What Drives Long-Term Interest Rates? Evidence from the Entire Swiss Franc History 1852-2020*

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Abstract: We study domestic and international drivers of long-term interest rates using newly compiled financial market data for Switzerland starting in 1852. We use a time-varying parameter model to estimate long-term trends in interest rates, the exchange rate, and inflation. We then decompose the Swiss long-term nominal interest rate trend into various drivers using an interest rate accounting framework. The decline in long-term interest rates since 1970 is mainly driven by a decline in the level of inflation. During the 19th century, Swiss real rates were higher than abroad. After World War 2, Swiss nominal and real interest rates were usually lower than abroad. Moreover, we find that (relative) inflation uncertainty is positively related to the (relative) level of Swiss real interest rates. This suggests that the currently low real interest rates are not only driven by real factors but also by low inflation risk.

JEL classification: E4, E5, F3

Keywords: Natural rate of interest, exchange rate, inflation risk, term spread, uncovered interest parity, historical data

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1 Introduction

Low nominal and real interest rates pose important challenges for policymakers and social security systems alike. The central bank's policy instrument, for example, is more regularly constrained by the effective lower bound and social security funds find it more difficult to meet their nominal obligations. To assess whether this environment is likely to persist, knowing the most important driving forces is key. Recent research has focused on real factors, such as demographic change, productivity slowdown, the convenience yield, and an international savings glut. The role of the monetary regime, inflation risk, and international factors is less well documented, however. This paper aims to fill this gap by analyzing the main drivers of Swiss long-term interest rates from 1852 to 2020 in an international context.

We first collect novel monthly Swiss data for long-term interest rates and exchange rates for Switzerland from archival sources.[1] This is a key contribution of the paper. To the best of our knowledge, this is the first time that 19th century data for Swiss long-term interest rates and the exchange rate vis-à-vis the Pound Sterling have been compiled.[2]

We then link these data with modern sources for Switzerland and construct trade-weighted international data for the rest of the world. Next, we extract long-term trends from these data in a time-varying parameter vector-autoregression (TVP-VAR), allowing for a few, but large, structural breaks. Finally, we decompose the long-term nominal interest rate trend into various components using an interest rate accounting framework. This allows us to analyze how the nominal long-term rate trend is affected by both domestic and international factors.

Several papers have presented estimates of the natural interest rate over longer samples in recent years. For instance, Del Negro et al. (2019) assess the natural rate for seven advanced economies over a long sample starting in 1870. They find that natural interest rates showed no trend until 1940, then increased until the 1980's, after which the trend reversed leading to the current low values. Fiorentini et al. (2018) also consider a long sample starting in 1890 for 17 countries, improving the method by Laubach and Williams (2003) to handle periods with underlying changes in the structure of the economy. They find a similar path as other studies with an increase in the natural rate from 1960 to the late 1980's, followed by a decrease. [3] Jordà et al. (2020) estimate the natural real interest rate for France, Germany, Italy, Netherlands, Spain

[1] Although we aggregate the monthly to annual data for the analysis because no monthly price data exists for Switzerland.

[2] Previous research mostly focused on short-term interest rates and inflation (see, e.g., Kaufmann, 2019, Jöhr, 1914, Herger, 2021).

[3] Similarly, Pescatori and Turunen (2016) allow the model estimates to change when the effective lower bound on short-term interest rates was binding, and also find a clear decrease in the natural rate over the last three decades.

and the UK using annual data starting, in some cases, as early as the 14th century. Focusing on the effect of pandemics, they argue that the impact on the natural real interest rate can last for decades. Our first contribution to this literature is to decompose long-term nominal interest rate trends of a small open economy in an interest rate accounting framework. Switzerland is an interesting case to study for two reasons. None of the existing studies provide estimates of the natural rate of interest for a small open economy and discuss the domestic and international drivers.[4] In addition, because the Swiss franc has been in existence for 170 years we are able to analyze these movements over a long sample period under various monetary regimes.

The existing literature uses two different approaches to measure the natural rate of interest. The standard approach for estimating the natural rate relies on restrictions from economic theory (Laubach and Williams, 2016). However, this approach is not well suited when considering a long sample which covers several economic crises, wars, and structural shifts in the underlying macroeconomic relations (such as the end of the Bretton Woods system). While one could rely on a model where relations can change through time, this would represent a complex exercise with a risk of the theoretical model being misspecified. Other studies use reduced-form time-varying parameter models to identify the long-term trends in the variables.[5]

However, TVP-VAR models typically restrict the coefficients of the model to evolve slowly over time in order to handle the large number of coefficients that have to be estimated from the data (see, e.g., Primiceri, 2005). This leads to estimates of the long-term trends that evolve gradually. This assumption is undesirable in our analysis because the sample includes sudden changes in the macroeconomic environment, such as the World War period or the demise of the Bretton Woods system. Another contribution of the paper therefore is to employ the model proposed by Huber et al. (2019) which allows for constant model coefficients, gradual changes, but also, for a few abrupt structural breaks. These structural breaks, in turn, allow for discrete changes in the long-term trend estimates. The result is estimates of the trend real interest rates that are more volatile than those found in other studies (for example Del Negro et al. (2019)). Our

[4]Several studies include annual Swiss data. Borio et al. (2017) and Borio et al. (2019) use annual data on 19 countries from 1870 to 2016 to assess the evolution of interest rates, including an estimate of the real interest rate trend. The full sample estimates are however only available on a narrower geographical scope. While Borio et al. (2017) obtain estimates for the entire sample period, they only report them for the US and UK. Borio et al. (2019) focus primarily on the US and on the period from the 1990s. As a result, no estimate of the natural rate of interest is reported for Switzerland.

[5]Reduced-form approaches to estimate long-term trends have a long tradition in macroeconomics. For instance, Cogley et al. (2010) rely on a multivariate time series models to analyze the money-inflation nexus. Similar econometric models have been employed to forecast inflation, treating the underlying inflation trend as an unobserved component (Stock and Watson, 1999, 2007, Chan et al., 2013, Stock and Watson, 2020); to decompose output into a long-term trend (potential or natural output) and the output gap (Planas et al., 2008, Jarociński and Lenza, 2018); and as mentioned before, to infer the unobserved natural real interest rate (e.g. Del Negro et al., 2017).

findings suggest that the smooth real interest rate trends found in the literature are an artifact of tightly restricted model parameters that rule out rapid shifts.

The final contribution of our paper is the proposal of an interest rate accounting framework which allows us to decompose the nominal long-term trend interest rate into various components. In particular, we can analyze how it is affected by trend inflation, the term spread, the world real interest rate, as well as deviations from uncovered interest parity (UIP) and relative purchasing power parity (PPP).

Using this interest rate accounting framework, we obtain several main findings, which may be summarized as follows. The main reason why Swiss long-term nominal rates declined since the 1970's is a reduction in trend inflation. The Swiss real long-term interest rate already declined during the interwar period and remained relatively low ever since. Real short rates were virtually zero following the Great Depression. This implies that we observe a positive term spread during most of the 20^{th} century. This term spread is positively related to the level and volatility of the Swiss inflation trend. This suggests that the term spread comprises an inflation risk premium, which vanished during the mildly deflationary environment since the Global Financial Crisis. Moving to international factors, we find that Swiss real rates were high compared to the rest of the world during the 19^{th} and first half of the 20^{th} century. During the Bretton Woods System, Swiss real rates were low relative to the rest of the world, suggesting that investors were willing to pay a premium to hold Swiss franc assets. This so-called 'Swiss interest rate island' gradually vanished starting in 1990. This coincides with a reduction in trend inflation abroad relative to inflation in Switzerland. Finally, we decompose the interest rate differential into deviations from UIP and relative PPP. We show that the Swiss interest rate island was partly caused by a negative deviation from UIP, but also, by a real trend appreciation of the Swiss franc towards the end of the Bretton Woods System. The interest rate differential and the deviation from UIP are positively related to relative inflation uncertainty. This suggests that the Swiss interest rate island was partly caused by the relatively low inflation risk in Switzerland.

The paper is structured as follows. In the next section, we explain how we compiled the data. In Section 3 we discuss the methodology for extracting trends from the data and how we decompose the long-term interest rate into various domestic and international components. Section 4 discusses the results. The final section concludes.

2 A novel data set 1852-2020

Modern Switzerland was established in 1848 as a Confederation of 22 cantons.[6] In 1850 the first Federal Coinage Act was passed, introducing the Swiss franc as the official monetary unit. The newly created silver currency replaced a wide variety of coins in circulation (Kaufmann, 2019). By 1852 the replacement of the predecessor currencies to the Swiss franc was mostly complete (Niederer, 1965). Therefore, interest rates and exchange rates in terms of Swiss franc became available. Over the following 170 years, the remarkable stability of the Swiss franc, and the Swiss financial system more broadly, led to Switzerland becoming a safe haven for capital in times of uncertainty, war and crisis.

Given this history, we compile a novel data set on short- and long-term interest rates, the exchange rate, and inflation from 1852-2020. Because data on long-term interest rates and exchange rates is lacking, we hand-collected monthly financial data from a range of archival sources, primarily quotation lists from exchanges in Basel, Zurich, and Geneva.[7] Although the analysis uses annual data, collecting monthly data is key to obtaining a sensible annual average during times with rapid changes in financial market variables. In addition, we construct trade-weighted statistics of interest rates and inflation to capture the developments in the rest of the world. In what follows, we describe how we construct the data and provide a graphical analysis.

2.1 Short-term interest rate

For most of the 19th century, we use the annual discount rate of banks of issue in Zurich, St. Gallen, Basel, and Geneva.[8] These discount rates initially show some dispersion during the 1850's and 1860's. This period has been characterized as one of free-banking (see Baltensperger and Kugler, 2017, ch. 8), which came to an end in 1881 when note-issuance became more strongly regulated (Herger, 2021). However, prior to 1881 there were several initiatives by the banks of issue to coordinate their actions and ensure that notes issued by one bank were

[6] The number of cantons increased to 23 in 1979 with the secession of Jura from Bern, and to 26 in 1999 with the designation of former half-cantons as cantons.

[7] Most of our data is obtained through the *Wirtschaftsarchiv Basel*, the *Universitätsbibliothek Basel*, the *Bibliothèque de Genève* and various online newspaper archives. We provide a detailed list of all sources in the Appendix.

[8] See Table 2 in Appendix B for a detailed list of sources.

accepted by another.[9] Against this backdrop, discount rates were quite similar by the 1870's. To account for the heterogeneity of discount rates before this, we compute the simple average over the various cities rather than using the discount rate of one particular city to represent the discount rate in Switzerland.

In 1893, the city-specific data in Jöhr (1914) ends. From 1894-1906 we therefore collected end-of-month values of the official discount rate of the banks of issue from the *Kursblatt der Basler Börse*.[10] The SNB was founded in 1907. We therefore use the annual average of the daily discount rate of the SNB (2007) from 1907-1947. From 1948-1998, we use the annual average of daily money market rates in Zurich also available from the SNB (2007). Finally, from 1999-2020 we use the annual average of the daily SARON, a secured overnight interest rate.[11]

2.2 Long-term interest rate

No data exists on Swiss long-term interest rates before 1899. We therefore hand-collected end-of-month values of cantonal and Confederation bond prices from quotation lists in Geneva, Basel, Zurich, and St. Gallen.[12] We then complement the data with information listed in various Swiss newspapers. The data is particularly scarce in the 1850's; for most of this period, we only observe a single 4% Geneva bond. In the 1860's we were able to obtain data for several Confederation and 14 cantonal bonds. From 1879-1925 we collected 43 Confederation bonds and 47 cantonal bonds.[13]

From our sources we obtain bond prices; therefore we need to calculate the yield-to-maturity. The information we collect includes the coupon interest rate, the repayment date, and the price quotes. Tables from the archival sources often comprise three columns, one for demand (*Geld*), one for supply (*Brief*), and one for actual transactions (*Bezahlt*). If available, we use the latter.

[9] During the 1850s, circulation of notes in removed areas was limited because the trustworthiness of banks of issue from other cities was unknown. The aim of those agreements were therefore that notes emitted were mutually accepted. For example, the *Konkordat* was an agreement from 1862 between banks of issue in Basel, St. Gallen, and Zurich (Feibelmann, 1897). The goal of this agreement was to facilitate the exchange of notes of various issuers. The *erste allgemeine Konkordat der schweizerischen Emissionsbanken* from 1876 was an agreement between banks of issue in Zurich, Basel, St. Gallen, Bern, and Geneva which ensured convertibility of notes for this broader group (see Bleuler, 1911, p. 279).

[10] The *zweite allgemeine Konkordat der schweizerischen Emissionsbanken* from 1882 revised the *erste Konkordat* from 1876 (Mangold, 1911). By 1893, the *zweite Konkordat* announced an official discount rate. We do not know, however, whether the members deviated from this official discount rate.

