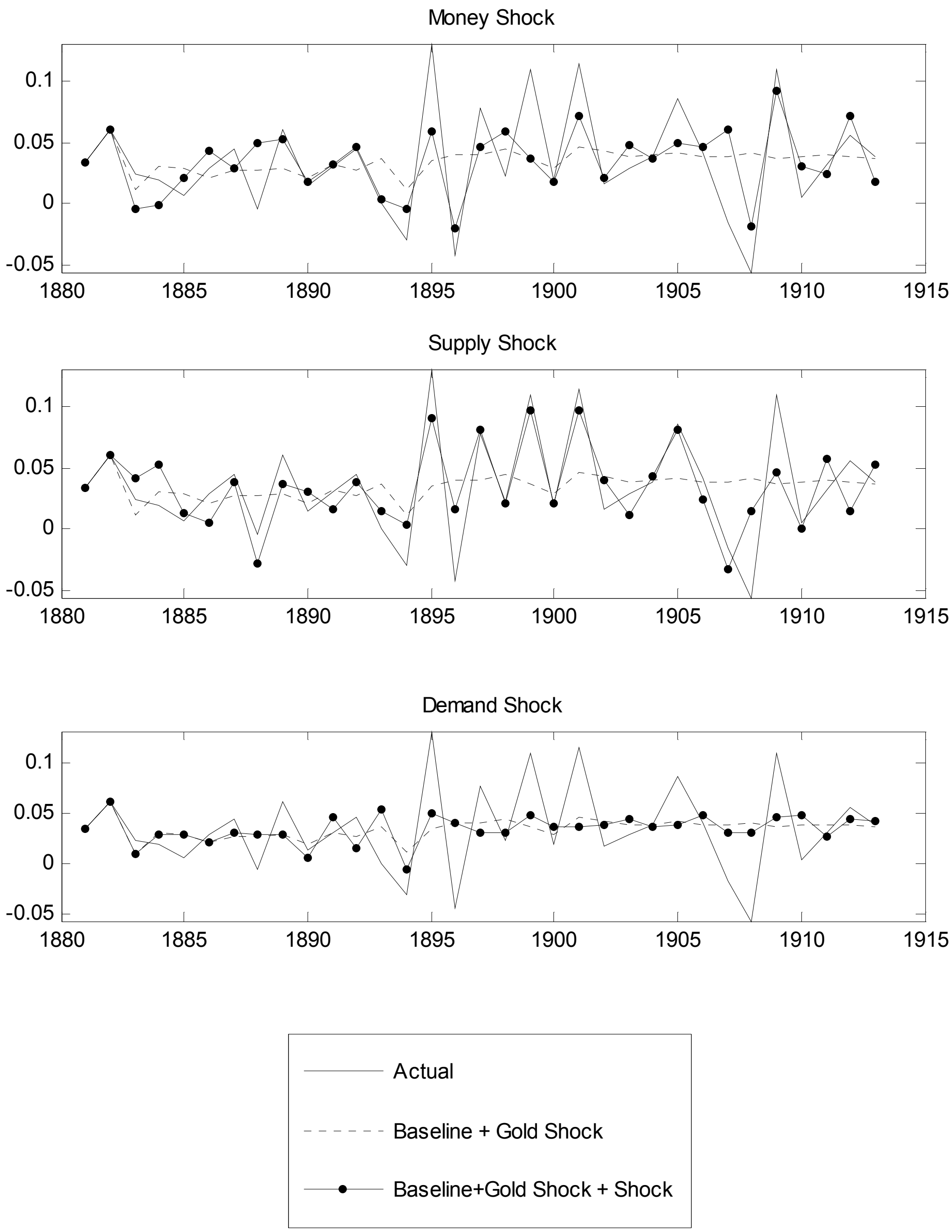


Figure 20: Historical decomposition for output (including world gold production): U.K.

