Nominal Stability over Two Centuries*

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Abstract

I assess the nominal stability of monetary regimes in Switzerland over the past two centuries. In order to control for transitory measurement errors, in particular during the 19th century, I use an unobserved-components stochastic-volatility model to extract the permanent components from several nominal variables. The descriptive analysis of these estimates suggests that our current monetary regime, flexible inflation targeting, provided a relatively stable monetary background. For the 19th century, the estimates are very imprecise. We should therefore be cautious when characterizing metal currency regimes as providing a stable monetary background. A discussion of the results shows that the apparent success of flexible inflation targeting poses new challenges for the implementation of monetary policy because the trend decline in inflation was associated with a trend decline in nominal interest rates.

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Keywords: Nominal stability, price stability, monetary regimes, monetary history, measurement error, unobserved-components stochastic-volatility model.

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Ultimately, it appears, one can check to see if an economy has a stable monetary background only by looking at macroeconomic indicators such as nominal GDP growth and inflation. On this criterion it appears that modern central bankers have taken Milton Friedman's advice to heart.

— Ben S. Bernanke, October 24, 2003

1 Introduction

Nowadays, central banks usually announce to stabilize inflation at an explicit numerical target. No modern central bank currently targets the gold price in domestic currency, or issues a commodity money, despite that economic historians view metal currency regimes as providing a high degree of nominal stability and firmly anchored inflation expectations. On the one hand, this may be related to the view that metal currency regimes limit discretionary policies in favor of long-term price stability. On the other hand, recent research for the US suggests that even the price level was less stable and predictable under 19th century metal currency regimes than during the 20th century (see Cogley and Sargent, 2015). In this paper, I aim to assess which monetary regime provided a stable monetary background in Switzerland over the past two centuries.

The quote by Bernanke (2003) highlights that this assessment should consider various macroeconomic indicators. I therefore compile a novel Swiss data set covering four indicators of nominal stability: consumer prices, wholesale prices, a GDP deflator, and nominal GDP per capita. In order to abstract from short-term fluctuations (over which the central bank has less control) and measurement errors (which would distort the analysis), I extract a permanent trend using an extension of the unobserved component-stochastic volatility (UC-SV) model by Stock and Watson (2007), which has been recently proposed by Chan (2013). The main advantage of the extended model is that it allows for a moderately persistent transitory component with time-varying volatility. This property is particularly important when analyzing historical data with possibly serially correlated measurement errors. In addition, the time-varying stochastic volatility allows for the importance of measurement errors to decline over time. These measurement errors are likely to be more important during the 19th century than after modern statistics emerged at the beginning of the 20th century (see e.g. Romer, 1986a,b, Allen, 1992, Kaufmann, 2017).

The descriptive analysis of these trends suggests that our current monetary regime, flexible inflation targeting, provided a relatively stable monetary background. Although the point estimates indicate that trend inflation was also relatively stable during the 19th century, the uncertainty associated with these estimates is too large to support this view with much confidence. When discussing the implications of the results I show that the decline in trend inflation since the Bretton Woods System can explain a relevant part of the trend decline in nominal interest rates. This poses new challenges for the conduct of monetary policy because of the effective lower bound on nominal interest rates.

The main contribution of this study is to analyze nominal stability on a long historical data set for Switzerland. It is therefore related to studies on the US and UK that estimate UC-SV models to assess price stability and movements in trend inflation. These studies dealt with measurement errors in historical data in several ways. Cogley and Sargent (2015) estimate a univariate UC-SV model on US WPI data controlling for persistent measurement error identified from overlapping, methodologically consistent, data sources. Cogley et al. (2015) estimate a model on CPI data for the UK without overlapping data sources; they instead assume that the measurement error variance changes when the sources of the historical series differ. Finally, Garnier et al. (2015) extract a common trend from various quarterly post-WW inflation series. This is another possibility to account for measurement issues to the extent that they are unrelated among various indicators.

The remainder of this paper is structured as follows. I define seven monetary regimes and provide some historical background to highlight their main characteristics. Then, I describe the data set before presenting the model. Afterwards, I provide the main results. The last section discusses the implications for the conduct of monetary policy and concludes.

2 Historical background

Assessing nominal stability over two centuries requires some historical background.[1] The purpose of this review is to classify the monetary regimes according to their main objectives and how they were integrated in the international monetary system. For the purpose of this paper, it is useful to distinguish between seven distinct regimes since the early 19th century: Competing currencies, Bimetallism, Gold Standard, the World War period, Bretton Woods, monetary targeting, and flexible inflation targeting.

2.1 Competing currencies (1804–1849)

During the first half of the 19th century a wide variety of currencies circulated on the territory of the Old Swiss Confederation. This variety was a consequence of the loose association of sovereign cantons (*Kantone*), associates (*Zugewandte Orte*), and condominiums (*Gemeine Herrschaften*) forming the Old Swiss Confederation. Only during the short period of the Helvetic Republic (1798–1803), which was an affiliated republic under French control, some centralized government services were introduced. In particular, the Swiss franc briefly emerged as the single currency (see Maissen, 2015, p. 331). However, after the Helvetic Republic collapsed the cantons took back the prerogative of coinage and partly reissued their old currencies. These domestically issued currencies were often of dubious quality, however. Therefore, transactions were often settled with foreign coins (see Baltensperger, 2012, p. 49-50). Despite a lack of banking regulation, banknotes played a minor role in payment transactions. Private banks and larger cities started to emit banknotes in 1825. Interestingly, these notes were often denominated in foreign currency, which may reflect that for large transactions it may have been preferable to use a well-known and widely accepted denomination.

The political environment was fragile, and therefore, the potential temptation to use monetary policy to finance wars substantial. In the Old Swiss Confederation, cantons and cities

[1] This historical review is based on other authors' more detailed work: see Willis (1901) for the history of the Latin Monetary Union, Flandreau (2004) for a detailed account of Bimetallism in France, Baltensperger (2012) for Swiss monetary regimes from 1805 to 2013, Swiss National Bank (2007a) for the history of the SNB from 1907 to 2007, Zurlinden (2003) for Switzerland during the Great Depression, Jordan et al. (2010) for the SNB's new monetary policy strategy from 2000 to 2010, Maissen (2015) for an overview of Swiss history since the 13th century, Eichengreen (2008) for the global monetary system, and Bernholz (2003) for a general assessment of various monetary regimes and their implications for inflation.

were engaged in several local conflicts. Examples are the war leading to the secession of the canton of Basel into Basel-city (*Stadt*) and Basel-rural area (*Landschaft*), and wars between conservative cantons and liberal rebels. Although these conflicts were local at first they ultimately led to a war between the Swiss Confederation and an association of conservative cantons in 1847, the so-called *Sonderbund* War. As the Swiss Confederation quickly won this war, the cantons agreed on a new republican constitution in 1848 (see Maissen, 2015, p. 202).

The variety of currencies implied that, unlike today, there was no central bank with a monopoly on minting coins or issuing banknotes. Therefore, a centralized policy with clearly defined objectives did not exist. However, researchers view this episode as a successful example of denationalized competing currencies with a relatively stable purchasing power (see Baltensperger, 2012, p. 59-61). Hayek (1978) argued that competition among currency issuers prevents inflation because, if they would issue too many banknotes or reduce the fineness of metallic coins, the public would simply switch to other currencies with a stable purchasing power.

2.2 Bimetallism (1850–1873)

The new constitution of 1848 enabled two major changes in the Swiss economic environment: forming a single market and moving towards a more integrated currency union. Important elements of the single market included abolishing internal tariffs, unifying external tariffs, generating income for central government services, and guaranteeing freedom of establishment for Christian citizens (see Maissen, 2015, p. 204-20).

With the new constitution, the prerogative of coinage moved to the Swiss Confederation and, in 1850, the Swiss franc finally replaced the large number of different coins in circulation. Originally, the Swiss franc was designed as a pure silver currency along the lines of the French franc. One Swiss franc was equivalent to 4.5 grams silver (see Willis, 1901, p. 27). In addition to the silver Swiss franc, the government issued token coins with a metallic content that was less valuable than their purchasing power (see Baltensperger, 2007, p. 32). These token coins were particularly useful for smaller transactions. Because France was on a bimetallic standard, i.e. the government promised to a pre-specified amount of gold and silver to coins of a certain value, the Swiss Confederation soon accepted foreign gold coins as legal tender. This step was necessary because the relative price of silver increased in the 1850s. Because silver became more valuable relative to gold, it was profitable to melt silver coins, buy gold with the proceedings, and mint gold coins in France. Therefore, silver vanished from monetary circulation and was replaced by French gold coins (see Baltensperger, 2012, p. 83).

In 1865, France, Switzerland, Belgium, Italy, and later on Greece, formed the Latin Monetary Union agreeing on the silver content of their currencies. Before, market forces repeatedly revealed unsustainable monetary arrangements (see Eichengreen, 2008). For example, in 1862 Italy reduced the metallic content of the small-denominated silver coins to 83.5%, whereas the silver content of the French franc was still 90%. Melting French coins and minting them to Italian coins offered therefore a profitable arbitrage opportunity. As a consequence, French coins vanished and were replaced by Italian silver coins. Although France reduced the silver content in 1864, Switzerland reduced the silver content even more. In turn, the Swiss currency tended to drive the other currencies out of circulation.

From a monetary perspective, the regime is best described as Bimetallism because of the close link to the French franc, because Switzerland soon accepted gold coins as legal tender, and because of its membership in the Latin Monetary Union. The constitution effectively removed competition in coin issuance so that a centralized monetary policy emerged. The main objective of the regime was a single currency that proves useful in payment transactions. Discretionary policies were limited because of the rules of the Latin Monetary Union and because the government had no monopoly on banknote issuance. Commercial banks still had the right to emit their own banknotes (see Baltensperger, 2007, p. 111). On the one hand, market forces probably prevented an excessive issuance of banknotes. On the other hand, banknotes were rarely used in payment transactions and therefore less useful than silver or token coins.

2.3 Gold Standard (1874–1906)

The fate of the Latin Monetary Union was heavily influenced by French monetary policy. Bimetallism came to an end when, by the end of 1973, France restricted the amount of silver the public was allowed to mint each day.[2] This restriction inflicted with the mechanics of Bimetallism as it limited arbitrage when the relative price of silver and gold was changing. Although the silver minting restrictions were regarded as temporary (see Flandreau, 2004, p. 176) the Latin Monetary Union adopted a *de facto* Gold Standard after 1873.[3] France suspended the minting of silver completely in 1876. In 1878 the other countries of the Latin Monetary Union followed.

