UNIVERSITÉ DE NEUCHÂTEL

Institut de recherches économiques

IRENE Working Paper 22-03

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

Niko Hauzenberger, Daniel Kaufmann, Rebecca Stuart and Cédric Tille

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Niko Hauzenberger† Daniel Kaufmann‡§ Rebecca Stuart¶|| Cédric Tille**††

6 April 2022

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 vector autoregressive model to estimate long-term trends in nominal interest rates, exchange rate growth, and inflation. We then decompose the Swiss long-term 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. Comparing Switzerland with the rest of the world, we show that while Swiss real interest rates were higher during the 19th century, the pattern reversed after World War 2 with Swiss nominal and real rates becoming lower than foreign ones. However, this Swiss "low interest rate island" has disappeared in recent years. We document a connection between inflation risk and the Swiss term spread, as well between relative inflation risk and the difference between Swiss and foreign real interest rates.

JEL classification: E4, E5, F3

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

*We cordially thank Camille Ballestraz, Teodoro Bevilacqua, Marc Burri, Tobias Cwik, Rui Esteves, Patrick Halbeisen, Nils Herger, Florian Huber, Eric Monnet, Thomas Nitschka, Vincent Pochon, Kilian Rieder, and Barbara Schlaffer Bruchez, as well as seminar participants at the SNB, the Central Bank of Ireland and University College Dublin, for invaluable discussions and help with historical data. Also, would like to thank staff at various archives and libraries, in particular, Martin Lüpold and Aronne Watkins. Finally, we thank Idy N'Dao, Benjamin Ignoto, Tajana Staub, and Vasily Zhuravlev for excellent research assistance. This paper is partly based on a mandated policy report conducted for the State Secretariat for Economic Affairs (SECO).

†University of Salzburg, Department of Economics, Mönchsberg 2A, AT-5020 Salzburg, niko.hauzenberger@plus.ac.at

‡University of Neuchâtel, Institute of Economic Research, Rue A.-L. Breguet 2, CH-2000 Neuchâtel, daniel.kaufmann@unine.ch

§KOF Swiss Economic Institute, ETH Zurich

¶University of Neuchâtel, Institute of Economic Research, Rue A.-L. Breguet 2, CH-2000 Neuchâtel, rebecca.stuart@unine.ch

||Queen's University Belfast, Northern Ireland

**Graduate Institute of International and Development Studies, PO Box 1672, CH-1211 Genève, cedric.tille@graduateinstitute.ch

††Center for Economic Policy Research, Paris

1 Introduction

Low nominal and real interest rates pose important challenges for policymakers and social security systems, by making the effective lower bound a more salient problem for central banks, and making it harder for pension funds to meet their nominal obligations. Understanding the driving forces behind interest rates has thus become a major research topic. While recent research has focused on real factors, such as demographic change, productivity slowdown, the convenience yield, and an international savings glut, the role of nominal factors, such as inflation risk and the monetary policy regime is less well documented. This paper contributes to filling this gap by using an interest rate accounting framework to decompose Swiss long-term interest rate trends into domestic and international components since 1852.

We first compile a novel data set of monthly Swiss interest rates and exchange rates from archival sources.[1] We then link these new data with existing sources for Switzerland and construct trade-weighted data for the rest of the world. Next, to extract long-term trends from these data, we use a flexible time-varying parameter vector-autoregression (TVP-VAR) model with stochastic volatility (SV), both allowing for large structural changes in the transmission channels (via TVPs) and controlling for time-variation in the variances of the exogenous shocks (via SV). Using these trends, we decompose the long-term nominal interest rate into various components using an interest rate accounting framework. This allows us to analyze how the nominal long-term rate is affected by both domestic and international factors.

The main findings of our analysis are as follows. A reduction in trend inflation is the main reason behind the decline of the Swiss nominal long-term rate since the 1970's. The Swiss real long-term interest rate already declined during the interwar period and remained relatively low ever since. Combining with the pattern for the real short rates, we observe a positive term spread during most of the 20$^{\text{th}}$ century. This term spread emerged after the Swiss inflation trend became positive after World War 1, which suggests a role for the inflation risk premium. That premium in turn declined during the mildly deflationary environment since the Global Financial Crisis.