[11] Since June 2019, the SNB announces a policy rate target. It aims to keep short-term money market rates, among which the SARON is the most relevant, close to this target. Before, the SNB announced a target range for the 3M CHF LIBOR. We prefer to use the SARON throughout because it matches the maturity of the other short-term money market rates in our sample better.

[12] See Table 3 in Appendix B for a detailed list of sources.

[13] Not all bonds are available over the entire sample period as there are several periods with declining interest rates where the bonds were called and new bonds were issued at a lower coupon interest rate.

Otherwise, we use the average of the demand and supply quotes.[14] For some months, no price may be available. We linearly interpolate missing prices up to three months. We also remove price quotes when the time to maturity falls below six years. Finally, some bonds are called before the actual maturity date. Once the repayment was announced, the bond's maturity therefore became very short. To remove such announcement effects from the data, we remove price quotes six months before the bond was repaid.[15]

When calculating bond yields, we resort to widely used formulas to calculate the yield-to-maturity. If we know the time to maturity (m) of a bond, the yield-to-maturity is the solution of i in the following bond pricing equation:

$$P = \frac{C}{1+i} + \frac{C}{(1+i)^2} + \ldots + \frac{C+F}{(1+i)^m}\,, \tag{1}$$

where the current price of the bond (P) equals the future discounted income stream, which consists of annual coupon interest payments (C) and repayment of the face value of the bond when it matures (F). In our setting, the bond price is often reported in percent of the face value of the bond; therefore, $F = 100$. In addition, the coupon payment is often reported in terms of coupon interest payment in percent (r); therefore, $C = r \times F$.

However, the maturity date is not known for some bonds in the early sample period. If the maturity date is unknown we have to resort to an approximation.[16] In this case, we assume that the bond is of very long maturity, which was very common during the 19th century. If m tends to infinity, the yield-to-maturity equals the current yield, which is the solution i to the bond pricing equation:

$$P = \frac{C}{i}\,. \tag{2}$$

This procedure yields individual bond yield data of various issuers (Confederation and cantons) over various sample periods. We compute an aggregate long-term bond yield as the median over all available individual bond yields. In doing so we are able to obtain a long-term interest rate for periods when the Confederation did not issue any debt.[17]

Existing data start in 1899 (SNB, 2007). From 1899-1923 these yields stem from bonds on

[14] Sometimes, only demand or supply is available. We then use the available quote.

[15] Some bonds were repaid in a random fashion. Each year, some bonds were drawn from the outstanding bonds and it was announced in newspapers which bonds would be immediately repaid. We ignore such random repayment schemes as we were not able to collect the number of repaid and outstanding bonds.

[16] In Appendix A we carry out a simulation to understand what the effect of this approximation might be. Overall, it is likely to bias our yields downwards, and make them somewhat smoother than otherwise.

[17] Note that the average cantonal bond yield is slightly higher than the average Confederation bond yield, suggesting that there is a positive liquidity or risk premium. However, the spread is smaller than 0.25 percentage points on average from 1860-1925 (see Appendix A).

the Swiss federal railway company. These bonds were widely traded and backed by the Confederation; according to SNB (2007) these therefore provide a good approximation to prices of Confederation bonds. The yields we compute based on Confederation bonds are quite similar to the existing data.[18] Because our data set considers a broader range of government debt at the national and cantonal level, we therefore prefer our new series. At the start of the First World War, the Swiss exchanges were closed. Therefore, we fill this gap using a linear interpolation. In 1924, SNB (2007) reports yields based on Confederation and railway bonds with a maturity of five years. Our series is quite similar on the overlapping sample. We therefore splice the series in 1926. Beginning in 1988, the SNB (2021) report zero coupon yields of 10-year Confederation bonds, which we use until the end of the sample.

2.3 Exchange rate

We hand-collected end-of-month values of the exchange rate vis-à-vis Sterling starting in 1852.[19] In order to account for potential regional heterogeneity during the early sample period under free-banking, we collect the exchange rate for Geneva, Basel, Zurich, and St. Gallen from 1852-1879. Tables from the archival sources often comprise two values, one for demand (*Begehrt*) and one for supply (*Angetragen*), in which case we take the average of the two.[20] In addition, we interpolate up to three consecutive missing months using a linear interpolation. We then take the median of the city-specific exchange rate as representative of Switzerland as a whole. Similar to the discount rates, the exchange rates in the various cities moved very closely together by the 1870's. We therefore use the exchange rate for Basel from 1880-1913.

Existing exchange rate data are available from 1914 on. From 1914 to 1963 we use an equally weighted average between the CHF/GBP and CHF/USD using data from the SNB (2021). From 1964 to November 1972, we use a nominal effective exchange rate from the BIS (2021). Starting in 1973, we use the new effective exchange rate index of the SNB (2021).[21] Before splicing the various segments, we normalize them to the same base year. We compute annual data by the average over the monthly values.

2.4 Inflation

Consumer price data for Switzerland are available from the SFSO (2021) starting in the early 19^{th} century. However, as Kaufmann (2019, 2020) suggests, these CPI data are probably prone

[18] See Appendix A for a comparison.
[19] A detailed description of the sources is given in Appendix B).
[20] If only one is available, we use the corresponding quote.
[21] See Müller (2017) for a methodological description.

to substantial measurement error and based on wholesale prices for part of the sample. We therefore prefer to use wholesale prices from 1852-1913 from HSSO (2012b), which are likely to be less prone to measurement issues.[22] We then splice this series in 1914 with consumer prices from HSSO (2012b). Finally, we splice the series in 1921 with the official CPI from the SFSO (2022). Before splicing the series, we normalize them to the same base year and aggregate monthly data to annual frequency using a simple average.

2.5 Rest of the World

We construct short- and long-term interest rates, as well as inflation for the rest of the world. The exact series used in the compilation of these data are set out in Appendix C. In what follows, we explain the general principles. The rest of the world is assumed to be the UK for the period until 1914. This is because it was the center of the global monetary system and 19th century data for the UK is regarded to be of good quality. From 1914 to 1963, we use an equal weighted average of US and UK data. We do this since the US became more and more important as a trading partner for Switzerland.[23] Starting in 1964, we compute short- and long-term interest rates including Switzerland's eight most important trading partners using annual weights from the SNB's exchange rate index. In addition, we compute an implicit trade-weighted consumer price index based on nominal and real effective exchange rates, as well as the Swiss CPI.[24]

2.6 Descriptive analysis of the data

Figure 1 shows the final data set. We observe that short- as well as long-term interest rates were higher in Switzerland than abroad during the 19th century (first and second panel). The gap narrowed during the World War period. After the Second World War interest rates were lower in Switzerland than abroad. This reversal coincides with Swiss inflation being persistently lower than abroad after the Second World War. But, during the metallic regimes of the 19th century the level and movements of inflation were similar in Switzerland and abroad (third panel).[25] This relative pattern of inflation vis-à-vis the rest of the world is also reflected in exchange rate movements (fourth panel). The exchange rate is defined as one unit of foreign currency expressed in Swiss francs; therefore, a decline is an appreciation of the Swiss franc.

[22] See Table 4 in Appendix B for a complete list of sources.

[23] In 1964, the sum of goods imports and exports amounted to CHF 1.9 bio. for the UK and CHF 2.4 bio. for the US. See Tables L.18, L.19, L.22, L.23 on HSSO (2012a).

[24] As Stulz (2007) highlights, a trade-weighted CPI can be calculated by dividing the CPI-based real effective exchange rate by the nominal effective exchange rate and multiplying the result by the Swiss price level.

[25] Gerlach and Stuart (2021) show that there were strong co-movements in international inflation during this period.

Fig. 1: Data 1852-2020

During the metallic regimes of the 19th century the Swiss franc did not change much vis-à-vis Sterling. The World War period brought more volatility. After the Second World War, with the exception of the Bretton Woods System until 1973, the Swiss franc more often than not appreciated over time.

3 Methodology

In this section, we explain how we extract long-term trends of interest rates and inflation. In addition, we present an interest rate accounting framework to explain long-term interest rate trends.

3.1 Model

Macroeconomic variables include both temporary factors (i.e., business cycle movements) and permanent factors (i.e., long-term trends). The latter represent hypothetical values that the economy would converge to once temporary factors have dissipated. Because we do not observe either of these two components directly, we must estimate them from the data.

Specifically, we estimate a time-varying parameter (TVP) VAR model. The TVP-VAR allows us to estimate the long-term trends, defined as the best long-term forecast at any given point in time. Because all coefficients in the model are allowed to change over time, these trends may evolve as well. This procedure is similar to a Beveridge and Nelson (1981)-type decomposition that has also been used by, e.g., Cogley et al. (2010) and Kliem et al. (2016). However, TVP-VAR models typically restrict the coefficients to evolve slowly over time in order to handle the large number of coefficients that have to be estimated from the data (see, e.g., Primiceri, 2005). This leads to estimates of the long-term interest rate trends that evolve slowly over time as well (e.g. Del Negro et al., 2017).

This assumption is undesirable in our analysis because the sample includes sudden changes in the macroeconomic environment. We therefore use a mixture innovation model proposed by Huber et al. (2019) which allows for constant model coefficients, gradual changes and a few abrupt structural breaks. These structural breaks, in turn, allow for sudden large changes in the long-term trend estimates.

Assuming that $\boldsymbol{y}_t$ is a vector of our variables of interest, we estimate the following TVP-VAR:

$$\boldsymbol{y}_t = \boldsymbol{c}_t + \sum_{i=1}^{p} \boldsymbol{B}_{it}\boldsymbol{y}_{t-i} + \boldsymbol{\epsilon}_t, \quad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\boldsymbol{0}, \boldsymbol{\Sigma}_t).$$

Here, $\boldsymbol{c}_t$ denotes an $M \times 1$ vector of intercepts, $\boldsymbol{B}_{it}$ is a $M \times M$ matrix of coefficients that relates the endogenous variables to their i^{th} lags and $\boldsymbol{\epsilon}_t$ represents a zero-mean shock vector with time-varying variance-covariance matrix $\boldsymbol{\Sigma}_t$. All parameters of the model are assumed to vary over time.

Let $\boldsymbol{\alpha}_t$ be a KM-dimensional vector which stores all coefficients of the model (for $K = pM$). We assume that the j^{th} element of $\boldsymbol{\alpha}_t$, α_{jt}, evolves according to:

$$\alpha_{jt} = \alpha_{jt-1} + \kappa_{jt} u_{jt}, \quad u_{jt} \sim \mathcal{N}(0, 1).$$

κ_{jt} is the state innovation variance which is given by:

$$\kappa_{jt} = \begin{cases} \kappa_j & \text{with probability } p_j \\ 0 & \text{with probability } 1 - p_j \end{cases} \tag{3}$$

Here, $\kappa_j > 0$ denotes the variance in case that α_{jt} varies over time and p_j is the corresponding probability that the coefficient is time-varying. By contrast, with probability $1 - p_j$ we have that $\alpha_{jt} = \alpha_{jt-1}$, implying a constant coefficient. This specification is highly flexible and allows for smooth, abrupt or no changes in the coefficients.

To extract the long-run trends, after estimating the reduced-form coefficients, we recast the VAR(p) model in its companion form:

$$\begin{aligned} \boldsymbol{y}_t &= \boldsymbol{J} \boldsymbol{z}_t \\ \boldsymbol{z}_t &= \boldsymbol{C}_t + \boldsymbol{B}_t \boldsymbol{z}_{t-1} + \boldsymbol{\zeta}_t, \quad \boldsymbol{\zeta}_t \sim \mathcal{N}(\boldsymbol{0}, \boldsymbol{\Omega}_t). \end{aligned}$$

Here, $\boldsymbol{z}_t = (\boldsymbol{y}'_t, \dots, \boldsymbol{y}'_{t-p+1})'$ denotes an $Mp \times 1$ matrix, $\boldsymbol{C}_t$ is a $Mp \times 1$-vector collecting $\boldsymbol{c}_t$ on the first M elements and is otherwise zero. Moreover, $\boldsymbol{B}_t$ refers to an $Mp \times Mp$ companion matrix that stores the time-varying coefficient matrices $\boldsymbol{A}_t = (\boldsymbol{A}_{1t}, \dots, \boldsymbol{A}_{pt})$ on the first M rows.

In the following, we are interested in the vector of equilibrium values measures, for example, the long-run trends of nominal interest rates, inflation, and therefore real interest rates. We follow Cogley et al. (2010) and estimate the Beveridge Nelson trend for each point in time. That is, the long-run equilibrium values are defined as the time-varying unconditional mean of the model:

$$\lim_{h \to \infty} \mathbb{E}_t \left[\boldsymbol{y}_{t+h} \right] \approx \boldsymbol{J} (\boldsymbol{I}_M - \boldsymbol{B}_t)^{-1} \boldsymbol{C}_t.$$

With this measure the equilibrium value of the variables is driven both by changes in the autoregressive coefficients $\boldsymbol{A}_t$ and by instabilities in intercept $\boldsymbol{c}_t$.