With the Gold Standard, a truly international monetary system emerged with Great Britain at its center. Each country effectively promised to keep the price of a certain quantity of gold fixed in their currency. Therefore, monetary policies oriented towards domestic goals were still restricted. In addition, the Gold Standard acted as a commitment device. Bordo and Kydland (1996) even suggest that the commitment was so strong that it anchored expectations even during temporary suspensions of the Gold Standard.

2.4 Foundation of the SNB and the World War period (1907–1944)

During meetings of the members of the Latin Monetary Union, Switzerland repeatedly favored to adopt the Gold Standard and to quickly leave the currency union (see e.g. Willis, 1901, p. 135 and p. 165). Although the foundation of the SNB opened up more leeway for discretionary policies, Switzerland therefore continued to operate in line with the rules of the Gold Standard. In 1907, the Swiss central bank received the monopoly on banknote issuance. The main objective was a fixed gold price in terms of Swiss francs. This objective was only abandoned during wars and towards the end of the Great Depression. A domestic price stability objective, if it existed implicitly, was clearly subordinated.[4]

The foundation of the SNB and the outbreak of WW1 justify distinguishing the classical Gold Standard from the World War period, even though the Latin Monetary Union officially continued to operate until 1927. Before WW1, the SNB promised to convert banknotes into the silver and gold currencies of the Latin Monetary Union (see Bordo and James, 2007, p. 33). With the outbreak of WW1 convertibility was suspended and money in circulation increased

[2] I thank Peter Bernholz for bringing this fact to my attention.

[3] It is noteworthy, however, that no Swiss gold coins have been minted until well after Bimetallism has been abandoned (see HSSO, 2018, Table O1a).

[4] This is also reflected in the fact that official CPI and WPI statistics were only introduced in the 1920s.

strongly in order to finance war-related government spending (see Baltensperger, 2012, p. 144-146). After WW1, the SNB's primary aim was to establish the pre-war gold-parity and, as of December 1929, the SNB reenacted convertibility but only with respect to gold and not with respect to silver. In the aftermath of the Great Depression, the SNB was determined to hold on to the Gold Standard until 1936, longer than other countries, even though this has exacerbated and prolonged the crisis (Zurlinden, 2003, Rosenkranz et al., 2014).[5]

Researchers date the end of the classical Gold Standard to the outbreak of WW1 because all major countries suspended convertibility. Afterwards, the international monetary regime during the inter-war years differed from the classical Gold Standard because central banks held their reserves partly in gold and partly in foreign currency. However, there is evidence that a Gold Standard "mentality" still shaped policy decisions as well as the public's expectations. Eichengreen and Temin (2000) suggest that, during the Great Depression, policy makers justified their actions with arguments valid under the classical Gold Standard, although they would have had more leeway to conduct a more expansionary monetary policy. In addition, Hoffmann and Woitek (2011) suggest that the public's expectations formation mechanism has remained fundamentally stable between the Gold Standard and the inter-war period.

2.5 Bretton Woods (1945–1973)

After WW2 Switzerland joined the Bretton Woods System. Countries fixed their exchange rate vis-á-vis the US Dollar; at the same time, the United States fixed the US Dollar price of gold. Although Switzerland was not an official member, it decided unilaterally to fix its exchange rate to the US Dollar and therefore implicitly participated in the system. The main objective therefore was a fixed exchange rate and price stability was subordinated.

The Bretton Woods System underwent significant changes during this period. Before 1951, the US kept the interest rate pegged for most of the time and therefore could not pursue an independent monetary policy (see e.g. D'Agostino and Surico, 2012). Afterwards, changes in US monetary policy had limited international spill-overs because capital controls were in place. Eichengreen (2008), p. 112, suggests that the Bretton Woods System has come into full operation only by January 1959, when the major currencies became fully convertible for current-account transactions. Bernholz (2007), p. 147, argues that this led to large capital inflows to Switzerland. As a consequence, the SNB increased the monetary base by intervening heavily in the foreign exchange market. Indeed the Swiss franc was often undervalued (see Bernholz, 2007, p. 111-112) and inflation was gradually rising. Towards the end of the Bretton Woods System, Switzerland adjusted the exchange rate peg two times, in 1971 and 1972. In January 1973, the SNB decided to let the Swiss franc float freely. All three adjustments implied a substantial appreciation of the Swiss currency.

According to Baltensperger (2012), p. 215, letting the Swiss franc float was not entirely voluntary. The SNB and the Swiss government judged the interventions required to maintain the peg as unsustainable, against the backdrop of massive speculative capital flows. Although inflation increased steadily already during the 1960s, the willingness to keep the exchange rate fixed was stronger suggesting that an implicit price stability objective was subordinated to an exchange rate stability objective. The exchange rate peg was adjustable to correct a "fundamental disequlibrium" (see e.g. Obstfeld, 1993); this option was rarely exercised in

[5] Switzerland belonged to the so-called gold bloc of countries that stuck to the Gold Standard for longer (see Eichengreen and Sachs, 1985).

practice, however (see Eichengreen, 2008, p. 91). This subordination is also presaged by Bernholz (2007), p. 110-111. He identifies two dominant themes for the SNB under the Bretton Woods System: First, the SNB wanted to keep a fixed price for gold in Swiss francs; this goal was widely shared by the government, politicians, and academics. Second, it wanted to allow the money supply to rise only as much as the growth of the economy, in order to keep inflation in check, as far as possible.

2.6 Monetary targeting (1974–1999)

With a floating exchange rate, the SNB obtained the possibility to conduct an independent monetary policy geared towards domestic goals.[6] Starting in 1974 the SNB developed a strategy for managing the money supply. The annual monetary growth targets were not an end but an intermediate target to maintain price stability. Therefore, this was the first time price stability emerged as the main objective. Jordan et al. (2010) suggest that, implicitly, an annual CPI inflation objective of roughly one percent was consistent with the SNB's communicated monetary targets. An explicitly announced inflation target, however, did not exist at the time.

Although the Swiss franc was floating, currency fluctuations were still taken into account in policy decisions. In October 1978 the SNB set a minimum exchange rate against the German Mark. There is evidence that maintaining price stability was not the main reason for introducing this policy. For one, the lowest annual CPI inflation rate (in 1978) amounted to 1.0%, in line with the SNB's implicit policy objective. Before and after, CPI inflation was higher than 2%. For another, Bernholz (2007), p. 179-181, suggests that worries about the export industry and political pressure have played a role for introducing the minimum exchange rate.

The monetary targeting framework was gradually adapted rather than suddenly abandoned. Because the SNB regularly missed its annual monetary growth objectives it started to announce a medium-term expansion path starting in 1991. Baltensperger (2007) emphasizes that, for pursuing its short-term objectives, the SNB also paid attention to a number of indicators, such as interest rates, the exchange rate and the business cycle. This paved the way for abandoning monetary targeting and led to a gradual shift towards flexible inflation targeting.

2.7 Flexible inflation targeting (since 2000)

In December 1999 the SNB officially announced its move to a flexible form of inflation targeting. The main differences relative to monetary targeting are reflected in the communication of objectives and decisions, as well as, the choice of the operational target. The new monetary policy strategy rests on three main principles (see Jordan et al., 2010). Firstly, the SNB announced an explicit definition of price stability of an annual CPI inflation rate below 2% in the medium term. Deflation, which the SNB defines as a protracted decline in the price level, is also inconsistent with its definition of price stability. It is therefore common to assume

[6] However, this move was not entirely voluntary. This is also reflected in the fact that, after the collapse of the Bretton Woods System, Switzerland applied to join other European countries in a system of managed exchange rates, the so-called currency snake. However, the application was vetoed by France in 1975 (Bernholz, 2007, p. 170-172).

that the medium-term inflation target of the SNB is a range of 0%-2%. The positive target range is justified by unmeasured quality changes so that the official statistic overstates the actual CPI inflation rate (Swiss National Bank, 2015). An influential report of the Boskin Commission (1996) estimates a bias of close to 1pp. Therefore, the SNB's target range for actual inflation amounts to -1% to 1%. Secondly, the SNB publishes an inflation forecast over three years, conditional on an unchanged 3M Libor, as the main communication tool of (future) policy decisions. Thirdly, it sets a range for the 3M Libor as an operational target.

In the wake of the Global Financial Crisis (GFC) and euro area debt crisis unconventional policy measures complemented the flexible inflation targeting framework. As the 3M Libor fell to close to 0% in early 2009, the Swiss franc came under substantial appreciation pressure. Therefore, the SNB conducted regular interventions in the foreign exchange market in order to limit the risk of deflation (see e.g. Swiss National Bank, 2009). As the Swiss franc appreciated to unprecedented highs in Summer 2011, the most prominent unconventional measure was the announcement of a minimum exchange rate against the euro as a complementary operational target.[7] Moreover, to defend the minimum exchange rate, the SNB announced to introduce negative interest rates on sight deposits in December 2014 and moved the target range for the 3M Libor into negative territory. In January 2015, facing potentially large interventions because of ever rising worries about Greek's debt situation, the minimum exchange rate was abandoned and the target range for the 3M Libor was lowered further. Meanwhile, however, the SNB emphasized that it will continue to intervene in the foreign exchange market if the Swiss franc were to appreciate further.

We have seen that under the flexible inflation targeting framework, the SNB conducted non-conventional policies similar as under monetary targeting. One important difference to earlier interventions is that the measures were taken in order to prevent deflation and thus pursue an explicitly announced price stability objective (see e.g. Swiss National Bank, 2009). This determination is reflected in a speech by Thomas Jordan (2009) discussing how the SNB plans to soak up the liquidity created by the exchange rate interventions in order to ensure price stability.

3 Data

This section presents four indicators to assess nominal stability over the past two centuries. As the quote by Bernanke (2003) at the beginning of this paper suggests a stable monetary background should be reflected in stable aggregate inflation and nominal GDP growth. However, there is no general agreement on the most appropriate measure of nominal stability and various indicators are likely to be informative. Moreover, each time series is prone to measurement error, in particular for retrospectively constructed historical statistics. Therefore, this analysis considers a range of various indicators. Available historical statistics for Switzerland allow to construct spliced measures for consumer prices (CPI), wholesale prices (WPI), a GDP deflator (DEFL) and nominal GDP per capita (NGDP).

CPI inflation is an obvious candidate because, since the introduction of the new monetary policy framework in 1999, the SNB bases its price stability definition on this statistic. Frankel

[7] Less well known unconventional measures include a purchase program of covered and non-bank corporate bonds from the markets between 2009 and 2010 (see Kettemann and Krogstrup, 2014), and several increases of bank's sight deposits in August 2011 (see Christensen and Krogstrup, 2018).