Contrasting Switzerland with the rest of the world, we find that Swiss real rates were relatively high during the 19$^{\text{th}}$ and first half of the 20$^{\text{th}}$ century. By contrast, Swiss real rates turned lower than foreign ones during the Bretton Woods period, suggesting that investors were willing to

[1] We aggregate the monthly to annual data for the analysis because no monthly price data exists for Switzerland. Hauzenberger et al. (2021) undertake an analysis at a quarterly frequency by constructing estimates for Swiss quarterly inflation rates, and find a similar pattern as this paper.

pay a premium to hold Swiss franc assets. This so-called "Swiss interest rate island" gradually vanished since 1990. This coincides with a reduction in trend inflation abroad relative to inflation in Switzerland. This pattern suggests that relatively low inflation risk in Switzerland contributed to lower real interest rates in Switzerland than abroad. We next decompose the interest rate differential into deviations from uncovered interest parity (UIP) and relative purchasing power parity (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 era. Finally, we assess the comovements between the term spread, the real interest rate differential, and the deviation from UIP on the one hand and various measures of (relative) inflation uncertainty on the other hand. Although we find that higher inflation uncertainty is associated with higher real interest rates, as expected, the estimates are imprecise and usually not statistically significant.

Our paper makes four main contributions to the existing literature. First, to the best of our knowledge, we are the first to compile 19th century data for Swiss long-term interest rates and the exchange rate vis-à-vis the Pound Sterling.[2] Second, we provide estimates of nominal and real interest rate trends for a small open economy. Switzerland is an interesting case to study because the Swiss franc has been in existence for 170 years. This allows us to analyze movements over a long sample period under various monetary regimes. While several papers have presented estimates of the natural interest rate over long samples, none of the existing studies consider a small open economy and discuss the domestic and international drivers.[3] For instance, Del Negro et al. (2019) consider 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, adapting 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.[4] Jordà et al. (2020) estimate the natural real interest rate for France, Germany, Italy, Netherlands, Spain and the UK using annual data

[2] Previous research mostly focused on short-term interest rates and inflation (see, e.g., Jöhr, 1915, Kaufmann, 2019, Herger, 2021).

[3] 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. Bacchetta et al. (2021) consider the case of Switzerland, but their paper focuses on the most recent decades.

[4] 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.

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.

Third, we use a TVP-VAR-SV model that allows for rapid changes in the underlying structural parameters to extract interest rate trends. Our flexible modeling technique additionally features mixture innovations in the state equation of the TVPs, effectively allowing for coefficients that are constant or evolve gradually, but that can also exhibit a few occasional abrupt structural breaks (see, McCulloch and Tsay, 1993, Gerlach et al., 2000, Giordani and Kohn, 2008). These structural breaks, in turn, allow for discrete regime-switches in the long-term trend estimates. The result is more precise estimates (i.e., lower estimation uncertainty), while at the same time the obtained trends feature larger and more abrupt changes in periods of turmoil (e.g., during World War 1) than those found in other studies (e.g., Del Negro et al., 2019). 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, models such as these 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.

Our final contribution is to interpret the long-term trends through the lens of an accounting framework which allows us to decompose the nominal long-term interest rate into various components. In particular, we can analyze how they are affected by inflation, the term spread, the world real interest rate, and deviations from UIP and relative PPP.

[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).

The paper is structured as follows. The next section presents the compilation of the data. Section 3 discusses the methodology for extracting trends from the data, and the decomposition of the long-term nominal interest rate into various domestic and international components. Section 4 discusses the results, and Section 5 focuses on the role of inflation risk. 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.

For the 19th century, however, existing data for Swiss interest and exchange rate are scarce. Our first step is therefore to compile a novel data set on short- and long-term interest rates, the exchange rate, and inflation from 1852 to 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] While our analysis relies on 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

[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.

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 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 (1915) ends. From 1894 to 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 to 1947. From 1948 to 1998, we use the annual average of daily money market rates in Zurich also available from the SNB (2007). Finally, from 1999 to 2020 we use the annual average of the daily SARON, a secured overnight interest rate.[11]

2.2 Long-term interest rate

Data on Swiss long-term interest rates do not exist 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, as we only observe a single 4% Geneva bond for most of the period. In the 1860's we use several Confederation and 14 cantonal bonds. From 1879 to 1925 we collected data on 43 Confederation bonds and 47 cantonal bonds.[13]

Our sources provide bond prices, which we transform into yield-to-maturity. The information includes the coupon interest rate, the repayment date, and the price quotes. Tables from the

[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.