3.2 Estimation

To be written

3.3 Interest rate accounting framework

With the estimated trends, we then perform a decomposition, which we call an interest rate accounting framework.[26] The framework uses various equilibrium conditions, and deviations thereof, to identify domestic and international drivers of long-term nominal interest rates. Recall that the long-term trends are estimates of the equilibrium values of the corresponding variables at any given point in time. Therefore, we ignore expectations in the equilibrium relationships when performing the decomposition. Also, all subsequent variables refer to the estimated trends from the TVP-VAR.

According to the Fisher effect, the real interest rate is the nominal interest rate corrected for inflation expectations. Therefore, we decompose the trend estimates of the long-term nominal interest rate (i_t^l) into the long-term real interest rate ($r_t^l \equiv i_t^l - \pi_t$) and inflation ($\pi_t$):

$$i_t^l = r_t^l + \pi_t \quad .$$

In our second decomposition, we note that the term spread is the difference between the long-term and short-term real interest rates. Therefore, we can further decompose the long-term real interest rate into the short-term real interest rate (r_t^s) and the term spread ($s_t \equiv r_t^l - r_t^s$):

$$i_t^l = r_t^s + s_t + \pi_t \quad .$$

In addition to the estimates of trend values for Switzerland, our approach provides us with similar trend estimates for the rest of the world. We therefore follow Cumby and Obstfeld (1984) and examine deviations from classical parity conditions. We decompose the Swiss short-term real interest rate into the world short-term real interest rate ($r_t^{s,w} \equiv i_t^{s,w} - \pi_t^w$) and the interest rate differential ($d_t \equiv r_t^s - r_t^{s,w}$):

$$i_t^l = d_t + r_t^{s,w} + s_t + \pi_t \quad .$$

[26] An additional advantage of the Bayesian framework is that we can not only identify the contributing factors, but also, Bayesian credible intervals to evaluate whether the various factors are statistically significantly different from zero.

Finally, we split the Swiss short-term real interest rate differential into a deviation from uncovered interest parity ($uip_t \equiv r_t - r_t^{s,w} - \Delta q_t$) and the deviation from relative PPP ($ppp_t \equiv \Delta q_t \equiv \Delta e_t - \pi_t + \pi_t^w$), that is the trend growth rate of the real exchange rate:

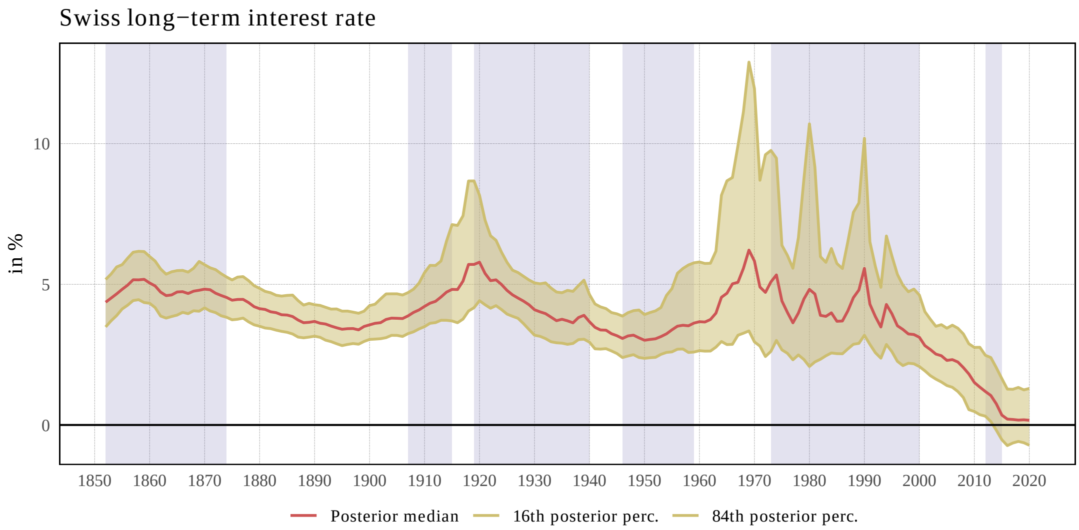
$$i_t^l = uip_t + ppp_t + r_t^{s,w} + s_t + \pi_t \quad .$$

4 Decomposing Swiss nominal long-term interest rates

Our estimate for the trend long-term nominal interest rate is presented in Figure 2. In addition to the median point estimate (red lines) and uncertainty intervals (shaded yellow), the figure also shows monetary regimes as shaded areas.[27]

The trend long-term interest rate declined slightly during the 19th century, in particular during the Classical Gold Standard (1873-1913). Following an increase around the time of the First World War, the trend remained elevated during the interwar period. However, during the Second World War and the first half of the Bretton Woods System, the long-term interest rate declined to a level last observed during the 19th century.

Fig. 2: Nominal long-term interest rate trend



Notes: The figure shows the trend estimate of the Swiss long-term nominal interest rate. The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. Shaded and non-shaded areas show various monetary regimes.

Our estimates display an increase in the trend in the second half of the Bretton Woods system. Thereafter, the estimates show a volatile pattern in the 1970's and 1980's, suggesting that the

[27]These are slightly adapted from Kaufmann (2019) and set out in Table 6 in the Appendix.

demise of Bretton Woods in 1973 and the move to flexible exchange rates, as well as the oil shocks in 1973 and 1979, led to higher macroeconomic volatility. In addition, our estimates of the long-run trend becomes less precise, suggesting that the long-term interest rate trend became harder to predict. Since the late 1990's the volatility receded and the long-term interest rate trend has been moving downward to reach unprecedented low levels in recent years.

From our model we also obtain estimates of trend short-term interest rates and inflation in Switzerland and abroad, as well as the exchange rate. As a result, we can use these variables to understand what drove the evolution of the long rate over the sample period. In the remainder of this section, we do so by decomposing Swiss nominal interest rate trends according to our interest rate accounting framework.

4.1 Inflation and the real rate

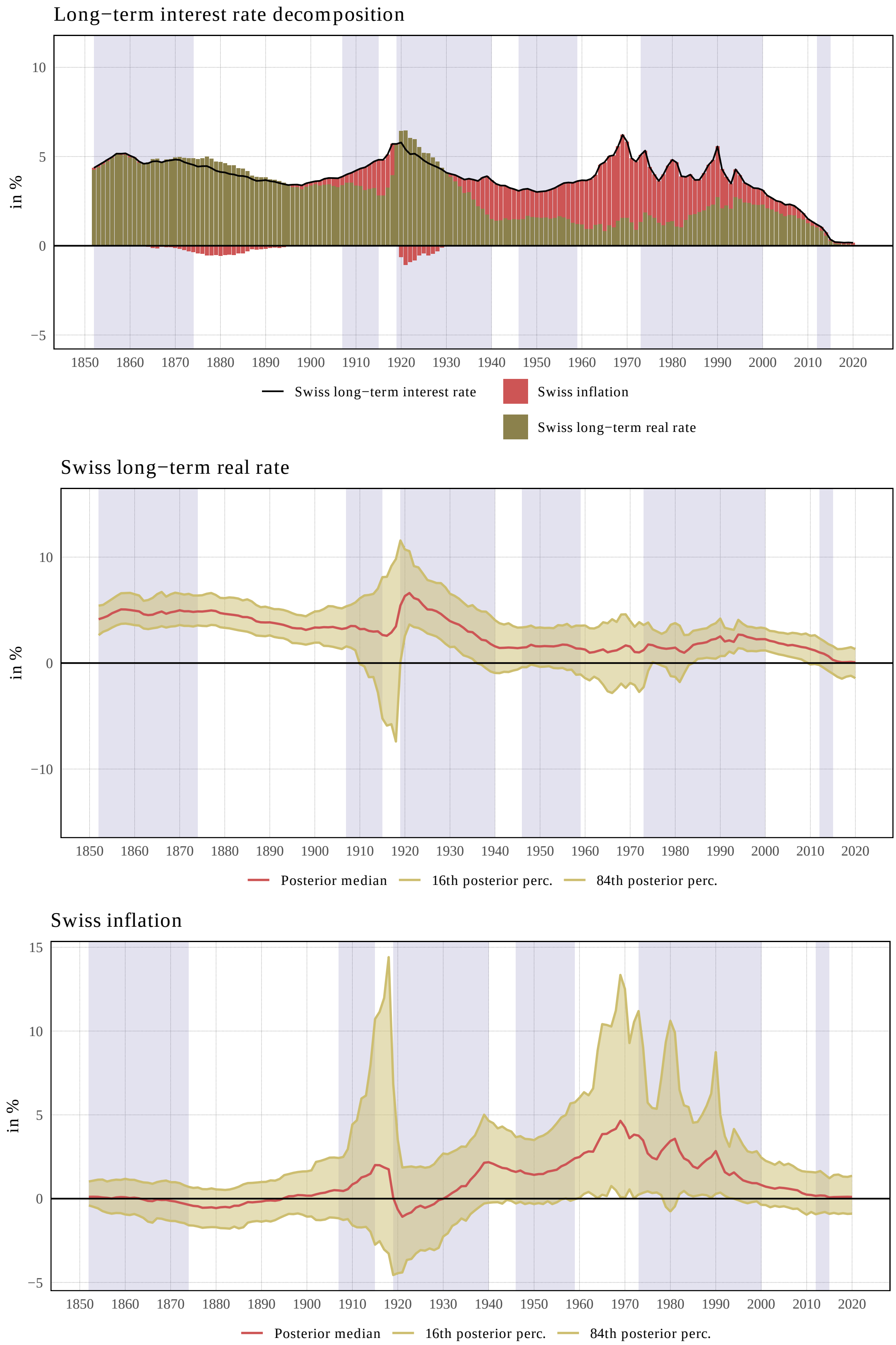
Figure 3 shows a decomposition of the long-term interest rate trend into the real interest rate and inflation (first panel). The second and third panels show the components along with uncertainty intervals.

The inflation trend was steady during the 19$^{\text{th}}$ and early 20$^{\text{th}}$ centuries, as the metallic monetary regimes in place resulted in inflation that was generally close to zero. The result is that the real and nominal rates are almost identical for much of the period.

In the immediate aftermath of the First World War, rates rose as the SNB aimed to return to the Gold Exchange Standard. However, from the early 1920's, nominal rates began a gradual but continuous decline, a trend which continued until the 1960s. Initially, falling inflation expectations after the First World War pushed up real interest rates. However, persistently positive inflation expectations emerged during the Great Depression, after Switzerland abandoned the peg to gold in 1936, and during the Second World War. Combined with the ongoing gradual decline in trend nominal rates, increasing inflation expectations pushed down real rates, which reached a trough close to zero during the Second World War.

Although real interest rates recovered somewhat during the early Bretton Woods period, they never again reached the levels observed in the 19$^{\text{th}}$ century. Instead, inflation expectations became an important driving force of the nominal interest rate trend. While they drifted down in the early Bretton Woods period, like in most other advanced economies, they rose markedly in the 1960's and 1970's. Only when inflation expectations were brought under control in the mid-1990's did inflation stop driving nominal interest rates. This may reflect deep changes in the structure of the world economy, with the end of the Bretton Woods system leading central

Fig. 3: Real interest rate and inflation trends



Notes: The first panel shows the Swiss long-term nominal interest rate trend decomposed according to the interest rate accounting framework. The second and third panels show the trend estimates of the components. The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. Shaded and non-shaded areas show various monetary regimes.

banks to face more uncertainty (at least initially) in gauging the impact of their policies.

From the early 1980's, inflation expectations began to decline and since the mid-1990's the Swiss economy has returned to a situation of very low trend inflation expectations. However, during the period up to the mid-1990s, this decline was partly offset by an increase in the long-term real interest rate (a similar pattern was observed in other countries). Thereafter, this increase reversed, and real rates declined continuously, reaching a value of 0% after the removal of the minimum exchange rate at CHF/EUR 1.20 in January 2015.

Before proceeding to our second decomposition, we note that our estimates of the trend real interest rate are more volatile than those found in other studies. This is a consequence of our flexible model that allows for rapid changes in the real interest rate trend: we do not impose smooth changes in the real interest rate trend, as is done by Del Negro et al. (2019), for example.[28] However, our estimates are consistent with the cycle of rising real rates in the 1980s, followed by a downward trend, that has been documented in several countries. For instance Del Negro et al. (2019) document such a pattern for the United States and other advanced economies. The magnitudes are however different than for Switzerland. Specifically, Del Negro et al. (2019) estimate that the natural real interest rate in 1980 was at a level above the pre-1920 one (also within the band of confidence), while our estimates indicate that it remained lower than during the early 20$^{\text{th}}$ century.