(2012b) suggests that a central bank of a small open economy should instead stabilize an index of producer prices because it includes export commodities. The central bank thus avoids to respond to terms of trade shocks over which it has no control. As an alternative, we can also analyze a GDP deflator that additionally includes consumer prices but excludes prices of imported goods and services. Finally, researchers have suggested that the central bank should target the growth rate or level of nominal GDP. Although this idea is not new, it was already proposed by Meade (1978), it regained attention in the wake of the GFC and the euro area debt crisis (see e.g. Frankel, 2012a, Sumner, 2014, and references therein). A particular advantage of nominal GDP is that this indicator takes into account changes in productivity.[8] Therefore, the analysis is not confounded by what Bordo and Filardo (2005) term "good" deflations.[9]

3.1 Sources

All indicators are of annual frequency and end in 2017 (2016 for per capita nominal GDP). The CPI is available for the entire 19th century and the WPI starts in 1804. Nominal and real GDP, and therefore the GDP deflator, start in 1851. The historical data for the 19th century stem from the historical database of the Swiss Federal Statistical Office (SFSO), Historical Statistics of Switzerland Online (HSSO) of the University of Zurich and Studer and Schuppli (2008). I splice various sources after calculating log-differences. Where overlaps of different sources exist I compute the correlation between the two series to check whether linking them makes sense.

Studer and Schuppli (2008) provide a retrospectively estimated CPI for the entire 19th century until 1914. It includes prices for a fixed basket of 12 goods sold in Zurich until 1890 and a fixed consumer goods basket for German-speaking Switzerland thereafter. From 1914 onward, I splice the series with the official CPI from the SFSO (2015c). HSSO (2018), Table H39, also comprises a CPI from 1804 to 2003 which is compiled from various data sources. Fortunately, the correlation between the two series is indeed high (0.85). I still favoured the measure by Studer and Schuppli (2008) because, between, 1835 and 1851, the HSSO (2018) CPI estimate is largely based on WPI data.[10]

The WPI stems from HSSO (2018), Table H39, and covers 1804-2003. This measure already links retrospectively calculated and official statistics in 1914. I link the series with the official WPI (*Preisindex des Gesamtangebots*) from the SFSO (2015c). No overlap of historical estimates and modern statistics exists, to the best of my knowledge.

Nominal GDP data starts in 1851, however, I have to splice three different sources before 1980 (HSSO, 2018, Tables Q1a, Q17a, Q6a). After 1980, the official annual nominal GDP series stems from the State Secretariat for Economic Affairs (SECO, 2015). The correlation

[8] Productivity changes are a major argument for adopting a NGDP target (see e.g. Sumner, 2014). Stabilising NGDP accounts for the fact that prices may fluctuate in response to productivity shocks but a central bank may not want to respond to these shocks. In other words, if positive productivity shocks lead to lower prices but higher real GDP, nominal GDP remains unchanged. By contrast, if a deflationary episode occurs because of a restrictive monetary policy stance rather than a positive supply shock nominal GDP declines.

[9] A similar argument can be made to look at the stability of nominal wages. Moreover, Erceg et al. (2000) show that, if nominal wages are less regularly adjusted than consumer prices, a central bank optimally puts more weight on stabilizing wage inflation.

[10] I examined the correlation between the inflation rates of the CPI and WPI measure from SFSO (2015d). Indeed, they are almost identical during this period.

between overlapping data sources is larger than 0.9. The only exception is the overlap between the historical series and the official series from the SECO, where the correlation amounts only to 0.76. To obtain a historical measure for nominal GDP per capita, I divide the spliced series by the annual permanent resident population of Switzerland starting in 1861 (SFSO, 2015a). The resulting series is linked with NGDP per capita series available from 1851 to 1861 (see HSSO, 2018, Table Q1a). After 1990, I use the official series from the SFSO (2015b), which ends in 2016. Correlations on overlapping samples between the three data sources are larger than 0.95. From the same sources, I constructed a measure of real GDP and then calculated the implicit GDP deflator.

To discuss the consequences of various nominal regimes I also construct an annual series of government bond yields from 1899-2017. The historical data stem from the Swiss National Bank (2007b) and the modern data from the SNB's website.[11] The first series is an average of outstanding Swiss railway bonds starting in 1899. The Swiss National Bank (2007b) suggests that railway bonds were representative of the Swiss capital market in the early 20th century. I splice this series with an average yield of railway and Confederation bonds in 1924. The residual maturity of the bonds included in this average was at least five years. I splice this series with a 10-year constant maturity Confederation bond yield in 1988.[12]

3.2 Descriptive statistics

Figure 1 shows the levels of the four nominal indicators in logarithms. The seven monetary regimes are represented by shaded and unshaded areas. The indicators display different long-term trends. The CPI and GDP deflator rise less, on average, than nominal GDP. This is related to the fact that nominal income rises not only because of increases in prices, but also, productivity. The WPI rises less than the other two price indices, in particular, since official price data is available (in 1914). One reason could be that services prices included in the CPI and GDP deflator rise more strongly than goods prices.

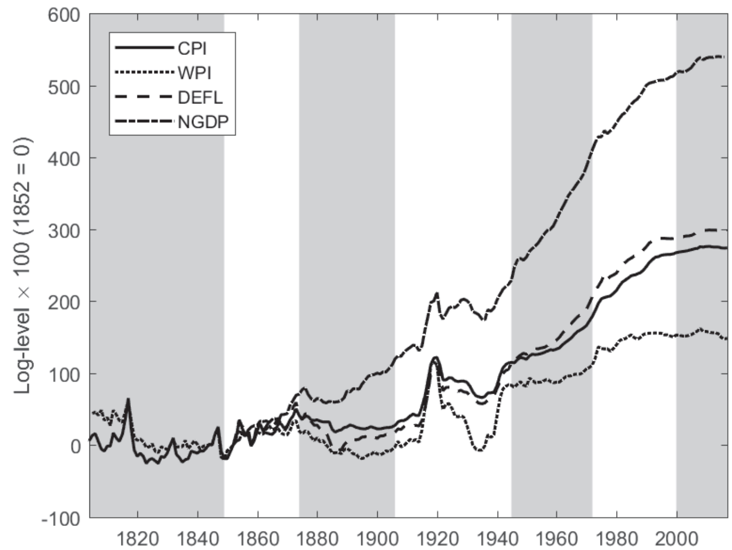
Abstracting from the long-term trends, the CPI, GDP deflator, and the WPI display periods with substantial deflation. For example, after Switzerland adopted a *de facto* Gold Standard in 1873 all price indices fell substantially. Meanwhile, the decline in nominal GDP was less pronounced. This was a period with substantial increases in productivity but a relatively fixed world-wide gold stock for monetary use. As a consequence, the argument goes, the decline in prices was caused by productivity gains and was therefore less harmful than, for example, deflationary episodes during the Great Depression (see e.g. Beckworth, 2007). By contrast, and in line with findings in other countries (see e.g. Bernholz, 2003, p. 3), the largest and most persistent increases in all nominal variables occurred during the 20th century fiat money regimes. The increase was less pronounced, however, under flexible inflation targeting than during Bretton Woods or monetary targeting.

To get a first impression whether the regimes provided a stable monetary background, we can compute the average growth rate and volatility of the indicators (see Table 1). Metallic regimes are often considered as providing a stable monetary background. The descriptive statistics paint a more nuanced picture. Focusing on the CPI, we observe secular deflation under competing currencies and the Gold Standard, and relatively high inflation under Bimet-

[11] See `data.snb.ch`, Interest rates, yields and foreign exchange market.

[12] This strategy follows Kugler (2017). Using other series published by the Swiss National Bank (2007b) yield qualitatively similar results.

Figure 1: Data



Notes: All series are shown in log-levels indexed to zero in 1852. The shaded areas highlight changes in monetary regimes.

allism. Since the foundation of the SNB secular inflation became the norm. During the world war period, under Bretton Woods, as well as under monetary targeting CPI inflation was on average higher than 2%. Only with flexible inflation targeting we observe a low and stable average inflation rate. Recall that the SNB currently defines price stability as an annual increase in CPI inflation between 0% and 2%, which was also in line with the implicit price stability objective under monetary targeting. CPI inflation was on average consistent with this target only under flexible inflation targeting. During the other monetary regimes, the average inflation rate was either higher (Bimetallism, Bretton Woods, monetary targeting) or lower (competing currencies, Gold Standard). The average inflation rate measured by the GDP deflator, but also nominal GDP growth, display similar patterns. The main difference is that nominal GDP growth is on average higher because of positive productivity growth. According to the WPI, however, average inflation was generally lower after WW2.

Average growth rates over long sample periods possibly conceal persistent episodes with high inflation which are offset by deflationary episodes. If the low average rate of inflation stems from offsetting periods with inflation and deflation, we would expect that inflation is rather volatile pointing to an unstable monetary background. Table 1 shows that inflation for all price indices was volatile under competing currencies and Bimetallism. Under the Gold Standard, the volatility generally declined. After the World War period, the volatility declined for all indicators and attained an all-time low under flexible inflation targeting.

The lower volatility after the World War period can have different causes, however. Bordo and Filardo (2005) suggest that volatile supply shocks make up for a larger share of the variation during the early sample period due to changes in the consumption basket. A 19th century consumption basket comprised a higher share of food products with relatively volatile

Table 1: Descriptive statistics

	CPI		WPI		DEFL		NGDP	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
1804-1849: Competing currencies	-0.8	13.3	-1.4	10.7				
1850-1873: Bimetallism	2.9	9.3	2.2	6.6	3.2	11.6	3.9	5.2
1874-1906: Gold Standard	-0.7	3.1	-1.1	4.3	-1.3	5.6	1.5	4.0
1907-1944: World War period	2.3	8.1	2.3	14.5	2.3	8.5	2.7	9.1
1945-1973: Bretton Woods	2.3	2.1	1.0	3.3	3.6	2.7	6.7	3.9
1974-1999: Monetary targeting	3.2	2.5	1.4	4.1	3.0	3.2	3.8	3.2
2000-2017: Inflation targeting	0.5	0.9	-0.1	2.3	0.6	0.9	1.6	2.4

Notes: Mean and standard deviation of log-changes in percent.

prices. But also, the lower volatility may stem from better quality of the official statistics emerging during the 20th century (see e.g. Romer, 1986a,b, Allen, 1992, Kaufmann, 2017, for the US). Finally, the declining volatility may reflect a more stable monetary background. While supply shocks and measurement errors are likely to affect the short-run dynamics of the indicators, a well managed monetary regime is likely to lead to a more stable trend. Therefore, in the subsequent analysis, I apply a statistical model to disentangle transitory from persistent fluctuations.[13]

4 Method

To measure the stability of the monetary background using historical series of varying quality I decompose the growth rates into a permanent and a transitory component. The permanent component represents the best long-run forecast of the corresponding indicator given the current state of information, following Beveridge and Nelson (1981). It is also common to interpret the permanent component as a measure of trend inflation (see Ascari and Sbordone, 2014, and references therein). I estimate the trend using an univariate unobserved component-stochastic volatility (UC-SV) model by Chan (2013). The model is a generalization of the popular UC-SV model by Stock and Watson (2007) allowing for a persistent transitory component.