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. Otherwise, we use the average of the demand and supply quotes.[14] As no price may be available for some months, 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. In these cases we to resort to an approximation,[16] assuming that the bond is of very long maturity, which was very common during the 19$^{\text{th}}$ 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

[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.

interest rate for periods when the Confederation did not issue any debt.[17]

Existing data start in 1899 (SNB, 2007). From 1899 to 1923, these yields stem from bonds issued by the Swiss federal railway company. These bonds were widely traded and backed by the Confederation; according to SNB (2007) they 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. As the Swiss exchanges were closed at the start of World War 1, we fill this gap using a linear interpolation. From 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, and we 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 to 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 to 1913.

Existing exchange rate data are available from 1914. From 1914 to 1963 we use an equally weighted average between the CHF/GBP and CHF/USD using data from the SNB (2021). From January 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. We define the exchange rate as one unit

[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).

[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.

of foreign currency expressed in Swiss francs, so a decline is an appreciation of the Swiss franc.

2.4 Inflation

Consumer price data for Switzerland are available from the SFSO (2021) starting in the early 19th century. However, as Kaufmann (2019, 2020) point out, these CPI data are probably prone to substantial measurement error and based on wholesale prices for part of the sample. We therefore prefer to use wholesale prices from HSSO (2012b) before 1913, 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. [23]

2.5 Monetary regimes

Over our long sample, Switzerland went through a serie of monetary regimes. These include metallic-based regimes until World War 1, the interwar period with a weaker anchoring to gold, the Bretton Woods period of fixed exchange rate, monetary targeting until 1999 and a flexible inflation targeting regime since. The various regimes are presented in more detailed in Table 6 in the Appendix, and are adapted from Kaufmann (2019).

2.6 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 described 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 as it was the center of the global monetary system and 19th century data for the UK are regarded to be of good quality. From 1914 to 1963, we use an equal weighted average of US and UK data because the US had then become more and more important as a trading partner for Switzerland.[24] 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. We also compute an implicit trade-weighted consumer price index based on nominal and real effective exchange rates, as well as the Swiss CPI.[25]

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

[23] In a companion working paper, Hauzenberger et al. (2021), we construct monthly price data using the annual Swiss data, foreign data, and the comovements between these since 1921.

[24] 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).

[25] 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.

Fig. 1: Data


Short−term interest rates
In %
Switzerland
World
Long−term interest rates
In %
Switzerland
World
Inflation
Growth rate, in %
Switzerland
World
Exchange rate growth
Growth rate, in %

2.7 Presentation of the combined data

Figure 1 shows our overall data set of interest rates (first two panels), inflation (third panel) and exchange rate (fourth panel). 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 between 1014 and 1945, and interest rates were lower in Switzerland than abroad after World War 2. This reversal coincides with Swiss inflation being persistently lower than abroad. But, during the metallic regimes of the 19th century the level and movements of inflation were similar in Switzerland and abroad (third panel).[26] This relative pattern of inflation vis-à-vis the rest of the world is also reflected in exchange rate movements (fourth panel). Turning to the exchange rate the Swiss franc external value remained steady during the metallic regimes of the 19th century. The World War period brought more volatility. After World War 2, with the exception of the Bretton Woods System until 1973, the Swiss franc more often than not appreciated over time.

3 Methodological approach

In this section, we first outline how we extract long-term trends from the data using our flexible multivariate time series model. We then present our interest rate accounting framework to decompose the Swiss long-term interest rate into its various components.

3.1 Estimation of long-term trends

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 these latent quantities from the data.

Specifically, we estimate a time-varying parameter vector autoregressive model with stochastic volatility (TVP-VAR-SV). By introducing TVPs and thus accounting for changing transmission channels between macroeconomic variables, this multivariate time series model allows us to estimate dynamically evolving long-term trends, defined as the best long-term forecast at any given point in time. By introducing SV, we additionally control for time-varying variances of the exogenous shocks to the economy (i.e., heteroscedasticity). This procedure is similar to a Beveridge and Nelson (1981)-type decomposition that has also been used by, e.g., Cogley et al.