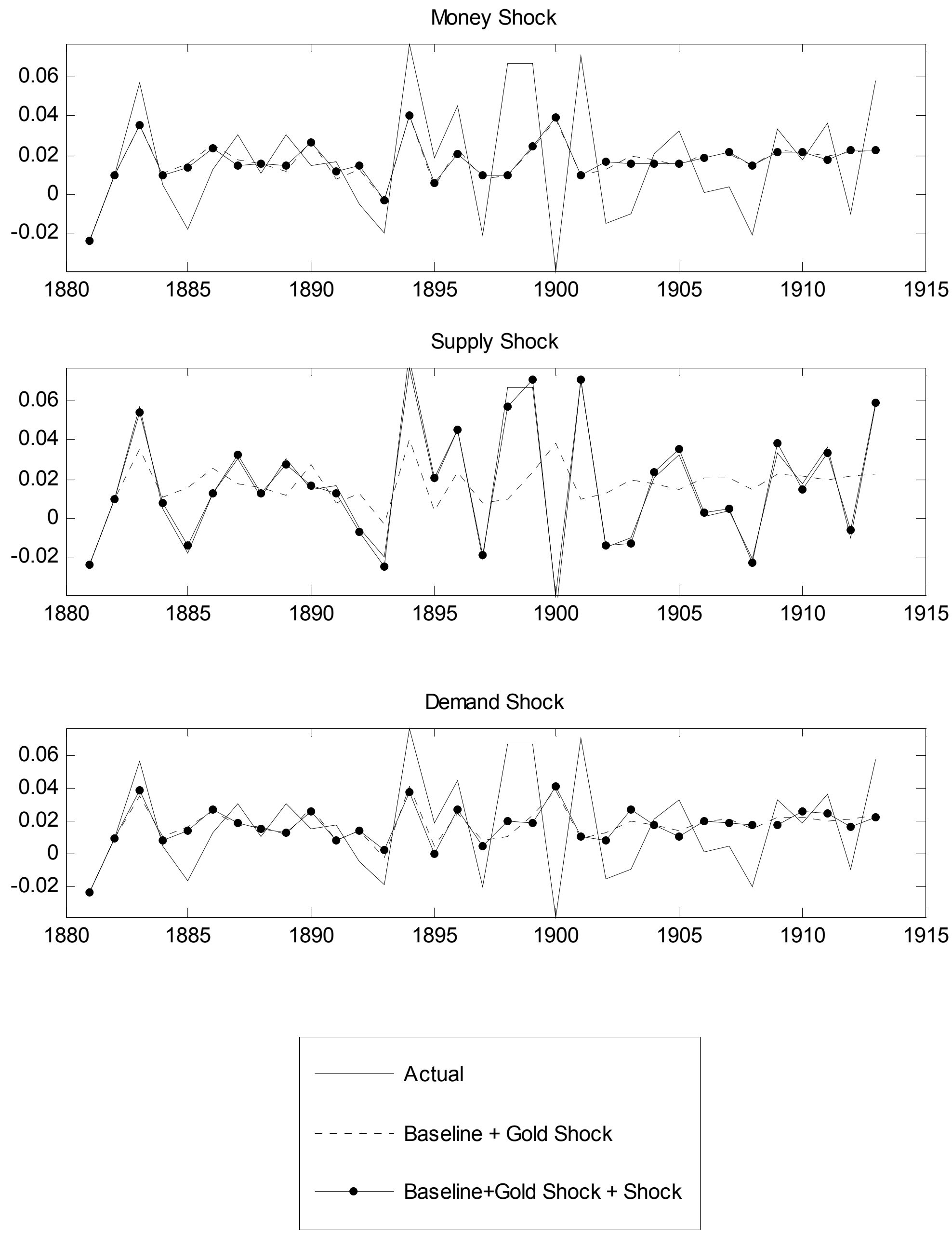


Figure 21: Historical decomposition for output (including US gold stocks): U.S.