4.1 Model

Assume that the log-change of the indicator of nominal stability (y_t) can be decomposed into a permanent component and a moving-average (MA) part (u_t):

$$y_t = \tau_t + u_t \quad .$$

The permanent component follows a random walk process:

$$\tau_t = \tau_{t-1} + \varepsilon_t^\tau \quad .$$

[13]The model has the additional advantage that the estimates take into account the substantial statistical uncertainty when assessing changes in the average inflation rate during the 19th century.

The MA-part is assumed to be of order one:

$$u_t = \varepsilon_t^u + \psi \varepsilon_{t-1}^u \quad .$$

The interpretation of the model in our application is that transitory movements in inflation stemming from non-systematic measurement errors, supply shocks, or short-lived recessions, are captured by u_t. Meanwhile, the long-term trend in inflation or nominal GDP growth, over which the central bank likely has more control, is captured by the permanent component.

The relevance of short-term factors, but also the volatility of the permanent component, has likely changed over time. Therefore, we allow the variance of the permanent shocks (ε_t^τ) and transitory shocks (ε_t^u) to change over time. Following Chan (2013), I assume that the permanent and transitory shocks have stochastic volatility. Formally we have that $\varepsilon_t^\tau \sim i.i.d.N(0, e^{g_t})$ with:

$$g_t = \mu_g + \phi_g(g_{t-1} - \mu_g) + \varepsilon_t^g, \quad \varepsilon_t^g \sim N(0, \sigma_g^2) \quad ,$$

and $\varepsilon_t^u \sim i.i.d.N(0, e^{h_t})$ with:

$$h_t = \mu_h + \phi_h(h_{t-1} - \mu_h) + \varepsilon_t^h, \quad \varepsilon_t^h \sim N(0, \sigma_h^2) \quad ,$$

where we assume that $|\phi_g| < 1$, $|\phi_h| < 1$.

The model is related to existing research on trend inflation. First, Stock and Watson (2007) propose a variant of the model without the MA-part. In the present application, however, it is desirable to allow for the possibility that transitory fluctuations are at least somewhat persistent. Second, Cogley and Sargent (2015) control for persistent measurement error exploiting overlapping, methodologically consistent, data sources of US inflation . Their results confirm that these measurement errors are somewhat persistent. The advantage of their approach is that they can estimate a permanent as well as a transitory component controlling for measurement error. Analyzing inflation volatility for the UK, Cogley et al. (2015) assume that the measurement error process is also autocorrelated, but, the parameters change discretely whenever the series is spliced with another source. Although their approach would be an alternative, it ignores that data quality can change substantially even for a price index obtained from the same source (see Kaufmann, 2017). Finally, an alternative would be to adopt a multivariate approach assuming that each indicator is a noisy measure of inflation but they are driven by a common inflation trend (see e.g. Garnier et al., 2015).

4.2 Estimation

The model is estimated using Bayesian methods. Chan (2013) develops an MCMC sampler exploiting the special structure of the problem to efficiently evaluate the likelihood function.[14] I assume relatively non-informative priors (see Appendix A). An exception are the autoregressive parameters in the stochastic volatility equations, where I put a large prior weight on the high persistence region. In addition, although the prior on σ_g^2 is not very informative, the posterior is almost identical: the data contain hardly any information on this variance (see Appendix A). I therefore provide some robustness tests for alternative prior assumptions.

[14] The interest reader is referred to Chan (2013). The estimates are based on adapted versions of his codes. All errors are of course my own.

Table 2: Posterior moments ψ

	CPI	WPI	DEFL	NGDP
$E[\psi\vert\mathbf{y}]$	0.44	0.25	0.31	0.27
$\sqrt{var[\psi\vert\mathbf{y}]}$	0.06	0.08	0.08	0.08
$P[\psi > 0\vert\mathbf{y}]$	1.00	1.00	1.00	1.00

Notes: Posterior moments of the MA-parameter ψ. The table gives the posterior mean, standard deviation, and the posterior probability that the coefficient is larger than zero.

The analysis is based on 150,000 iterations of the MCMC algorithm where the first 100,000 iterations are discarded for convergence. I provide plots of the Markov chain for several key parameters to check convergence (see Appendix A). They suggest that the algorithm has converged.

To check whether it is necessary to allow for a persistent transitory component, Table 2 provides posterior moments for the MA parameter (ψ). We see that the point estimate, the posterior mean, ranges from 0.25 to 0.44 depending on the indicator. The posterior standard deviation shows that the parameter is precisely estimated for all indicators. This suggests that the data indeed favour a specification with a MA part. This is confirmed by the high posterior probability that the parameter is positive.

5 Results

I first discuss the estimated trends in a descriptive way before assessing the regimes in terms of a definition of nominal stability. Then, I show that variation in trend inflation explains a relevant part of the trend decline in nominal interest rates

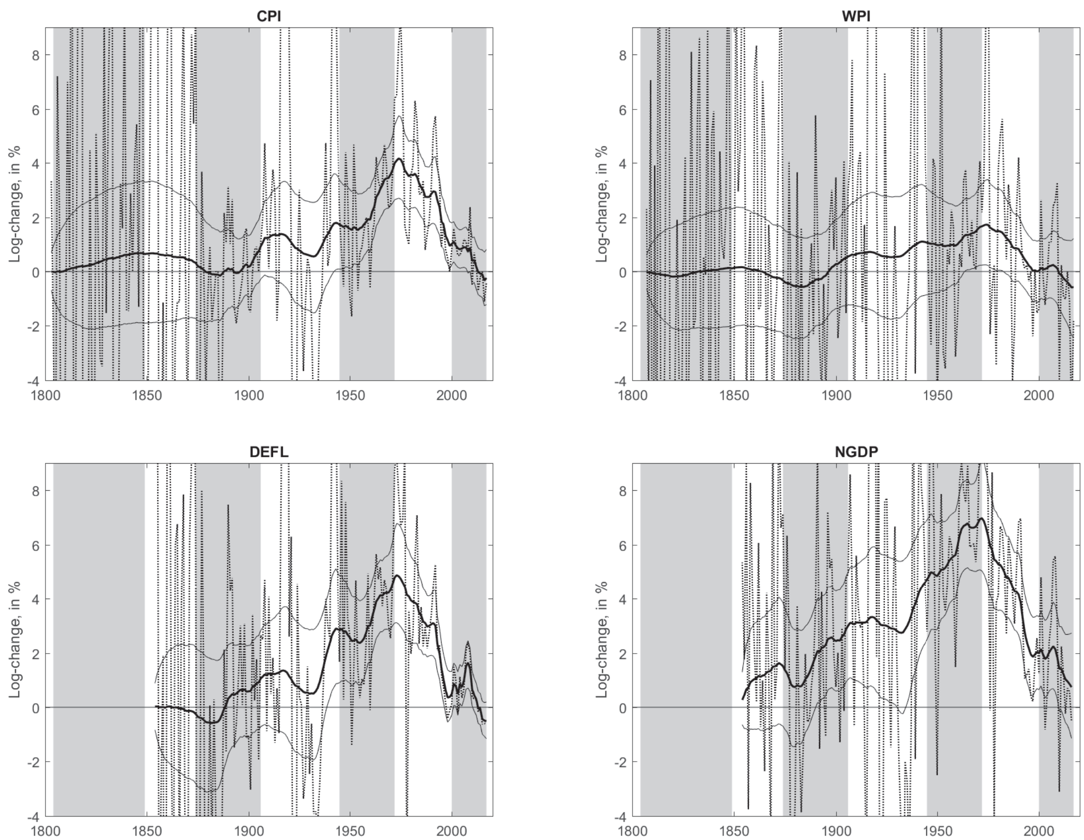
5.1 Nominal stability

Figure 2 shows the posterior mean of the permanent component jointly with 5th and 95th percentiles. The dashed line represent the underlying data.

For CPI inflation, we observe a stable trend for most of the 19th century. In line with the descriptive statistics, trend inflation was slightly positive during Bimetallism and essentially zero during the Gold Standard. For most of the 19th century, however, the estimates are imprecise. For example, the difference between the 95th and 5th percentile amounts to more than 5pp in the 1850s. The high volatilty of the data hampers to obtain a precise estimate and we should be careful to interpret this period as featuring a stable monetary background. Put differently, the data do not allow to identify with much confidence whether the trend inflation rate amounted to -2% or +2% during this period.

The estimates become somewhat more precise during the Gold Standard period, where the inflation trend fell to essentially zero. This decline can be explained against the backdrop of international developments. In the early 1870s, Germany and other European countries adopted the Gold Standard and liquidated their silver currency reserves. The result was a strong deflation in Great Britain, which adopted the gold standard already in the early 19th

Figure 2: Permanent component



Notes: Estimated permanent component (mean, 5th percentile, 95th percentile) and actual data (dashed line). The shaded and unshaded areas represent various monetary regimes.

century, and other countries because the increased global demand for monetary gold was not matched by an equal increase in supply (Eichengreen, 2008, p. 17).[15]

After the Gold Standard period, however, the trend increases before falling slightly during the inter-war period. This lines up well with the fact that Switzerland suspended convertibility with the outbreak of WW1. Afterwards, deflationary pressures emanated from establishing the pre-war gold-parity as well devaluing relatively late during the Great Depression. Nevertheless, the model attributes most of the fluctuations during the inter-war period to the transitory component, which is consistent with Hoffmann and Woitek (2011) suggesting that the expectations formation mechanism has remained largely unchanged during the inter-war period for various countries.