4.2 The term spread

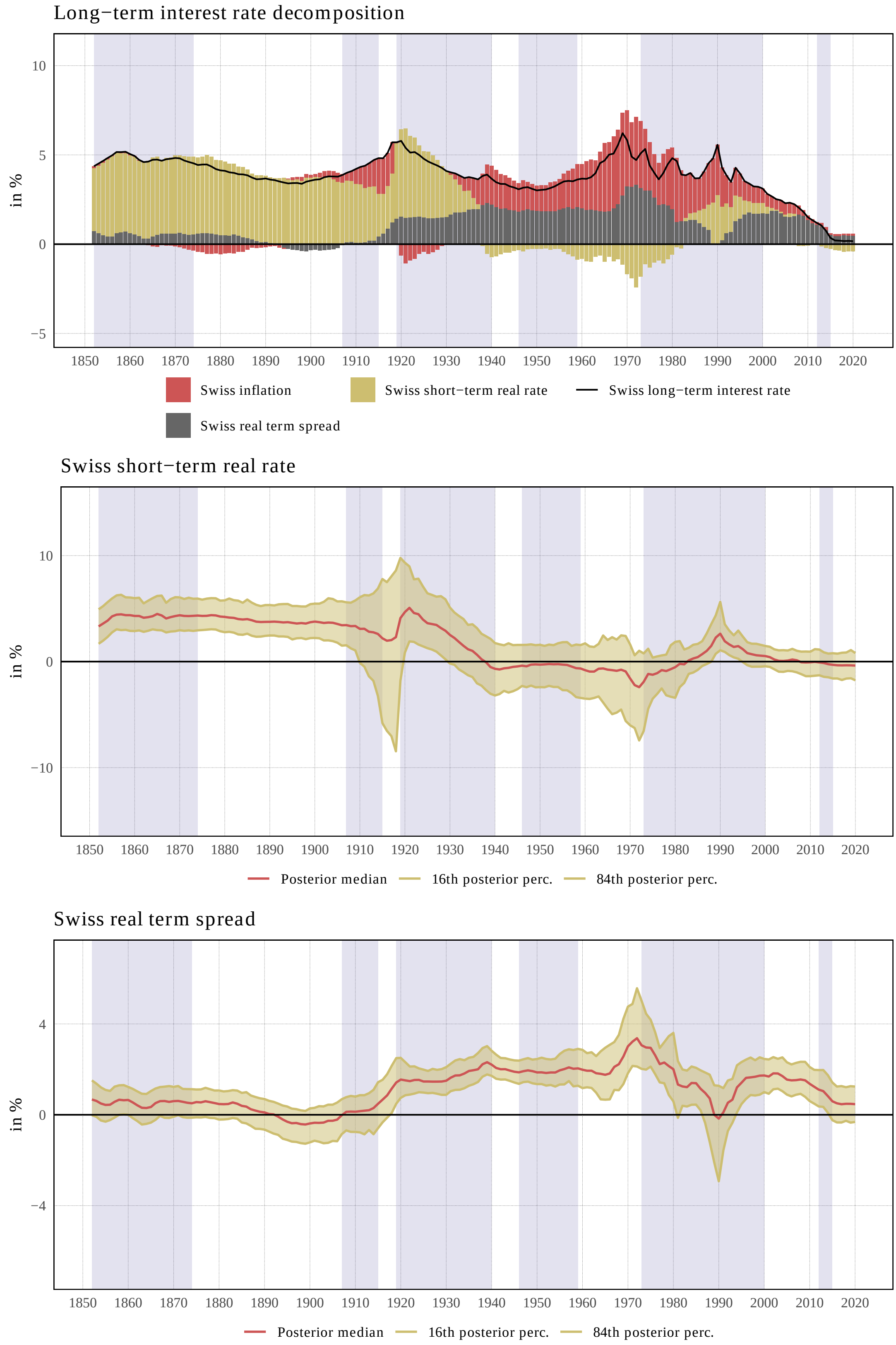
Figure 4 shows a decomposition of the long-term interest rate trend into the real short-term interest rate, the term spread, and inflation (first panel). The second and third panels show the individual components along with uncertainty bands.

Throughout the 19$^{\text{th}}$ century, the term spread was close to and not statistically significantly different from, zero. Therefore, the real long-term interest rate trend largely coincided with the real short-term interest rate trend. The trend short-term interest rate was steady, but quite elevated at close to 5%, until the early 20$^{\text{th}}$ century. The predictability of interest rates and absence of inflation risk perhaps explains the fact that there was little or no spread between real short- and long-term rates.

The term spread only emerged consistently in the wake of the First World War. This may be due to an increase in inflation risk perceptions following the leaving of the Gold Standard

[28] There is no particular theoretical reason that the natural rate of interest should evolve gradually, in particular, during periods with rapid structural changes.

Fig. 4: Term spread trends



Notes: The first panel shows the Swiss long-term nominal interest rate trend decomposed according to the interest rate accounting framework. The second and third panels show the trend estimates of the components. The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. Shaded and non-shaded areas show various monetary regimes.

during the war. Indeed, at least by the standards of the 19th century, there was a significant temporary peak in inflation when Switzerland abandoned gold during the war effort. These risk perceptions appear to have been confirmed through higher inflation expectations once Switzerland finally left gold in 1936 and, particularly, following the start of the Second World War.

The term spread stabilized at a higher level in the aftermath of the Second World War. Meanwhile, the short-term real rate trend turned negative (although not significantly so) in the wake of the Great Depression. The short-term real rate trend remained close to zero until the late 1980's.

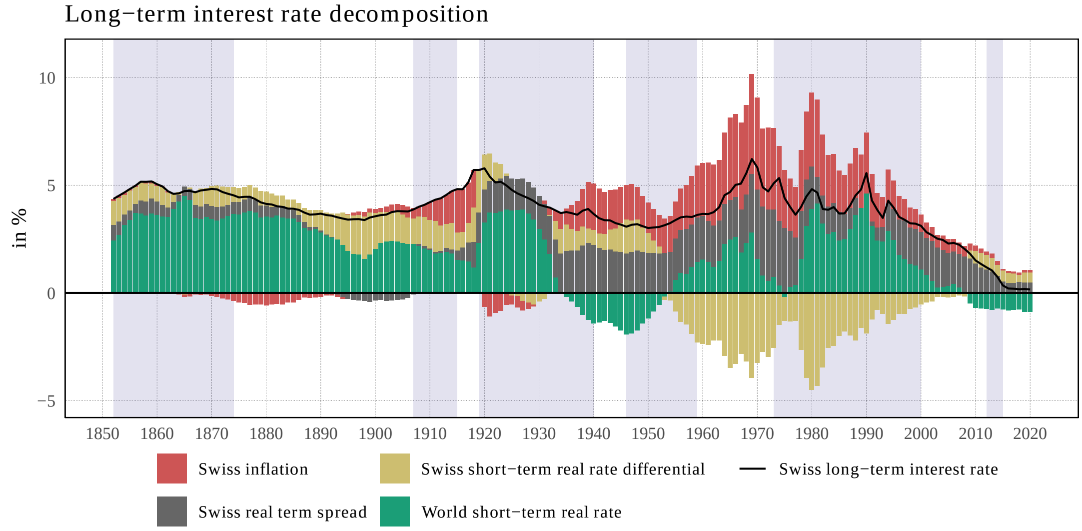
Interestingly, the short-term interest rate increased, and the term spread fell around the 1990's when the SNB implemented a rather restrictive monetary policy which curbed inflationary pressures (see Peytrignet, 2007). Thereafter, the short-term interest rate trend fell back to 0% and the term spread rose when the new monetary policy strategy was introduced in late 1999. Around 2015, when the SNB removed an exchange rate floor vis-à-vis the euro and the European Central Bank (ECB) announced a large-scale asset purchase program, the term spread again declined to around 0%. The recent drop in the term spread could therefore reflect an environment of very low inflation, or even mild deflation, which accompanied the end of the exchange rate floor policy.

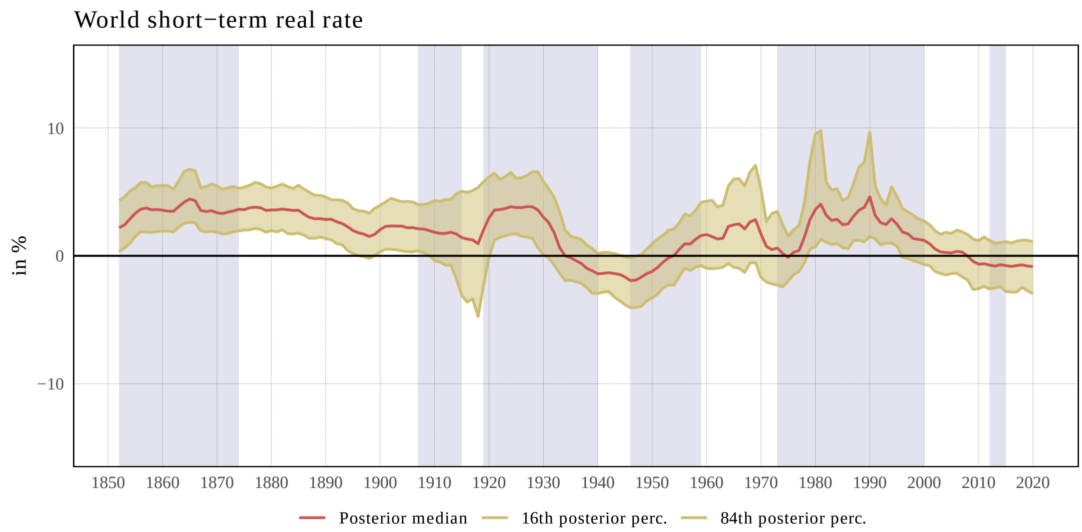
4.3 Foreign interest rate differential

Figure 6 shows a decomposition of the long-term interest rate trend into the short-term interest rate differential vis-à-vis the rest of the world, the world short-term interest rate, the term spread, and inflation (first panel). The second and third panels show the components along with uncertainty bands.

Before proceeding, we note that the pattern for world short-term real interest rates, shown in the bottom panel of Figure 6, is similar to those documented by Del Negro et al. (2019). The values fluctuated moderately around a steady average until the Great Depression, before falling rapidly until the Second World War. The drop was short-lived, and real interest rates subsequently increased until the 1980's (with a temporary drop when the Bretton Woods System disintegrated) reaching levels moderately above the ones prevailing in the early 20th century. Starting in the early 1990's, real interest rates have been on a downward path that brought them to values that had only been seen at the time of the Second World War and briefly during the mid-1970's.

Fig. 5: World interest rate trends





Notes: The first panel shows the Swiss long-term nominal interest rate trend decomposed according to the interest rate accounting framework. The second and third panels show the trend estimates of the components. The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. Shaded and non-shaded areas show various monetary regimes.

Turning to the decomposition, the movements of the Swiss real interest rate before the Second World War were primarily driven by rates abroad. This is unsurprising, since exchange rates were fixed via metallic monetary regimes before the First World War.[29] In addition, there were few capital controls in place with the result that capital flowed freely across international borders (Obstfeld and Taylor, 2005, Bordo and Meissner, 2015). Nonetheless, Swiss interest rates were higher than those abroad, suggesting that investors viewed Switzerland as an emerging economy and demanded a premium to hold Swiss franc assets.

In contrast, the period from the Great Depression through to the middle of the Bretton Woods regime was characterized by significant capital controls (see, e.g., Eichengreen, 2008). At the same time, the importance of the world rate as a driver of Swiss rates declined. However, the Swiss real rate differential turned negative in the 1950's and remained so until the 1990's (with the exception of a short period in the late 1970's). This is consistent with the Swiss interest rate island documented by Kugler and Weder di Mauro (2002, 2004, 2005) which we will discuss further in the next decomposition.

A gradual decline in world interest rates contributed to the fall in Swiss interest rates observed since the 1980's. However, this was partly offset by an increase in the Swiss interest rate differential. As a result, real interest rates abroad became more similar to real interest rates in Switzerland. This period coincides with the adoption of inflation targeting in many economies. The associated reduction in inflation as an increasing number of central banks began to focus on price stability may explain the increasing similarity of interest rates in Switzerland and abroad.