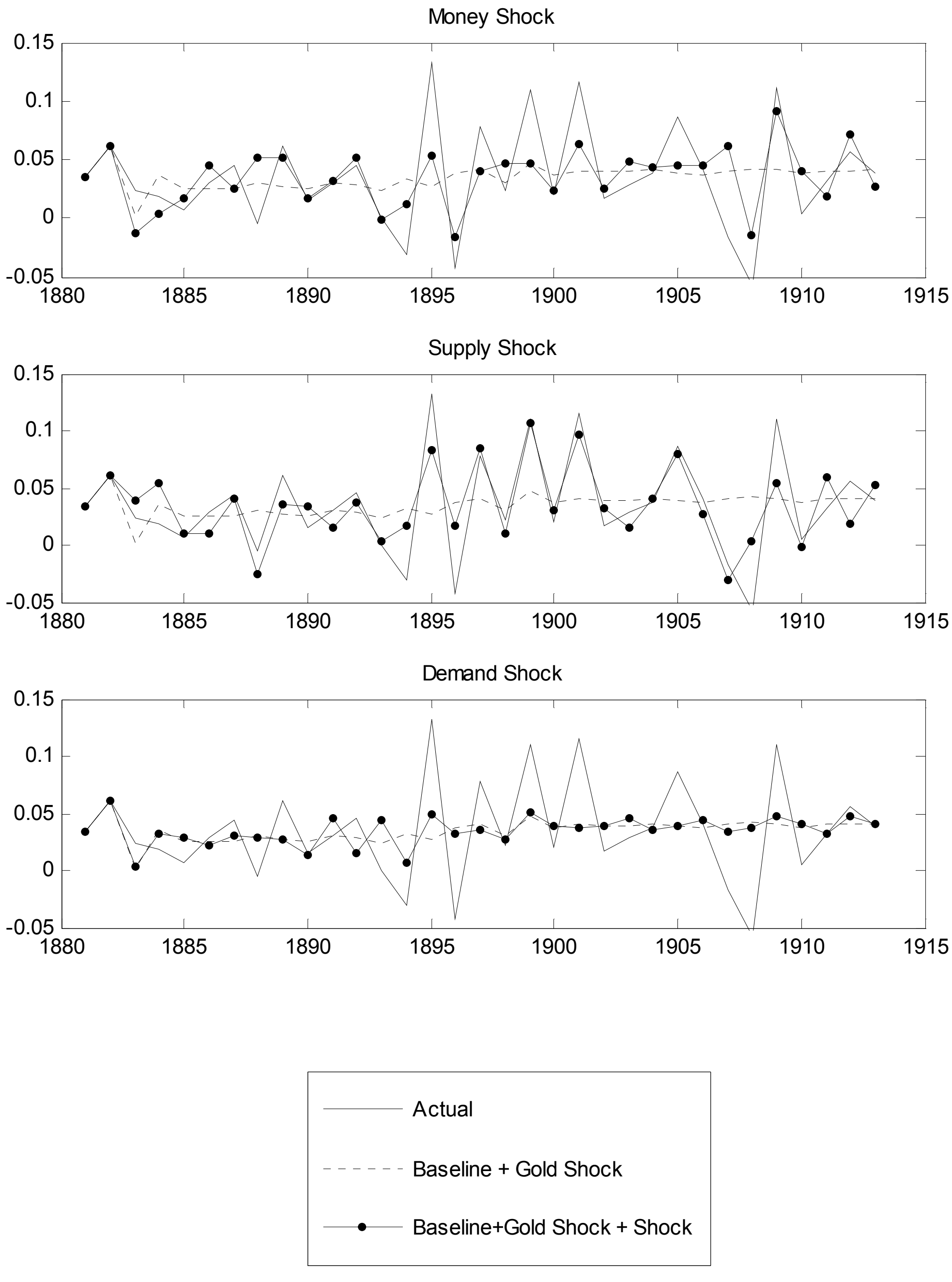


Figure 22: Historical decomposition for output (including UK gold stocks): U.K.