During WW2, the inflation trend increased again towards 2% and remained at this level

[15] The literature does not fully agree why the silver standard or the bimetallic systems were replaced by the Gold Standard. Some authors argue that the bimetallic system, which was in particular implemented by France, tended to be unstable since changes in the relative price of silver and gold tended to drive one of the two currencies out of circulation. Other authors, such as Eichengreen (2008) emphasize that network externalities may have been a major force pushing countries towards adopting uniformly the Gold Standard.

for the first part of the Bretton Woods regime. The increase in the trend can be attributed to an expansionary monetary and fiscal policy in the US and the unavoidable spillovers because of a fixed exchange rate. The trend inflation rate attained about 4% towards the end of the Bretton Woods System.

Recall that, under monetary targeting, the SNB's implicit inflation target was 1%. We see, however, that the inflation trend remained elevated throughout the 1980s. Trend inflation then declined during the 1990s and remained low and stable during flexible inflation targeting. Importantly, the estimates based on modern data are much more precise. Therefore, we can say with some confidence that flexible inflation targeting provided the lowest inflation trend among the modern fiat money regimes.

The other indicators qualitatively confirm this assessment. We observe relatively imprecise estimates during the metal currency regimes of the 19th century. If anything, however, all indicators point to a falling trend at the beginning of the 1870s. During WW2, the trend rose to a higher level and continued its increase towards the end of Bretton Woods. Finally, we observe a falling trend towards the end of monetary targeting, and, a historically low trend under our current monetary regime. The pattern is less visible for the WPI than for the GDP deflator and nominal GDP. This could be related to the fact that a WPI is strongly influenced by volatile supply shocks and therefore driven to a smaller extent by the permanent component .

An alternative way to assess nominal stability is to take the SNB's current objective of a medium-term CPI inflation rate between 0%-2%. Recall that the permanent component is a measure of the best long-run forecast of inflation given all available information. Therefore, it is a measure where inflation will settle in the long-run once transitory shocks dissipate. To show whether the monetary regimes performed well from today's perspective I therefore calculate the posterior probability that the permanent component remains in the target range.[16]

Table 3 shows the results. The posterior probability includes estimation uncertainty and therefore gives a good summary of what we know given the relatively poor quality of the data for the 19th century. Focusing on the CPI inflation trend there was about a 50% chance that a metal currency regime provided nominal stability according to today's standard. For the paper currency regimes, the evidence is mixed. The Bretton Woods System performed worse. But in particular under monetary targeting, the probability of nominal stability fell to a low of 20%. As Baltensperger (2012) and Bernholz (2007) emphasize, the stability provided by the monetary targeting regime with flexible exchange rates may still have been a success in relative terms, against the backdrop of high inflation rates observed internationally. Finally, the table confirms the visual impression of the permanent component that our current regime performed remarkably well. No other regime was associated with a probability of nominal stability of 76%.

It is also interesting to investigate why the regimes failed. The model can be used to judge whether a monetary regime showed an inflationary or deflationary tendency by looking at the posterior probability that trend inflation fell short of or exceeded the nominal stability range (Panels b and c). Focusing on the CPI, the fixed exchange rate regime of Bretton Woods

[16]Cogley and Sargent (2015) calculate the probability that the price level declines over the next five years. In doing so, they include both, the permanent and transitory component. Because I cannot disentangle measurement errors from actual movements in the transitory component, this approach is not applicable for Switzerland. In addition, focusing on the long-term trend is more closely related to the SNB's definition of price stability that emphasizes that inflation has to remain in that range only in the medium term.

Table 3: Probability of nominal stability

(a) Nominal stability: $P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$

	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.48	0.65		
1850-1873: Bimetallism	0.50	0.60	0.44	0.31
1874-1906: Gold Standard	0.55	0.62	0.49	0.49
1907-1944: World War period	0.63	0.64	0.49	0.43
1945-1973: Bretton Woods	0.40	0.65	0.15	0.04
1974-1999: Monetary targeting	0.20	0.72	0.21	0.27
2000-2017: Inflation targeting	0.76	0.73	0.70	0.53

(b) Overshooting: $P[\tau_t > \overline{\tau}|\mathbf{y}]$

	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.12	0.07		
1850-1873: Bimetallism	0.15	0.09	0.06	0.04
1874-1906: Gold Standard	0.02	0.05	0.08	0.11
1907-1944: World War period	0.21	0.22	0.31	0.45
1945-1973: Bretton Woods	0.59	0.31	0.85	0.96
1974-1999: Monetary targeting	0.79	0.24	0.77	0.68
2000-2017: Inflation targeting	0.01	0.02	0.04	0.03

(c) Undershooting: $P[\tau_t < \underline{\tau}|\mathbf{y}]$

	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.41	0.28		
1850-1873: Bimetallism	0.35	0.31	0.51	0.65
1874-1906: Gold Standard	0.43	0.33	0.43	0.41
1907-1944: World War period	0.16	0.15	0.20	0.12
1945-1973: Bretton Woods	0.01	0.04	0.00	0.00
1974-1999: Monetary targeting	0.00	0.04	0.03	0.06
2000-2017: Inflation targeting	0.23	0.25	0.26	0.43

Notes: The table shows the average posterior probability that the nominal trend is in line with today's definition of nominal stability ($P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$), and the probability of under- and overshooting the definition of nominal stability. This definition differs among the various indicators. For CPI inflation, the official target range amounts to [0%, 2%], whereas, for the other indicators, no official target ranges exist. To account for the fact that the indicators have different trend growth rates, the CPI target range is adapted by subtracting the average growth rate of the CPI and adding the average growth rate of the various indicators. To obtain a stability range that would be applied in practice, the numbers are rounded to half a percentage point for the WPI ($[-0.5\%, 1.5\%]$), the GDP deflator ($[0\%, 2\%]$) and nominal GDP ($[2.5\%, 4.5\%]$). For nominal GDP, this implies an average 2.5% productivity growth trend over the entire sample period.

and monetary targeting show an elevated probability of an excessively high inflation trend. Meanwhile, the metal currency regimes are associated with a higher probability of deflation. But also, flexible inflation targeting exhibits a 1/4 chance that inflation is too low.[17]

The other indicators confirm the results at least qualitatively. One issue with applying a definition of nominal stability to the other indicators is that the WPI and nominal GDP exhibit different trend growth rates. I therefore lower the definition of price stability by 0.5pp for the WPI and increase the range by 2.5pp for nominal GDP. This choice is to some extent arbitrary, but, the main results are robust to variations in this assumption. The highest probability of nominal stability we always observe under inflation targeting. In addition, the metal currency regimes are associated with a higher probability of undershooting the range, whereas, the probability of surpassing the range is elevated under monetary targeting. One advantage of looking at nominal GDP growth is that it takes into account that falling prices may be desirable if productivity growth is elevated. According to this measure, the probability of stability is only 53% under inflation targeting, not much higher than under the Gold Standard.

This descriptive analysis cannot establish a causal direction from the monetary regime to nominal stability: For example, does inflation targeting cause a low and stable inflation trend, or, has inflation targeting been adopted during a period where trend inflation was low in the first place? Although it is beyond the scope of this paper to answer this question definitively, Figure 3 provides the posterior probability of nominal stability to assess the timing relative to the monetary regimes in place. The dark grey areas give the probabilities of overshooting and undershooting. The area in between the probability of nominal stability.

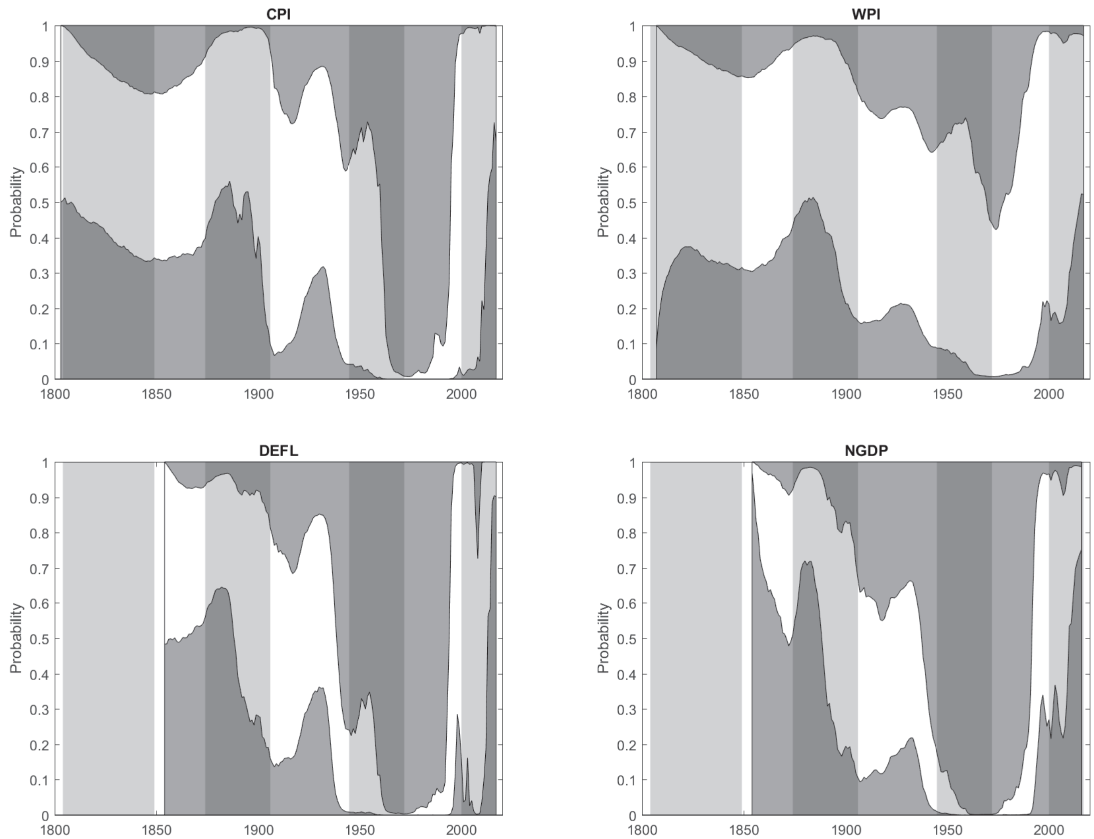
For brevity, I focus on the results for CPI inflation. The figures show some interesting variation during the various monetary regimes. The first half of the Bretton Woods regime was associated with a relatively high probability of nominal stability. Only during the second half, when most capital controls were lifted and the US conducted an expansionary monetary and fiscal policy, do we see a strong increase in the probability of overshooting. In addition, the probability of nominal stability increased already before flexible inflation targeting was officially introduced. This suggests that the new regime was not the cause of the decline in inflation. Rather, the SNB exploited a good moment to announce an explicit inflation target range. Finally, the probability of undershooting the price stability range rose considerably in recent years. The decline coincides with the GFC and, in 2017, the probability of an inflation trend that is too low amounts to 70%. Of course, the estimates at the end of the sample have to be interpreted with caution because future data points will change the assessment of this period.