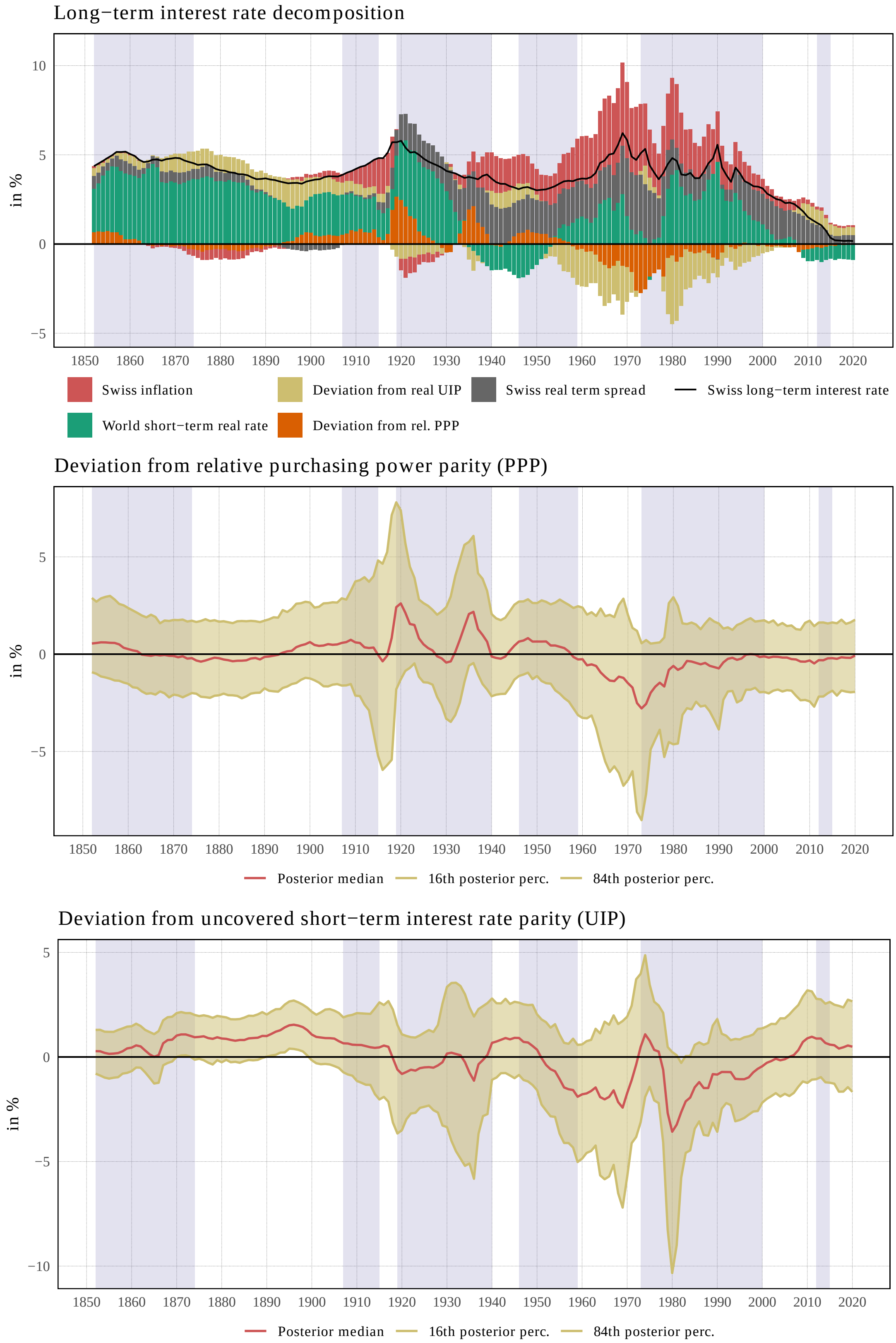
4.4 Deviations from UIP and PPP

Figure 6 shows a decomposition of the long-term interest rate trend into deviations from UIP, relative PPP (growth of the real exchange rate), world short-term interest rates, the term spread, and inflation (first panel). The second and third panels show the components along with uncertainty bands.

The deviations from relative purchasing power parity are virtually zero throughout most of the period until the breakdown of the Bretton Woods system. The World Wars provide an exception, but these periods are subject to marked uncertainty (see the point estimates and uncertainty intervals in the second panel). This is in line with the high correlation between Swiss and foreign inflation, as well as the relatively stable nominal exchange rate. The end of Bretton Woods marked the lifting of capital controls. The Swiss exchange rate appreciated

[29] Specifically, the Bimetallic Regime (1852-1873) and the Classical Gold Standard (1874-1914). For a history of monetary regimes in Switzerland, see Baltensperger and Kugler (2017) and Kaufmann (2019).

Fig. 6: Deviations from trend UIP and relative PPP



Notes: The first panel shows the Swiss long-term nominal interest rate trend decomposed according to the interest rate accounting framework. The second and third panels show the trend estimates of the components. The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. Shaded and non-shaded areas show various monetary regimes.

sharply and deviations from relative PPP turned negative during the 1970's (although this period is again measured with uncertainty). The deviations gradually reduced in size, and since the mid-1990's has been close to zero.

The deviation from uncovered interest parity was steady and marginally positive throughout the period prior to the First World War, reflecting the fact that Switzerland was closer to an emerging economy during this period. The pattern abruptly shifts in the aftermath of the Second World War: the deviation became negative, confirming the emergence of the Swiss interest rate island during this period. However, the estimates are associated with substantial uncertainty. The deviation was most strongly negative during the early 1970's and early 1980's. Finally, in the recent period, the deviation from UIP becomes much smaller, consistent with the virtual disappearance of the Swiss interest rate island.

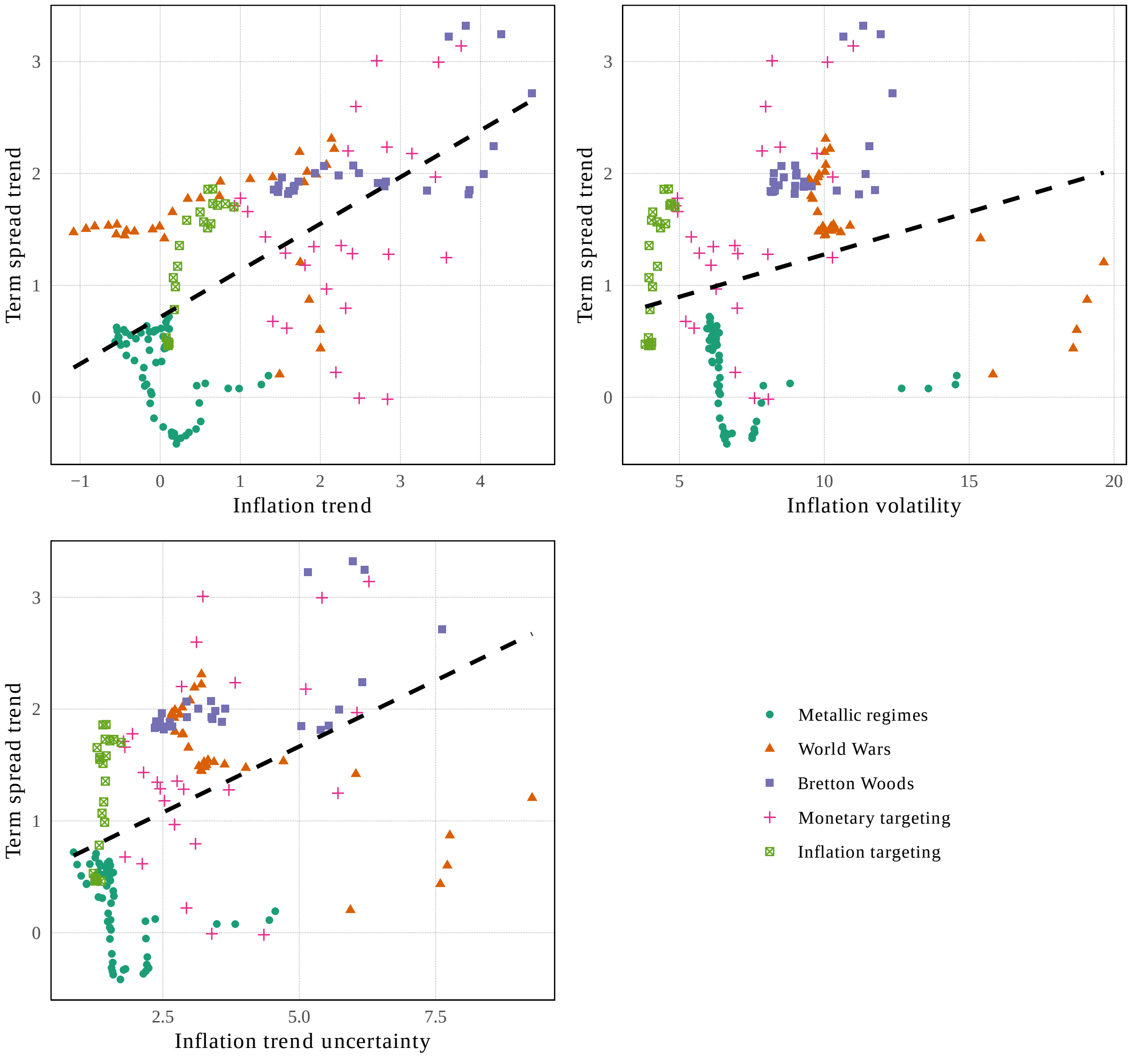
4.5 Inflation uncertainty and spreads

The previous sections suggested that the trends in the term spread, the interest rate differential, and the deviation from UIP emerged during periods with (relatively) high inflation uncertainty. This section provides more formal evidence. We measure inflation uncertainty in three ways. First, a higher level of trend inflation is often associated with a higher degree of inflation uncertainty. Second, our TVP-VAR allows us to estimate a time-varying measure of the unconditional volatility of inflation. Third, the interquartile range of the posterior distribution of the long-run trend is a statistical measure of uncertainty about the level of trend inflation.

Figure 7 shows scatter plots with linear regression lines of the term spread trend against the three different measures of inflation uncertainty. In all cases, there is a positive relationship. The scatter plots distinguish between various monetary regimes. The metallic regimes of the 19$^{\text{th}}$ century were associated with low inflation uncertainty and a small term spread. During the World War period, Bretton Woods, and monetary targeting, the term spread and inflation uncertainty were generally higher. Inflation targeting was associated with a decline in inflation uncertainty comparable to the metallic regimes with a somewhat smaller decline in the term spread trend.

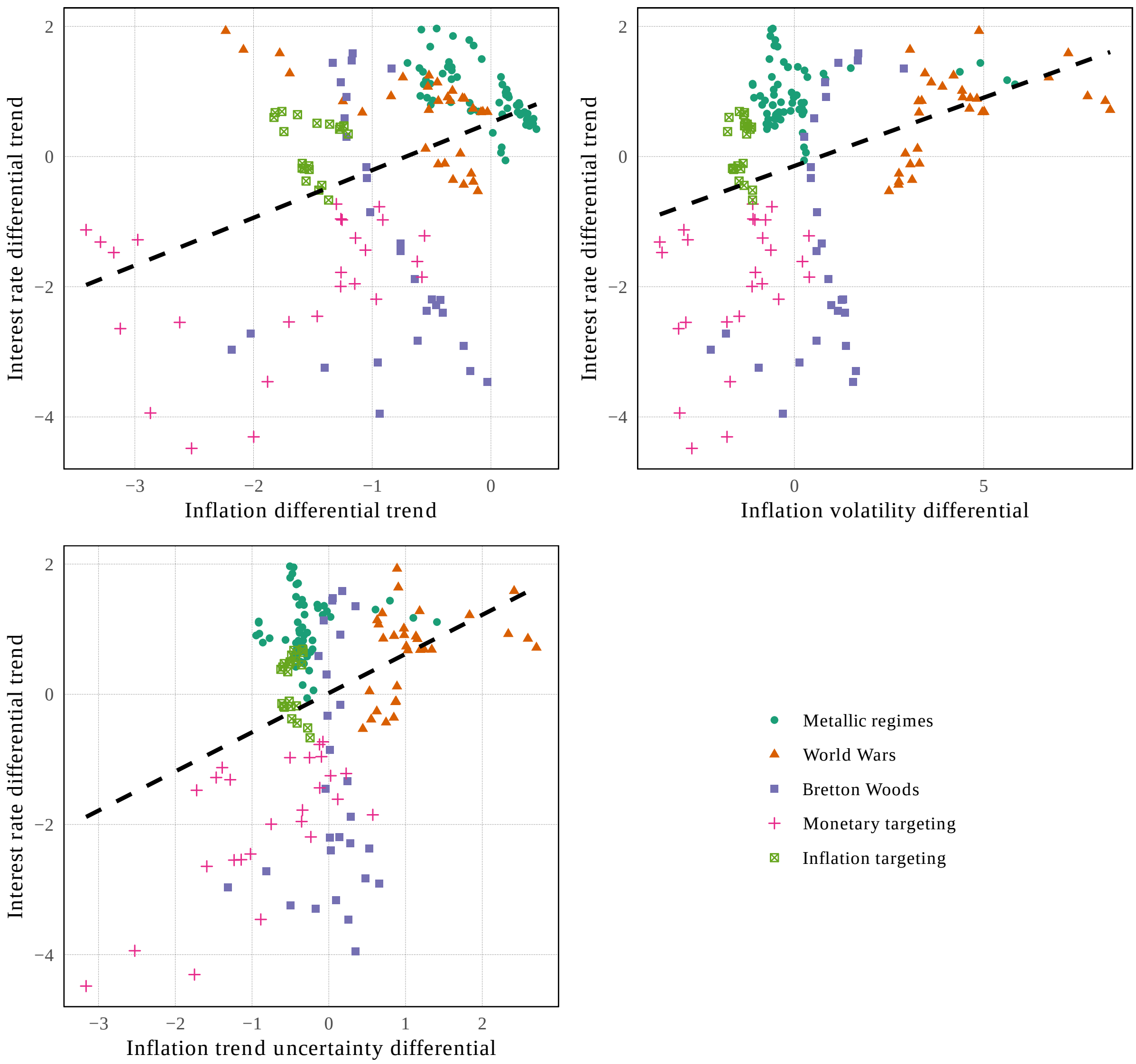
Do differences in inflation uncertainty in Switzerland and abroad explain the interest rate differential? To answer this question, we provide scatter plots of the interest rate differential against three measures of relative inflation uncertainty: the difference in trend inflation, the difference in the unconditional volatility of inflation, and the difference in the interquartile range of the posterior distribution of trend inflation.