The analysis has shown that flexible inflation targeting was successful in its main objective: keeping inflation low and stable. However, the analysis also shows that the inflation trend is lower than under most other monetary regimes over the past two centuries. This section therefore discusses the implications of the SNB's current low inflation target for the level of nominal interest rates.

Figure 4 gives the yield on government bonds jointly with the estimated permanent component for the CPI and GDP deflator. The bond yield fell by about 7.5pp between 1974 and

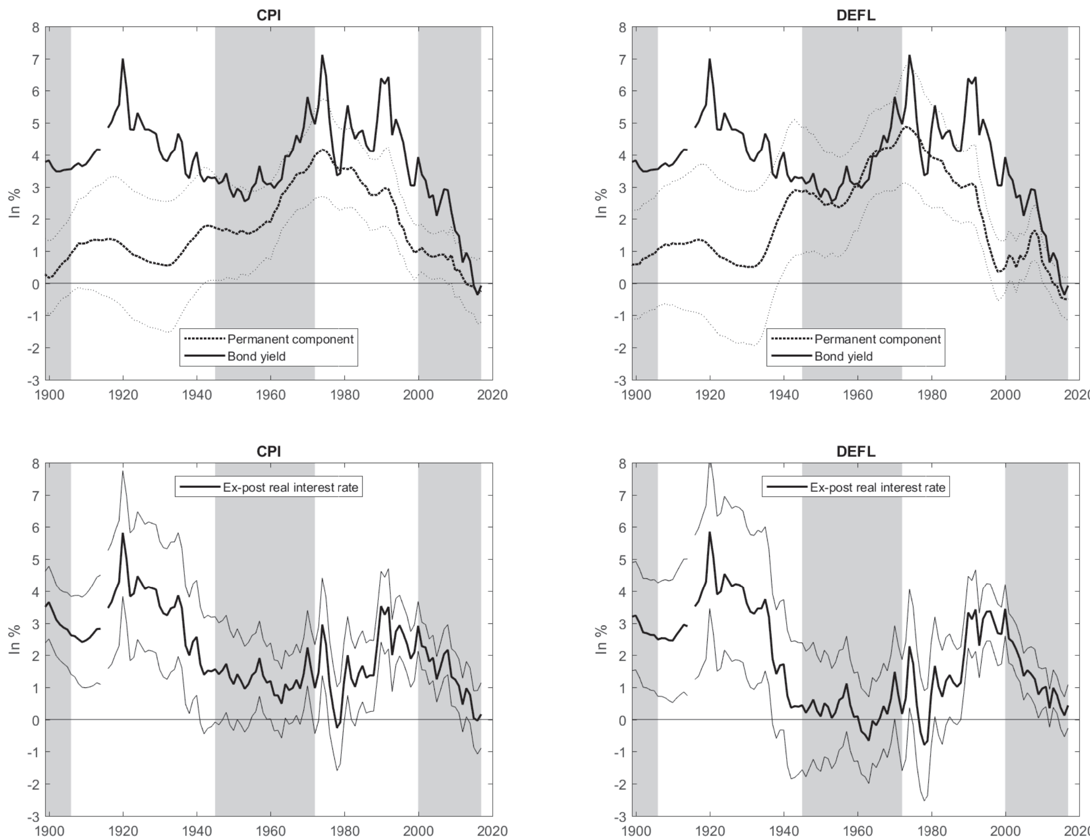
[17] For CPI inflation, Bordo and Filardo (2005) report a frequency of deflationary episodes of 36% between 1880 and WW1, 15% between 1950 and 1969 and 0% until 2002 for Switzerland. Their exercise differs as they examine the frequency of CPI deflation, whereas, I examine the probability that trend inflation is below of the SNB's definition of nominal stability.

Figure 3: Probability of nominal stability



Notes: The grey areas shows the posterior probability that the nominal trend is above or below of today's definition of nominal stability ($P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$). The area in between gives the probability of nominal stability. This definition differs among the various indicators. For CPI inflation, the official target range amounts to [0%, 2%], whereas, for the other indicators, no official target ranges exist. To account for the fact that the indicators have different trend growth rates, the CPI target range is adapted by subtracting the average growth rate of the CPI and adding the average growth rate of the various indicators. To obtain a stability range that would be applied in practice, the numbers are rounded to half a percentage point for the WPI ($[-0.5\%, 1.5\%]$), the GDP deflator ($[0\%, 2\%]$) and nominal GDP ($[2.5\%, 4.5\%]$). The shaded areas highlight changes in monetary regimes.

Figure 4: Bond yields and real interest rates



Notes: The solid lines in the upper panels shows a spliced measure of government bond yields (maturity between 5 and 10 years). The dashed lines show the estimated permanent component (mean, 5th percentile, 95th percentile). The lower panels show the implied ex-post real interest rate. The shaded areas highlight changes in monetary regimes.

2017. According to the estimated CPI trend, more than half can be attributed to lower inflation. According to the GDP deflator, even more of the decline in nominal interest rates can be attributed to lower inflation. The lower panels give the corresponding ex-post real interest rates. Today's real interest rates are in line with most of the after-war period. Only during the late 1990s do we observe a brief increase before the declined starting in the year 2000. Note that there are other reasons than a lower inflation rate why interest rates decline (see e.g. Bean et al., 2015). Recent studies emphasized demographic factors, declines in productivity growth, but also, a high propensity to save in emerging economies. In addition, Kugler and Weder di Mauro (2002) and Baltensperger and Kugler (2016) emphasize that low interest rates in Switzerland can be traced back to the safe economic and political environment. The estimates show, however, that at least for Switzerland a relevant part of the decline in nominal interest rates can be attributed to the trend decline in inflation rather than real factors.

5.2 Robustness

I conducted four robustness tests (see Appendix B). First, I varied the prior assumptions for the autoregressive parameter and variance in the stochastic volatility equation of the permanent component. I applied a less informative prior for the autoregressive parameter and increased the prior mean for the variance. The results are qualitatively identical.

Second, I lowered the definition of price stability by 1pp for all indicators. Recall that the SNB justifies the positive range by measurement error due to quality changes (see Swiss National Bank, 2015). In the absence of such measurement issues one might argue that the SNB would target an inflation rate in a symmetric range around 0%. Using today's range of nominal stability may hamper the intertemporal comparison of the monetary regimes because measurement error due to quality changes are likely a more serious issue after WW2 than before. To check the robustness of the results and avoid a potential bias in favour of the current monetary policy regime the exercise is repeated with an alternative nominal stability range of $[-1\%, 1\%]$ for CPI inflation. With this alternative definition, the Gold Standard performs somewhat better. Overall, however, the current monetary regime still provides the highest probability of nominal stability.

Third, I also estimate the UC-SV model by Stock and Watson (2007) which is a special case with an i.i.d. transitory component. As we would expect, more of the variation in the data is therefore attributed to the permanent component and it becomes more volatile as a result. The main result, that trend inflation was historically low under flexible inflation targeting, remains intact, however.

Fourth, I estimated the ex-post real interest rates with quarterly data on a shorter sample. The quarterly estimates starting in 1960 confirm that the ex-post real interest rate is currently at a level observed regularly from 1960-1980.

6 Concluding remarks

This paper applies recent statistical methods on a long historical data set of various indicators of nominal stability and compares the performance of Swiss monetary regimes over the last two centuries.

The estimates reveal that, on the one hand, flexible inflation targeting was associated with a historically stable monetary background. A fiat currency regime combined with a firm nominal anchor can be associated with a remarkably low inflation trend. On the other hand, the estimates uncover that assessing the monetary background for the 19th century is associated with much more uncertainty. Although it is possible that the metal currency regimes were associated with a stable monetary background, the available data does not allow to reach this conclusion with much confidence. This is in line with the finding by Cogley and Sargent (2015) for the US that the price level was in fact more predictable during post-WW2 paper currency regimes.

This favourable assessment of the current policy regime comes with at least one caveat, however. Because trend inflation has fallen to a historically low level, nominal interest rates are low as well. It is therefore not surprising that Switzerland, having one of the lowest inflation targets among major economies, also has one of the lowest policy interest rates.

This limits what are nowadays considered conventional monetary policy actions because of the effective lower bound on short-term interest rates. Because, under the current monetary arrangements, nominal interest rates cannot fall substantially below zero, a low inflation target imposes a constraint on the monetary policy response during recessions. The SNB primarily justifies its low inflation target by a measurement bias in CPI data.[18] However, other central banks usually have adopted a higher inflation target because they take into account not only measurement issues but also the effective lower bound.

An implication of the findings of this paper is that complementary monetary policy instruments, such as exchange rate interventions or negative interest on reserves, will likely belong to the standard toolkit in the years to come. Besides factors over which the central bank has little control, the SNB's low inflation target is an additional reason why non-conventional monetary policy measures became necessary. An open question worth investigating therefore is whether alternative definitions of nominal stability, for example a higher inflation target range or a nominal GDP target, would facilitate the conduct of Swiss monetary policy.

[18]The Boskin Commission (1996) estimate a bias of about 0.8pp for the US. There is some uncertainty regarding the size of this bias, however. On the one hand, the SFSO has improved CPI measurement in Switzerland over the last 15 years taking quality changes into account (see e.g. SFSO, 2011). On the other hand, recent research for the US by Goolsbee and Klenow (2018) suggests that the bias stemming from newly introduced products that are not yet incorporated in the CPI tends to be larger than what the Boskin Commission (1996) suggested. If this is the case, the actual inflation trend may even be lower than what the model estimates suggest.

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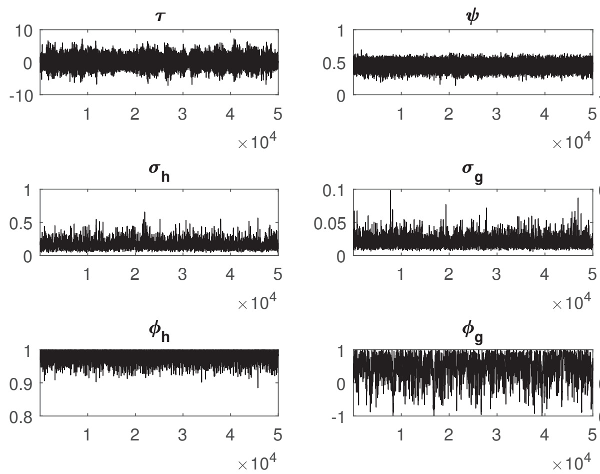
Appendix A Priors and and convergence of sampler

The prior specification follows Chan (2013). For the MA coefficient I assume a truncated normal prior $\psi \sim N(\psi_0, V_\psi)\mathbf{1}_{\{|\psi|<1\}}$ with $\psi_0 = 0$ and $V_\psi = 1$. The truncation ensures that the MA process is invertible. For the variance of the stochastic volatility equation I assume independent inverse-gamma priors $\sigma_i^2 \sim IG(\nu_i, S_i),\ i \in \{g, h\}$ with $\nu_g = \nu_h = 10$ and $S_g = 0.18,\ S_h = 0.45$. This implies a prior view that the variance of the transitory shocks changes more than the variance of the permanent shocks. For the stochastic volatility equation, I assume (truncated) normal priors with $\mu_i \sim N(\mu_{i0}, V_{\mu i})$ and $\phi_i \sim N(\phi_{i0}, V_{\phi i})\mathbf{1}_{\{|\phi_i|<1\}}$ where I put a relatively strong prior on a persistent stochastic volatility equation: $\mu_{g0} = \mu_{h0} = 0,\ V_{\mu g} = V_{\mu h} = 5,\ \phi_{g0} = \phi_{h0} = 0.9,\ V_{\phi g} = V_{\phi h} = 0.2$.

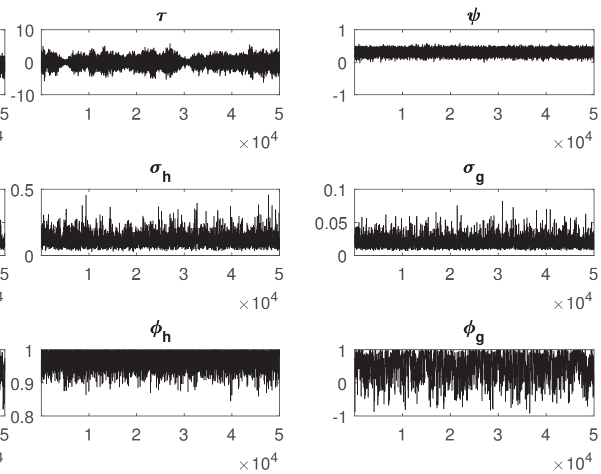
Figure 5 shows the Markov chain of 50,000 draws, after discarding the first 100,000 draws, for some key parameters for the baseline specification. The chains appear to be stationary and display no breaks or jumps.

Figure 6 shows that the posterior distribution for σ_g^2 is almost identical with the prior in the baseline specification. In a robustness test, I therefore set $S_g = S_h = 0.45$ and make the prior for the autoregressive parameters in the stochastic volatility equations less informative with $V_{\phi g} = V_{\phi h} = 1$. All main results remain intact.

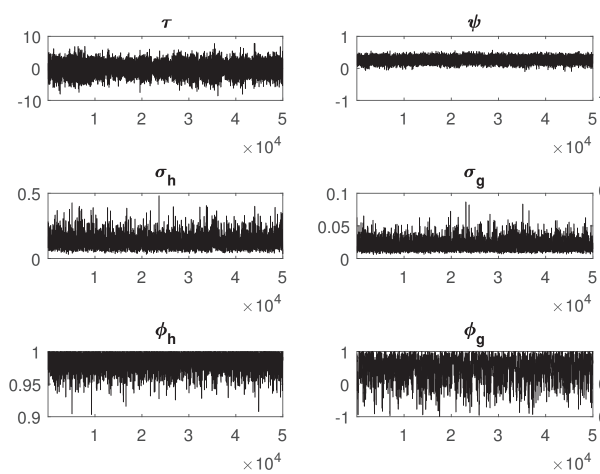
Figure 5: Markov chain MA-UC-SV



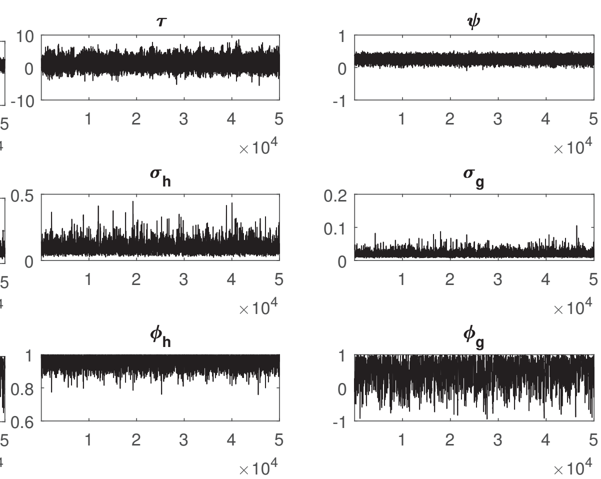
(a) CPI



(b) WPI



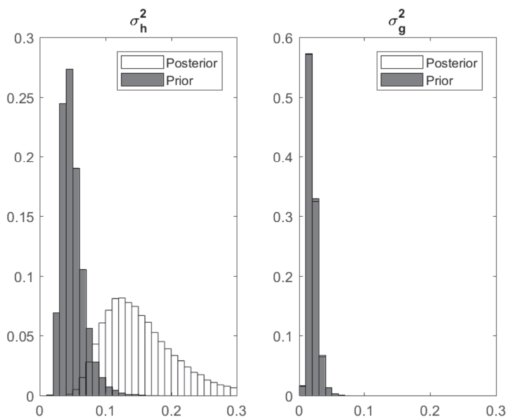
(c) DEFL



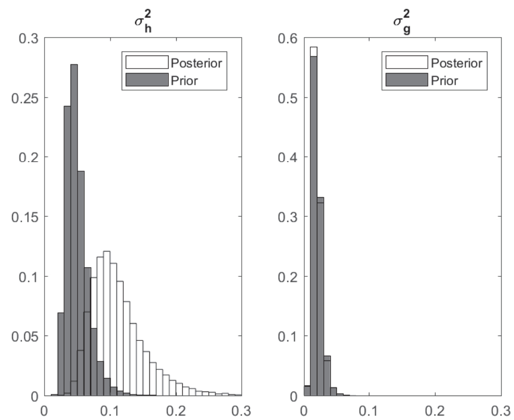
(d) NGDP

Notes: Markov chain of key parameters for the MA-UC-SV model.

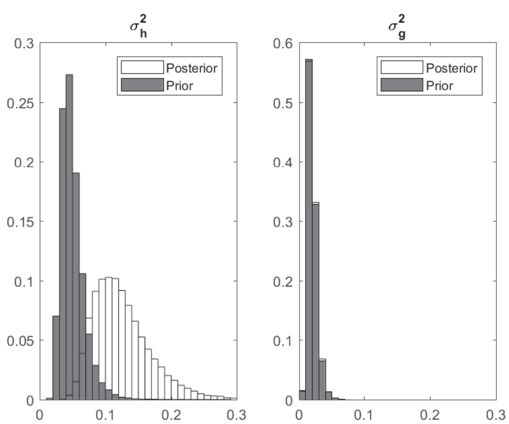
Figure 6: Prior and posterior σ_h^2, σ_g^2



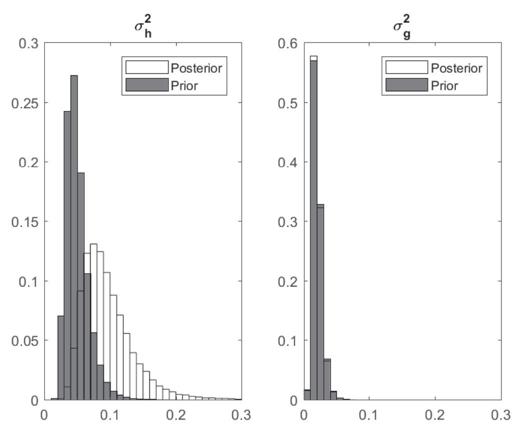
(a) CPI



(b) WPI



(c) DEFL

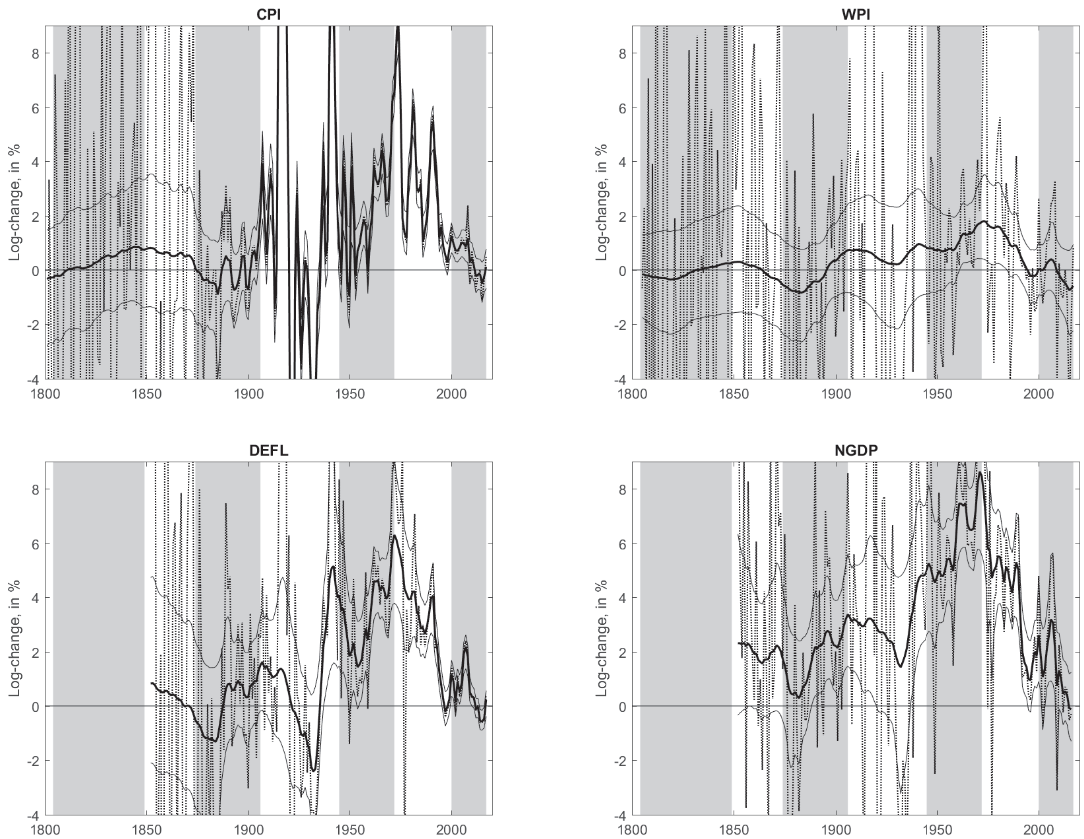


(d) NGDP

Notes: Prior distribution (grey bars) and posterior distribution (white bars) for the variance in the stochastic volatility equation.