Fig. 7: Term spread trend and inflation risk



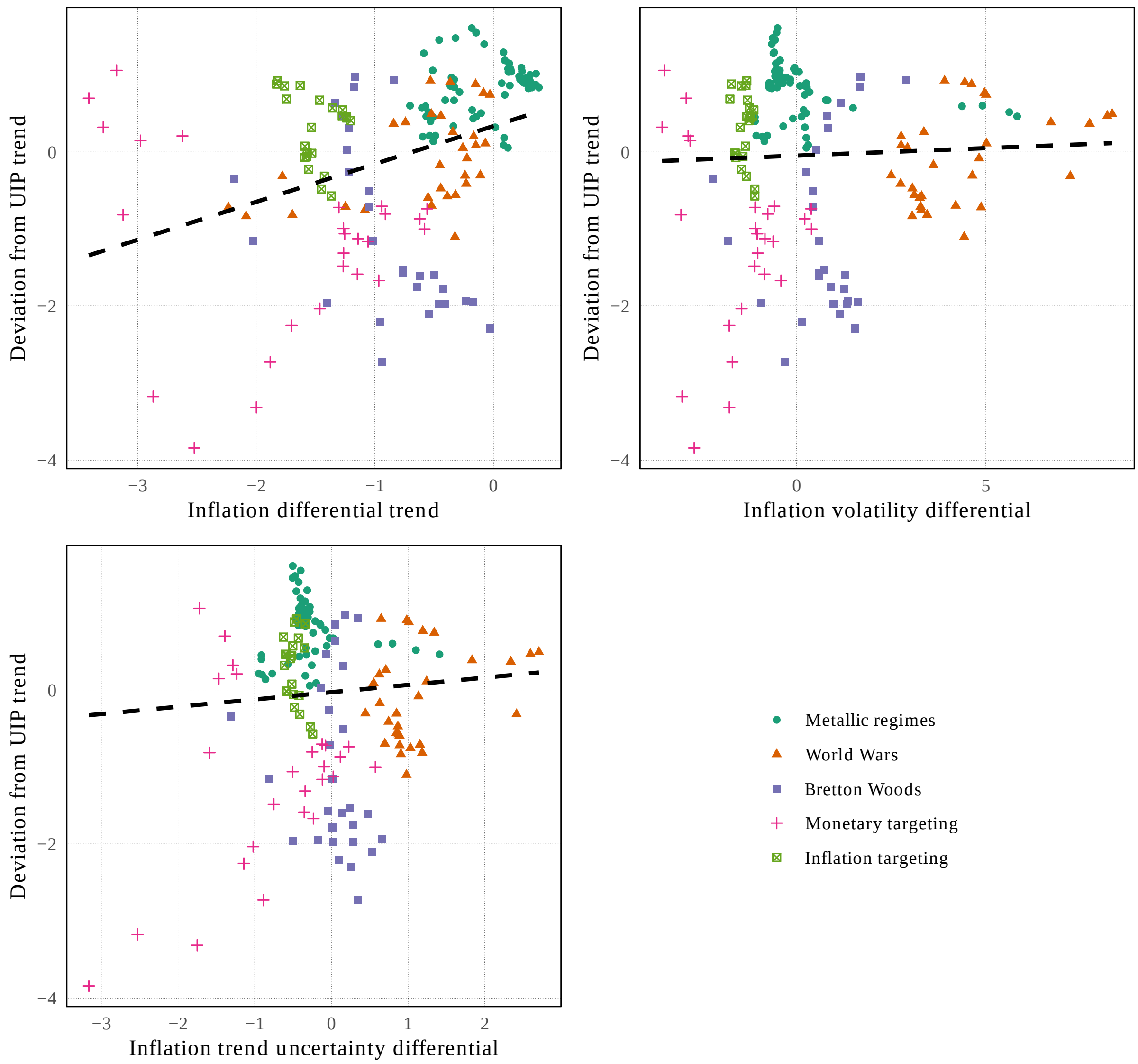
Notes: Scatter plots of various inflation uncertainty measures against the term spread trend. Dashed line gives a linear trend. The uncertainty measures are defined as follows. The inflation trend is measured by the posterior median of the inflation trend. Inflation volatility is the posterior median of the unconditional standard deviation of inflation implied by the TVP-VAR. Inflation trend uncertainty is the interquartile range of the posterior distribution of trend inflation in the TVP-VAR.

Fig. 8: Interest rate differential and inflation risk



Notes: Scatter plots of various relative inflation uncertainty measures against the interest rate differential trend. Dashed line gives a linear trend. The relative uncertainty measures are computed as the difference between Switzerland and abroad. A positive value therefore implies higher uncertainty abroad. They are defined as follows. The inflation trends are measured by the posterior median of the inflation trends. Inflation volatilities are the posterior medians of the unconditional standard deviations of inflation implied by the TVP-VAR. The inflation trend uncertainty in Switzerland and abroad are the interquartile ranges of the posterior distribution of trend inflation in the TVP-VAR.

Fig. 9: Deviation from UIP and inflation risk



Notes: Scatter plots of various relative inflation uncertainty measures against the deviation from UIP. Dashed line gives a linear trend. The relative uncertainty measures are computed as the difference between Switzerland and abroad. A positive value therefore implies higher uncertainty abroad. They are defined as follows. The inflation trends are measured by the posterior median of the inflation trends. Inflation volatilities are the posterior medians of the unconditional standard deviations of inflation implied by the TVP-VAR. The inflation trend uncertainty in Switzerland and abroad are the interquartile ranges of the posterior distribution of trend inflation in the TVP-VAR.

If inflation uncertainty is higher abroad than in Switzerland, these measures of relative inflation uncertainty are negative. In addition, if higher inflation uncertainty is associated with higher real interest rates we expect a positive relationship between relative inflation uncertainty and the interest rate differential. Figure 8 shows that this is indeed the case. The interest rate differential is particularly negative during the Bretton Woods period and monetary targeting. Meanwhile, relative inflation uncertainty and the interest rate differential are lower during inflation targeting and the metallic monetary regimes.

The relationship is less pronounced when we look at scatter plots of the deviation from UIP and inflation uncertainty (Figure 9). Recall that the difference between the deviation from UIP and the interest rate differential is the real exchange rate growth trend. This suggests that part of the positive correlation we observe for the interest rate differential is driven by a correlation of inflation uncertainty with the real exchange rate trend.

Table 1 shows linear regressions of the various spreads on various inflation uncertainty measures, for three reasons. First, we can base inference on HAC-robust standard errors that account for the highly persistent nature of the data. Second, the level of inflation may be related to uncertainty itself. The regressions allow us to examine whether uncertainty has a relationship after controlling for the level of trend inflation. Third, we can control for various monetary regimes to examine which period drives the correlation between uncertainty and the spreads most.

Columns (1) and (2) show the results for the term spread regressed on the interquartile range and the unconditional volatility, respectively. Each specification controls for the trend inflation level. In addition, we include monetary regime dummies and interactions with trend inflation and inflation uncertainty (metallic currency regime being the base period). The coefficients on trend inflation and uncertainty are not statistically significant. This suggests that the relationship is period-specific. Indeed, the term spread is significantly higher in the World War period than in the base period. Otherwise, most coefficients are not significant at conventional levels. When looking at the specification using the unconditional volatility as a measure of inflation uncertainty, there are two exceptions. There is a significant interaction with the monetary targeting dummy. In addition, the term spread is significantly higher during inflation targeting relative to the metallic currency period.

Columns (3) and (4) show the results for the interest rate differential regressed on the inflation differential and measures of relative uncertainty. The regime dummies show that the interest rate differential was lower during Bretton Woods and monetary targeting. In addition, we

Tab. 1: Spreads, uncertainty, and trend inflation

	Term spread		Interest rate differential		Deviation from UIP	
	IQR	UCV	IQR	UCV	IQR	UCV
	(1)	(2)	(3)	(4)	(5)	(6)
Trend inflation (diff.)	−0.38	−0.63	−0.88	−0.95	0.33	0.26
	(0.37)	(0.49)	(0.63)	(0.61)	(0.62)	(0.63)
Uncertainty (diff.)	−0.02	0.06	−0.02	−0.04	−0.004	−0.04
	(0.23)	(0.11)	(0.43)	(0.11)	(0.42)	(0.12)
World Wars	2.10***	3.22***	−0.87	−1.30	−1.03**	−1.34***
	(0.61)	(1.00)	(1.11)	(0.94)	(0.45)	(0.43)
Bretton Woods	1.08*	1.14	−5.13***	−7.49***	−3.73***	−5.40***
	(0.65)	(1.73)	(0.86)	(0.66)	(0.63)	(0.36)
Monetary targeting	0.44	−2.42	−3.06***	−2.67**	−3.53***	−3.34***
	(0.96)	(1.82)	(0.34)	(1.08)	(0.32)	(0.78)
Inflation targeting	0.15	3.19**	−1.47	−1.05	−2.04	−1.52
	(1.67)	(1.55)	(1.79)	(2.84)	(1.66)	(2.55)
Inflation (diff.) x World Wars	0.51	0.82*	0.23	0.30	0.22	0.26
	(0.39)	(0.49)	(0.68)	(0.65)	(0.63)	(0.65)
Inflation (diff.) x Bretton Woods	0.09	0.79	−2.17	−3.25***	−2.29*	−3.20***
	(0.44)	(0.51)	(1.74)	(0.86)	(1.18)	(0.66)
Inflation (diff.) x Monetary targeting	0.34	−2.21*	0.03	0.44	−2.08***	−2.16**
	(1.05)	(1.19)	(0.65)	(1.32)	(0.65)	(1.10)
Inflation (diff.) x Inflation targeting	2.07*	3.06*	0.60	0.55	−1.01	−0.97
	(1.18)	(1.70)	(1.50)	(2.26)	(1.43)	(2.21)
Uncertainty (diff.) x World Wars	−0.21	−0.20*	0.26	0.20	0.39	0.21*
	(0.25)	(0.12)	(0.59)	(0.18)	(0.44)	(0.12)
Uncertainty (diff.) x Bretton Woods	0.40	0.01	3.31**	2.13***	1.35	1.24***
	(0.25)	(0.20)	(1.51)	(0.37)	(1.13)	(0.16)
Uncertainty (diff.) x Monetary targeting	0.28	1.39**	1.57***	0.74	1.91***	1.34
	(0.52)	(0.55)	(0.45)	(0.69)	(0.43)	(1.04)
Uncertainty (diff.) x Inflation targeting	0.10	−0.71	−0.70	0.24	−0.97	0.10
	(1.45)	(0.46)	(1.58)	(1.27)	(1.30)	(1.41)
Constant	0.29	−0.15	0.87***	0.87***	0.84***	0.83***
	(0.59)	(0.92)	(0.18)	(0.21)	(0.18)	(0.22)
N	169	169	169	169	169	169
R^2	0.77	0.83	0.77	0.85	0.76	0.74
Adjusted R^2	0.75	0.81	0.75	0.84	0.74	0.72

Notes: OLS regressions of the term spread, interest rate differential, and deviation from UIP trends on trend inflation (differential), two different volatility measures, and monetary regime dummies. Inflation volatility is either measured by the interquartile range of the trend inflation estimate (IQR) or the unconditional standard deviation of inflation (UCV). For the interest rate differential and deviation from UIP, we use the trend inflation and volatility differential vis-à-vis the rest-of-the-world. Inference based on HAC-robust standard errors. */**/*** denotes statistical significance at the 10%/5%/1% level.

observe a positive correlation between the interest rate differential and the volatility measures during Bretton Woods and monetary targeting (for three out of four coefficients). The correlation vanishes, however, under inflation targeting.