Appendix B Robustness

Figure 7: Permanent component (UC-SV model)



Notes: Estimated permanent component (mean, 5th percentile, 95th percentile) and actual data (dashed line). The shaded and unshaded areas represent various monetary regimes.

Table 4: Probability of nominal stability (UC-SV model)

(a) Nominal stability: $P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.51	0.60		
1850-1873: Bimetallism	0.52	0.60	0.40	0.45
1874-1906: Gold Standard	0.44	0.57	0.49	0.48
1907-1944: World War period	0.21	0.62	0.33	0.42
1945-1973: Bretton Woods	0.31	0.67	0.20	0.05
1974-1999: Monetary targeting	0.40	0.67	0.19	0.22
2000-2017: Inflation targeting	0.72	0.68	0.63	0.37
(b) Overshooting: $P[\tau_t > \overline{\tau}|\mathbf{y}]$	**CPI**	**WPI**	**DEFL**	**NGDP**
1804-1849: Competing currencies	0.10	0.07		
1850-1873: Bimetallism	0.14	0.09	0.17	0.15
1874-1906: Gold Standard	0.04	0.05	0.08	0.11
1907-1944: World War period	0.42	0.21	0.29	0.39
1945-1973: Bretton Woods	0.55	0.29	0.79	0.94
1974-1999: Monetary targeting	0.59	0.26	0.74	0.63
2000-2017: Inflation targeting	0.01	0.02	0.09	0.08
(c) Undershooting: $P[\tau_t < \underline{\tau}|\mathbf{y}]$	**CPI**	**WPI**	**DEFL**	**NGDP**
1804-1849: Competing currencies	0.39	0.33		
1850-1873: Bimetallism	0.34	0.32	0.44	0.39
1874-1906: Gold Standard	0.52	0.39	0.43	0.42
1907-1944: World War period	0.37	0.17	0.38	0.19
1945-1973: Bretton Woods	0.14	0.04	0.01	0.00
1974-1999: Monetary targeting	0.01	0.07	0.07	0.15
2000-2017: Inflation targeting	0.27	0.30	0.28	0.55

Notes: The table shows the average posterior probability that the nominal trend is in line with today's definition of nominal stability ($P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$), and the probability of under- and overshooting the definition of nominal stability. This definition differs among the various indicators. For CPI inflation, the official target range amounts to [0%, 2%], whereas, for the other indicators, no official target ranges exist. To account for the fact that the indicators have different trend growth rates, the CPI target range is adapted by subtracting the average growth rate of the CPI and adding the average growth rate of the various indicators. To obtain a stability range that would be applied in practice, the numbers are rounded to half a percentage point for the WPI ($[-0.5\%, 1.5\%]$), the GDP deflator ($[0\%, 2\%]$) and nominal GDP ($[2.5\%, 4.5\%]$). The estimates are based on the UC-SV model by Stock and Watson (2007).

Table 5: Probability of nominal stability (with alternative prior)

(a) Nominal stability: $P[\underline{\tau} < \tau_t < \overline{\tau}\vert\mathbf{y}]$	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.46	0.65		
1850-1873: Bimetallism	0.48	0.60	0.43	0.31
1874-1906: Gold Standard	0.53	0.62	0.49	0.49
1907-1944: World War period	0.59	0.64	0.49	0.43
1945-1973: Bretton Woods	0.40	0.65	0.15	0.04
1974-1999: Monetary targeting	0.20	0.72	0.21	0.27
2000-2017: Inflation targeting	0.75	0.73	0.70	0.53
(b) Overshooting: $P[\tau_t > \overline{\tau}\vert\mathbf{y}]$	**CPI**	**WPI**	**DEFL**	**NGDP**
1804-1849: Competing currencies	0.14	0.07		
1850-1873: Bimetallism	0.18	0.09	0.06	0.04
1874-1906: Gold Standard	0.03	0.05	0.08	0.11
1907-1944: World War period	0.23	0.22	0.31	0.45
1945-1973: Bretton Woods	0.58	0.31	0.85	0.96
1974-1999: Monetary targeting	0.79	0.24	0.77	0.68
2000-2017: Inflation targeting	0.01	0.02	0.04	0.03
(c) Undershooting: $P[\tau_t < \underline{\tau}\vert\mathbf{y}]$	**CPI**	**WPI**	**DEFL**	**NGDP**
1804-1849: Competing currencies	0.41	0.28		
1850-1873: Bimetallism	0.34	0.31	0.51	0.65
1874-1906: Gold Standard	0.44	0.33	0.44	0.41
1907-1944: World War period	0.18	0.15	0.20	0.12
1945-1973: Bretton Woods	0.02	0.04	0.00	0.00
1974-1999: Monetary targeting	0.00	0.04	0.03	0.06
2000-2017: Inflation targeting	0.24	0.25	0.26	0.43

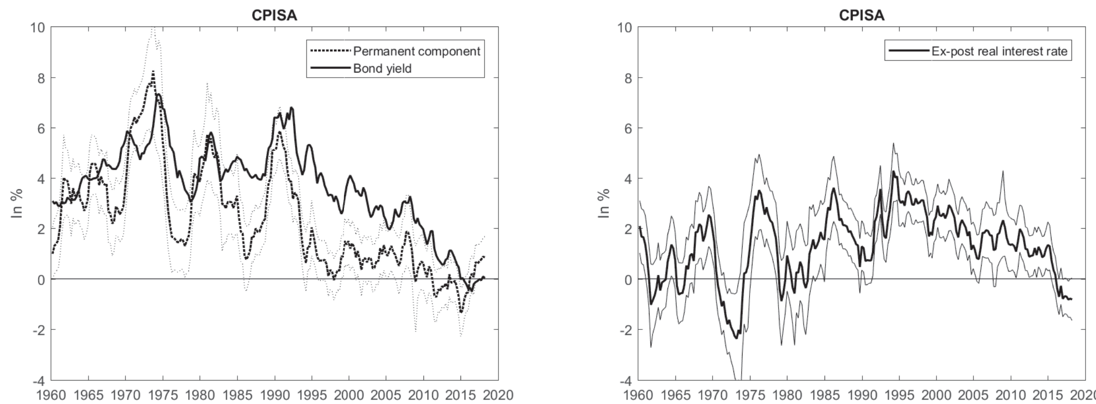
Notes: The table shows the average posterior probability that the nominal trend is in line with today's definition of nominal stability ($P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$), and the probability of under- and overshooting the definition of nominal stability. This definition differs among the various indicators. For CPI inflation, the official target range amounts to [0%, 2%], whereas, for the other indicators, no official target ranges exist. To account for the fact that the indicators have different trend growth rates, the CPI target range is adapted by subtracting the average growth rate of the CPI and adding the average growth rate of the various indicators. To obtain a stability range that would be applied in practice, the numbers are rounded to half a percentage point for the WPI ($[-0.5\%, 1.5\%]$), the GDP deflator ($[0\%, 2\%]$) and nominal GDP ($[2.5\%, 4.5\%]$). The models are estimated separately before and after 1907 to account for potential changes in the MA parameter.

Table 6: Probability of nominal stability (with alternative definition of nominal stability)

(a) Nominal stability: $P[\underline{\tau} < \tau_t < \overline{\tau}\|\mathbf{y}]$	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.52	0.66		
1850-1873: Bimetallism	0.47	0.59	0.60	0.54
1874-1906: Gold Standard	0.70	0.64	0.53	0.52
1907-1944: World War period	0.40	0.42	0.36	0.26
1945-1973: Bretton Woods	0.13	0.24	0.03	0.01
1974-1999: Monetary targeting	0.06	0.34	0.12	0.17
2000-2017: Inflation targeting	0.72	0.70	0.71	0.66
(b) Overshooting: $P[\tau_t > \overline{\tau}\|\mathbf{y}]$	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.32	0.27		
1850-1873: Bimetallism	0.39	0.32	0.19	0.13
1874-1906: Gold Standard	0.18	0.27	0.27	0.31
1907-1944: World War period	0.55	0.55	0.57	0.70
1945-1973: Bretton Woods	0.87	0.75	0.97	0.99
1974-1999: Monetary targeting	0.94	0.66	0.88	0.82
2000-2017: Inflation targeting	0.25	0.25	0.27	0.20
(c) Undershooting: $P[\tau_t < \underline{\tau}\|\mathbf{y}]$	CPI	WPI	DEFL	NGDP
1804-1849: Competing currencies	0.16	0.07		
1850-1873: Bimetallism	0.14	0.09	0.21	0.33
1874-1906: Gold Standard	0.12	0.09	0.20	0.18
1907-1944: World War period	0.05	0.03	0.07	0.04
1945-1973: Bretton Woods	0.00	0.00	0.00	0.00
1974-1999: Monetary targeting	0.00	0.00	0.00	0.01
2000-2017: Inflation targeting	0.02	0.04	0.01	0.14

Notes: The table shows the average posterior probability that the nominal trend is in line with an alternative definition of nominal stability ($P[\underline{\tau} < \tau_t < \overline{\tau}|\mathbf{y}]$), and the probability of under- and overshooting the definition of nominal stability. This definition differs among the various indicators. For CPI inflation, the official target range is lowered to $[-1\%,\ 1\%]$, whereas, for the other indicators, no official target ranges exist. To account for the fact that the indicators have different trend growth rates, the CPI target range is adapted by subtracting the average growth rate of the CPI and adding the average growth rate of the various indicators. To obtain a stability range that would be applied in practice, the numbers are rounded to half a percentage point for the WPI ($[-1.5\%, 0.5\%]$), the GDP deflator ($[-1\%, 1\%]$) and nominal GDP ($[1.5\%, 3.5\%]$). The models are estimated separately before and after 1907 to account for potential changes in the MA parameter.

Figure 8: Trend decline in bond yields and real interest rate (quarterly data)



Notes: The solid lines in the upper panels shows a quarterly measure of 10-year government bond yields. The dashed lines show the estimated permanent component (mean, 5th percentile, 95th percentile) for quarterly CPI inflation. The lower panels show the implied ex-post real interest rate. The shaded areas highlight changes in monetary regimes. The data stem from the OECD and were seasonally adjusted using TRAMO-SEATS via `www.seasonal.website`.