The regressions using the deviation from UIP are broadly in line with the previous results (columns 5 and 6). One difference is that the deviation from UIP was significantly lower during the World War period. In addition, the relationship between relative inflation uncertainty and the deviation from UIP is significant only for two out of four coefficients.

5 Conclusion

The low nominal and real interest rate environment in recent years has created unique challenges for policymakers. Researchers attempting to understand the causes of this have focused on demographic change, the productivity slowdown, the convenience yield, and an international savings glut. We study domestic and international drivers of long-term interest rates using newly compiled financial market data for Switzerland starting in 1852. In particular, we consider the role of the monetary regime and inflation risk in a comparative international context.

In doing so, we make three main contributions. First, to obtain a long time series, we hand-collected a novel dataset of long-term interest rates and exchange rates for Switzerland from archival sources during the 19$^{\text{th}}$ century. These data are linked with more recent series for Switzerland, enabling us to examine the entire Swiss franc history. We also constructed trade-weighted international data for the rest of the world.

Second, together with data on short-term rates and inflation, we then use the time-varying parameter VAR model proposed by Huber et al. (2019) to extract trends in the variables. In contrast to models employed elsewhere in the literature, this model allows for constant model coefficients, gradual changes, and a few structural breaks. Thus, we obtain estimates of the trend real interest that are more volatile than in other studies. We believe that our approach is well-suited to our long sample period, which includes, for instance, economic crises, wars, and rapid changes in monetary regime. Indeed, our results suggest that the smooth estimates of real interest rate trends found previously in the literature are a result of tightly restricted model parameters that rule out abrupt shifts.

The third contribution of the paper is to employ what we term an 'interest rate accounting' framework to decompose the long-term nominal interest rate trend into various components.

In particular, using this framework we are able to understand how the nominal long-term rate trend is affected by trend inflation, the term spread, the world real interest rate, as well as deviations from uncovered interest parity (UIP) and relative purchasing power parity (PPP).

Our main findings are as follows.

First, the Swiss real long-term rate has been low since the interwar period, with the result that the decline in long-term nominal rates since the 1970's arises from a reduction in trend inflation.

Second, since the real short term rate has been low since the Great Depression, Switzerland has experienced a positive term spread throughout much of the 20^{th} century. Because the term spread is positively related to the level and volatility of the Swiss inflation trend, it appears that it includes an inflation risk premium. More recently, this inflation risk premium disappeared as inflation declined and turned mildly deflationary following the Global Financial Crisis.

Third, although Swiss real rates were high compared to the rest of the world for much of the early sample period, during the Bretton Woods System this relationship reversed and investors were willing to pay a premium to hold Swiss franc assets. The demise of the 'Swiss interest rate island' since the early 1990's coincides with a reduction in the differential between relatively higher inflation abroad and low Swiss inflation.

Fourth, by decomposing the interest rate differential into deviations from UIP and relative PPP we find that the Swiss interest rate island was caused by a combination of a negative deviation from UIP and a real trend appreciation of the Swiss franc. The interest rate differential and the deviation from UIP are positively associated with periods when Swiss inflation uncertainty is low compared to abroad, suggesting that the Swiss interest rate island was at least partly caused by relatively low inflation risk in Switzerland.

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Appendix

A 19th century long-term interest rate data

This Appendix provides a simulation exercise on various assumptions on the repayment terms of bonds. In addition, it gives a comparison between existing and new data, as well as, Confederation and cantonal bond yields.

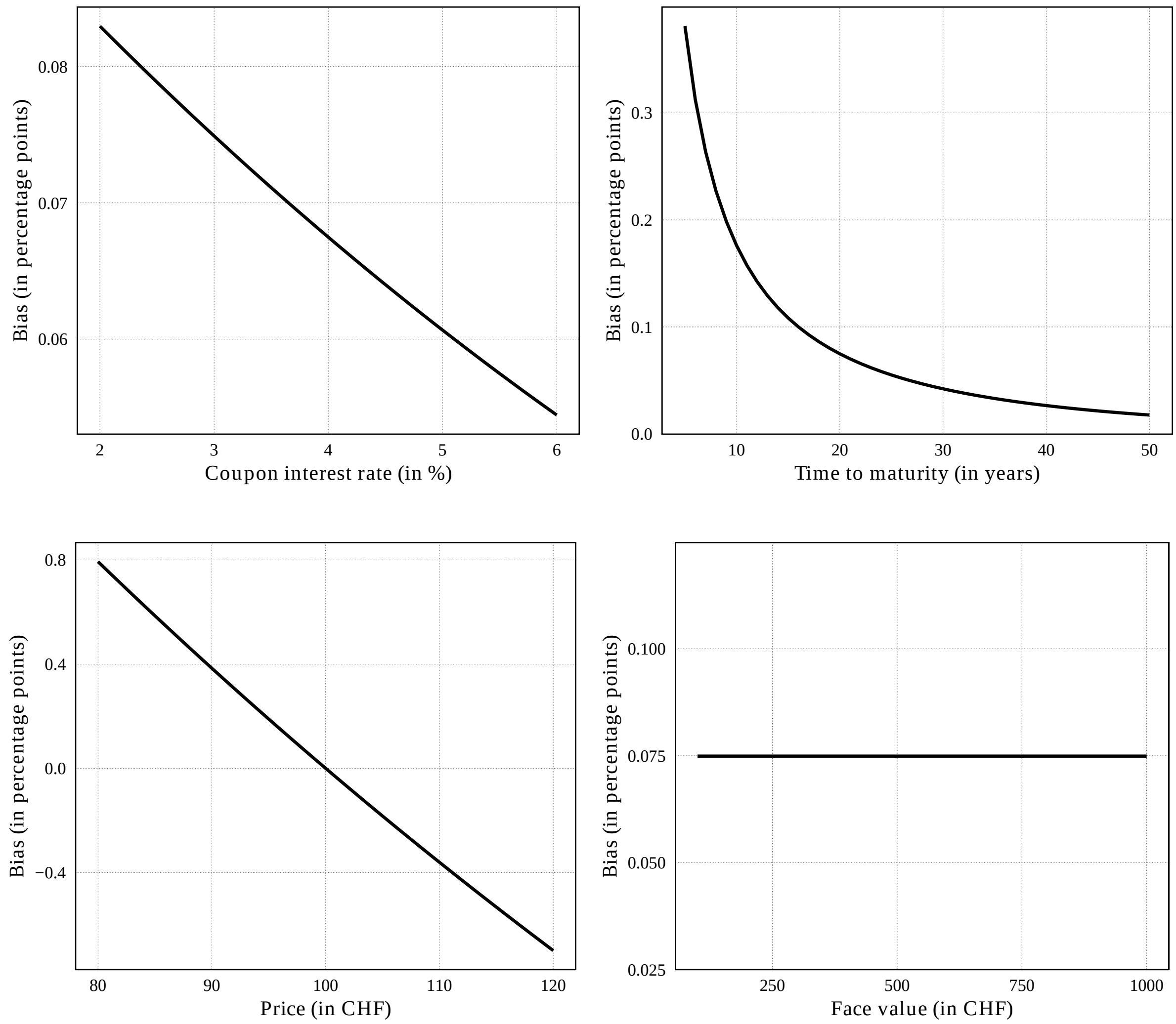
A.1 Simulation exercise

If the maturity date of a bond is unknown, we assume that the bond is of very long maturity. If m tends to infinity, the yield-to-maturity equals the current yield. Although assuming that the bonds are of very long maturity is a sensible assumption for 19th century data, we assess in a simulation exercise how this assumption affects the data.

We compare the difference of the bond yield calculated using the current yield (Eq. 2) and yield-to-maturity (Eq. 1) formulas, respectively (see Figure 10). In the baseline, we assume that the true bond has a coupon interest rate of 3%, a time to maturity of 20 years, a price of CHF 98, and a face value of CHF 100. We then vary each of these characteristics for a range of sensible values encountered in the historical data. The figure then shows the bias (true yield-to-maturity minus current yield) for each of these different parameter values.

Using the current yield formula tends to underestimate the true bond yield for most parameter values (the bias is positive). The bias falls if the coupon interest rate increases. The intuition is that the current yield ignores the face value repayment. But the face value payment matters relatively less if the coupon interest rate is higher. For a sensible range of the coupon interest rate (2% to 6%) the difference is very small (smaller than 0.1 percentage points). As we would expect, the bias is more severe if the time to maturity is small. The reason is that the current yield formula discounts the repayment of the face value of the bond too much and therefore we underestimate the yield of the bond for a given price. For long-term bonds the face value is also strongly discounted using the exact formula so that the bias is less severe. Importantly, the bias is below 0.1 percentage points for time to maturities of 15 years and longer. When varying the price of the bond, however, the bias switches sign. For a low price, we underestimate the bond yield, while for a high price we overestimate the bond yield. This is a direct consequence of the fact that the price and yield to maturity are inversely related and implies that we underestimate the variance of the bond yields. As a consequence, ignoring the time to maturity results in a long-term interest rate series that is too smooth. Finally, varying the face value of the bond has no impact because it changes proportionally with the coupon interest payments.

Fig. 10: Bias when using current yield formula

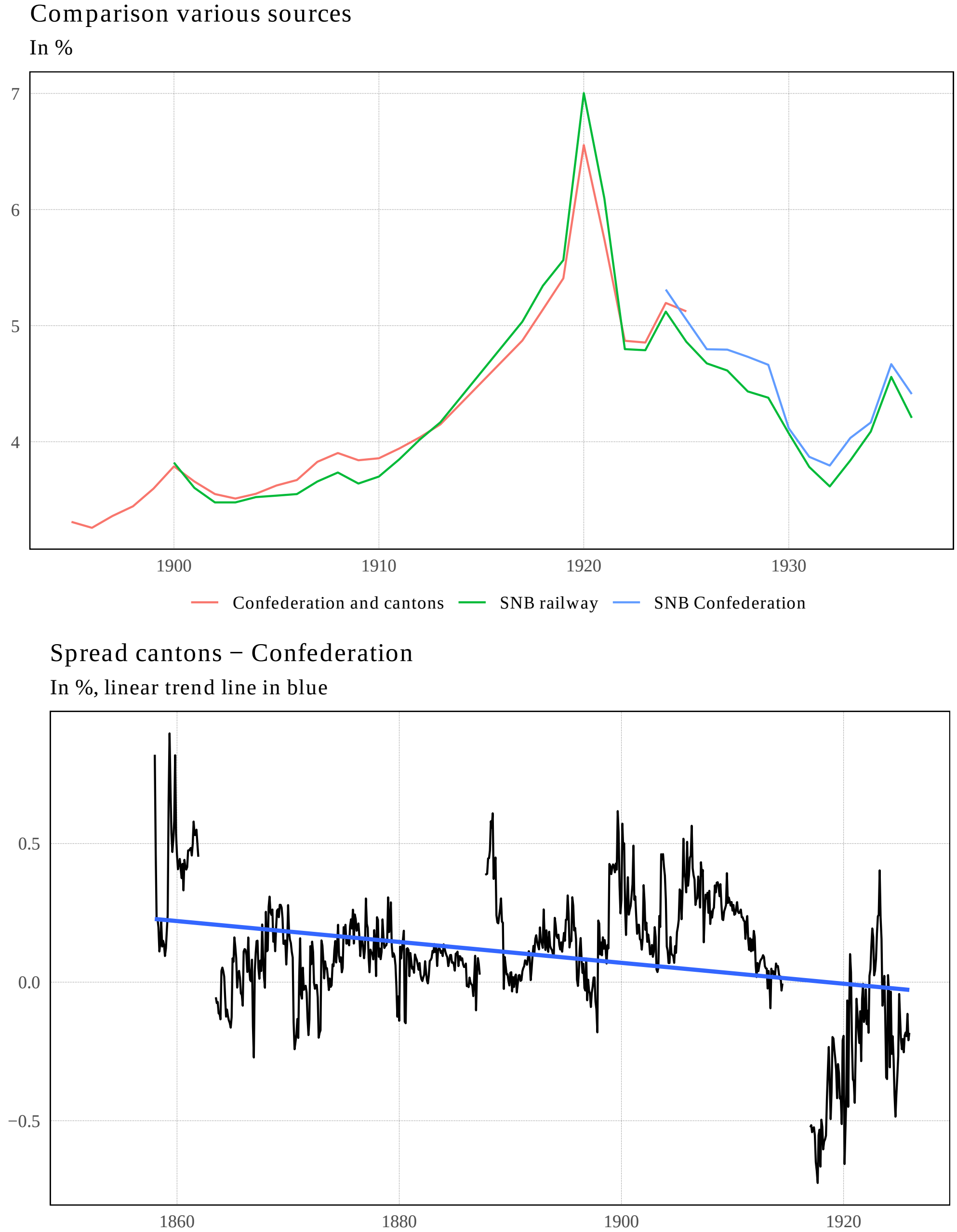


Notes: The figure shows the bias when using the current yield instead of the yield-to-maturity formulas. We assume that the true bond has a coupon interest rate of 3%, a time to maturity of 20 years, a price of CHF 98, and a face value of CHF 100. We then vary each of these characteristics for a range of sensible values encountered in the historical data. The figures then show the bias (true yield-to-maturity minus current yield) for each of these different parameter values.

A.2 Additional results

The first panel of Figure 11 shows a comparison between our new series (Confederation and cantons), existing data on railway bonds (SNB railway) and Confederation bonds (SNB Confederation). Our series is quite similar to the existing data. It closely matches the level of the SNB's Confederation bond yields in 1924-1925. Therefore, we link the two. It also shows a similar pattern as the SNB's railway bond yields. It is somewhat higher in the run-up and lower during the First World War. Because the new series is based on more data, we prefer our new series over the existing railway bond data.

Fig. 11: Railway, Confederation, and cantonal bond yields



The second panel of Figure 11 shows the spread of the median cantonal and Confederation bond yields when both are available. We see that the spread is especially elevated early in the sample. Thereafter, however, it is usually below 0.25 percentage points and sometimes even negative. We therefore use both data sources without a level adjustment. This implies that our long-term bond yield may be biased slightly upwards if smaller cantons had to pay a risk premium compared to the Confederation. However, this comes at the benefit of a larger sample and that we obtain a long-term bond yield even if no Confederation debt was outstanding. In addition, taking into account cantonal bond yields may give a more representative picture of government debt in a strongly federal state.

B Data for Switzerland

Tab. 2: Short-term interest rates 1846-2020

Range	Source	Type	Comments
1846-1893	Jöhr (1914)	Discount rate various cities	Annual average of note-issuing banks. Simple average over Zurich, St. Gallen, Basel, and Geneva.
1894-1906	*Wirtschaftsarchiv Basel*	Discount rate *Emissionsbanken*	Annual average of end-of-month values collected from the *Kursblatt der Basler Börse*
1907-1947	SNB (2007)	Discount rate SNB	Annual average of daily values. From January to mid-June 1907 discount rate *Emissionsbanken*
1948-1998	SNB (2007)	Money market rate Zurich	Annual average of daily values. Call money up to 1971, tomorrow/next afterward
1999-2020	SNB (2021)	SARON	Annual average of daily values. Swiss Average Overnight (secured money market rate).

Notes: The various interest rate segments are linked without level adjustments. Aggregation to annual frequency takes place before linking the data.

Tab. 3: Long-term interest rates 1852-2020

Range	Source	Type	Comments
1852-1864	*Bibliothèque de Genève*	4% Genevois	From quotation sheets *Cotes des agents de change réunis*. Missing values completed with *Journal de Genève* from letempsarchive.ch. A few months still missing.
1858-1864	e-newspaperarchives.ch	4.5% and 5% *Schweiz. Anleihen* and 4.5% *Kanton St. Gallen*	From *St. Galler Zeitung*. Single months missing.
1863-1879	*Wirtschaftsarchiv Basel*	Four confederation and 14 cantonal bonds	Quotes from various Swiss exchanges listed in *Handelszeitung*. Cantons of Basel-City, Bern, Fribourg, Vaud, Geneva, St. Gallen, Zurich. Missing values completed with quotes from newspapers on e-newspaperarchives.ch and letempsarchive.ch.
1879-1925	*Wirtschaftsarchiv Basel*	43 confederation bonds and 47 cantonal bonds	Quotes from *Kursblatt der Basler Börse*. Cantons of Basel-City, Bern, Fribourg, Vaud, Geneva, St. Gallen, Zurich.
1926-1987	SNB (2007)	Federal railway and confederation bonds	Maturity of five years.
1988-2020	SNB (2021)	Long-term government bond yield	Maturity of ten years.

Notes: Aggregate for each segment computed as the median over all available bond yield series. The various interest rate segments are linked without level adjustments. Before 1926 simple average over all available bond yields. Aggregation from monthly to annual frequency takes place after linking the data.

Tab. 4: Inflation 1804-2020

Range	Source	Type	Comments
1804-1913	HSSO (2012b)	Wholesale prices	Indexed to average of 1921 = 100
1914-1920	HSSO (2012b)	Consumer prices	Indexed to average of 1921 = 100
1921-2020	SFSO (2022)	Consumer prices	Indexed to average of 1921 = 100

Tab. 5: Trade-weighted exchange rate 1852-2020

Range	Source	Type	Comments
1852-1879	Various	Exchange rate CHF/GBP in various cities	Annual average of end-of-month values. Median over Zurich, St. Gallen, Basel, and Geneva. Some periods missing for some cities. *Neue Zürcher Zeitung*, *Eidgenössiche Zeitung*, *St. Galler Zeitung* from e-newspaperarchives.ch. *Kursblatt der Basler Börse* and *Handelszeitung* from *Wirtschaftsarchiv Basel*. *Basler Nachrichten* from *Universitätsbibliothek Basel*. *Cotes des agents de change réunis* from *Bibliotèque de Genève*.
1880-1913	*Wirtschaftsarchiv Basel*	CHF/GBP in Basel	Annual average of end-of-month values collected from the *Kursblatt der Basler Börse*
1914-1963	SNB	Average CHF/USD and CHF/GBP	CHF/USD and CHF/GBP indexed to same base before averaging. Annual average of monthly values. Retrieved on 4/1/2022 from data.snb.ch. Missing values for 1950-1951 for CHF/GBP filled with information from *Der Bund* from e-newspaperarchives.ch.
1964-1972	BIS (2021)	Narrow effective exchange rate	Annual average of monthly values. Inversed so that a decline corresponds to an appreciation. Retrieved on 4/1/2022 from www.bis.org/statistics/eer.htm
1973-2020	SNB (2021)	Broad effective exchange rate	Annual average of monthly values.

Notes: The CHF/GBP segments are linked without level adjustments. Further segments are linked by normalizing them to the same base period. Aggregation to annual frequency takes place after linking the monthly data.

Tab. 6: Monetary regime time dummies

Regime	From	To	Comments
Metallic regimes	1852	1913	Swiss franc fully replaced variety of local currencies during 1852. Bimetallism until 1873. Classical Gold Standard thereafter. No standardized note issuance until 1881. Swiss National Bank was founded in 1907.
World Wars	1914	1945	Includes WWI, WW2 as well as interwar period and Great Depression.
Bretton Woods	1946	1972	Until 1858 with capital controls.
Monetary targeting	1973	1999	Start date corresponds to break-down of Bretton Woods. SNB floated exchange rate in January 1973. Monetary targeting was introduced slightly later.
Flexible inflation targeting	2000	2020	New SNB strategy introduced at the end of 1999. Includes an effective-lower-bound period (2009-2020), a minimum exchange rate policy (2011-2014), as well as negative interest on reserves (since 2015).

Notes: These segments broadly follow the discussion by Kaufmann (2019).

C Data for the rest of the world

Table 7 sets out the data we collected for the rest of the world. In addition, we discuss the trade weighting below. Before 1964 we use a simple average of UK and US data to approximate the rest of the world. Before 1914, we use UK data. Starting in 1964, we compute our own trade-weighted measures.

We splice the three segments (UK, UK and US, trade-weighted data) to obtain a long series representing the rest of the world from a Swiss perspective. To do so, we normalize price indices to have the same base year. Interest rate segments are linked without a level adjustment.[30]

C.1 Trade weighted interest rates

After 1964 short- and long-term interest rate data are sourced from the OECD Main Economics Indicators database, and are used from 2020 as far back as they are available (OECD, 2021b,a). These data are not uniform in their sample periods, and we complement them with information from FRED (2021). Because we were not able to collect consistent data for all of Switzerland's trading partners, we focus on eight of the most important trading partners for which we were able to collect data: Austria, France, Germany, Italy, Japan, The Netherlands, the UK and the US. We then calculate a weighted average using the SNB's exchange rate index weights.[31]

The trade weights used for the rest of the world interest rate data are as follows. The SNB provides weights for a large number of countries. These weights take account of trade in goods (including precious metals) and services, and use data on imports, exports and GDP. Since 2000, countries are included in the weightings if they account for at least 0.2 per cent of Swiss imports or exports, or if they are a member of the euro area. Prior to that, a fixed sample of 15 countries and eight euro area member states are used (see Müller, 2017, for a detailed discussion).

However, most countries receive very low weights (only the top six most heavily weighted countries in 1973 and 2020 have a weighting of four per cent or more). For the most part, countries that receive a high weighting in 1972 also receive a high weighting in 2020. In particular, the top 8 most highly weighted countries in 1973 are all included in the top 10 most highly weighted countries in 2020.[32]

[30] Although, we adjust the level of US railway bond yields to match the level of US government bond yields to obtain a long series for US long-term interest rates.

[31] The weights are re-calculated to sum to 100 whenever a country enters the sample.

[32] The ninth and tenth most heavily weighted countries in 1973 (which are not included in our sample) are Belgium and Sweden, both which were weighted approximately 3.5 per cent in 1973.

Tab. 7: Rest of the World data

Variable	Period	Weighting	Source	Comments
Prices	1852-1913	UK only	Thomas and Dimsdale (2017)	We use wholesale prices to match the Swiss data. FRED identifier: SWPPIUKM
	1914-1963	UK and US average	Thomas and Dimsdale (2017), FRED (2021)	Consumer prices. FRED identifiers: CPIUKA, CPIAUCNS. Indexed to same base year before averaging.
	1964-2020	Trade-weighted	SNB (2021), BIS (2021)	Consumer prices. Based on nominal and real effective exchange rates. See Section C.2
Short-term interest rate	1852-1913	UK only	Thomas and Dimsdale (2017)	Discount rate on short-term paper. FRED identifier: DRSTPUKM
	1914-1963	UK and US average	Thomas and Dimsdale (2017), FRED (2021)	Discount rates on short-term paper. From 1914-1955 New York commercial paper rate. FRED identifiers: DRSTPUKM, M13002US35620M156NNBR, DFF.
	1964-2020	Trade-weighted	OECD (2021b), FRED (2021)	See Section C.1
Long-term interest rate	1852-1913	UK only	Thomas and Dimsdale (2017)	UK consol yield.
	1914-1963	UK and US equal weight	Thomas and Dimsdale (2017), FRED (2021)	UK consol yield until 1935. US railway bond yield until 1937. FRED identifiers: LTCYUKA, MTGB10UKM, M13019USM156NNBR, M13024USM156NNBR, M1333BUSM156NNBR, DGS10
	1964-2020	Trade-weighted	OECD (2021a), FRED (2021)	See Section C.1

Notes: All data are aggregated to annual frequency before linking. Price indexes are linked after normalizing them to the same base year. Railway bond yields are linked with a level adjustment. All other interest rates are linked without adjustment.

As a result, we initially select the ten most heavily weighted countries in 2020. Two countries are included in the sample in 2020 which receive no weight at all in 1973: China and India. However, a search produced little to no relevant data for those countries. Thus, our final sample comprises nine countries as follows: Austria, France, Germany, Italy, Japan, The Netherlands, the UK and the US. According to the SNB's weights, these countries represent 85.6% and 59.7% of the most important trading partners in 1973 and 2020, respectively. The sample of countries becomes somewhat less representative over time but still includes the most important trading partners (see Table 8).

Tab. 8: Sample periods international interest rate data (1964-2020)

Country	Weight 1973	Weight 2020	Short-term rate	Long-term rate
Austria	6.2	2.6	1964-2020	1965-2020
France	13.8	6.8	1964-2020	1964-2020
Germany	26.3	17.2	1964-2020	1964-2020
Italy	9.7	6.2	1964-2020	1980-2020
Japan	3.8	2.8	1964-2020	1989-2020
Netherlands	3.9	2.6	1982-2020	1964-2020
United Kingdom	11.5	6.9	1964-2020	1964-2020
United States	10.5	14.6	1964-2020	1964-2020
Total	85.6	59.7		

Notes: Weights measured in percent. Short- and long-term interest data sourced from the OECD (2021a,b) and FRED (2021). Weights stem from the SNB (2021).

C.2 Trade weighted price indices

To compute a trade-weighted foreign price index starting in 1964, we follow Stulz (2007) and divide the nominal effective exchange rate by the corresponding real exchange rate, multiplying this fraction with the Swiss CPI. By definition, this results in a trade-weighted price index representative of Switzerland's most important trading partners. The effective exchange rates stem from the SNB (2021) and the Bank for International Settlements (BIS, 2021). The CPI stems from the SFSO (2022).