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

(2010). However, TVP-VAR models (irrespective of the variance specification) involve a large number of coefficients that have to be estimated from the data. To avoid excessive over-fitting, the literature therefore typically constrains the TVPs to evolve rather slowly over time (see, e.g., Primiceri, 2005). This feature leads to trend estimates that evolve gradually over time as well (see, e.g., Del Negro et al., 2017, who focus on estimating long-term interest rate trends).

This restrictive assumption is undesirable in our analysis because the sample includes sudden changes in the macroeconomic environment. We therefore equip our model with mixture innovations in the state equation of the TVPs, effectively allowing for coefficients that are constant or evolve gradually, but that can also exhibit a few occasional abrupt structural breaks (McCulloch and Tsay, 1993, Gerlach et al., 2000, Giordani and Kohn, 2008). These mixture innovations models have proven useful in a variety of macroeconomic applications ranging from forecasting (e.g., Huber et al., 2019, Hauzenberger, 2021) to structural impulse response analysis (e.g., Koop et al., 2009). The structural breaks, when they occur, in turn also result in sudden large changes in the long-term trend estimates.

Assuming that $\boldsymbol{y}_t$ is an $M \times 1$ vector of our endogenous variables of interest, we estimate a TVP-VAR-SV model of the following form:

$$\boldsymbol{y}_t = \boldsymbol{c}_t + \sum_{i=1}^{p} \boldsymbol{B}_{it} \boldsymbol{y}_{t-i} + \boldsymbol{\epsilon}_t, \quad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\boldsymbol{0}_M, \boldsymbol{\Sigma}_t). \tag{3}$$

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

In what follows, let $\boldsymbol{\beta}_t$ be a $KM \times 1$ vector which stores all coefficients of the model (for $K = pM + 1$). Similar to the literature on mixture innovation models, we then assume that the j^{th} element of $\boldsymbol{\beta}_t$, β_{jt}, evolves according to a random walk equipped with a mixture distribution in the variances:

$$\beta_{jt} = \beta_{jt-1} + u_{jt}, \quad u_{jt} \sim \mathcal{N}(0, \kappa_{jt}). \tag{4}$$

The state innovation variance κ_{jt} is then defined as:

$$\kappa_{jt} = \begin{cases} \bar{\kappa}_{1j} & \text{with probability } p_j, \\ \bar{\kappa}_{0j} & \text{with probability } 1 - p_j. \end{cases} \tag{5}$$

Here, $\bar{\kappa}_{1j} > 0$ denotes the variance in case that β_{jt} varies over time and p_j is the corresponding probability that the coefficient is indeed time-varying. By contrast, $\bar{\kappa}_{0j} \approx 0$ with probability $1-p_j$ we have that $\beta_{jt} \approx \beta_{jt-1}$, implying an (occasionally) constant coefficient. This specification is highly flexible and allows for smooth, abrupt, or no changes in the coefficients.

Moreover, we assume that $\boldsymbol{\Sigma}_t$ can be decomposed as $\boldsymbol{\Sigma}_t = \boldsymbol{D}_t \boldsymbol{H}_t \boldsymbol{D}_t'$, where $\boldsymbol{D}_t$ refers to the normalized lower Cholesky factor (i.e., a lower triangular matrix with ones on the diagonal) and $\boldsymbol{H}_t = \text{diag}(\{h_{jt}\}_{j=1}^{M})$ with h_{jt} denoting the structural error variance of the j^{th} equation following an independent SV process (for details, see Appendix D).

This completes the basic idea of our modeling framework and of the mechanism to sufficiently introduce flexibility in a TVP-VAR-SV when using historical data over a long time span. Our proposed prior and estimation set-up of this model closely follows Huber et al. (2019). To be precise, we rely on an equation-by-equation estimation of the TVP-VAR-SV and define the respective priors and laws of motion of the coefficients for the structural-form of the TVP-VAR-SV. After defining the prior distributions for all the parameters involved, we combine them with the likelihood of the model to obtain the joint posterior. Since this posterior distribution of this highly flexible modeling approach is not available in closed-form, we rely on Markov Chain Monte Carlo (MCMC) techniques to successfully draw from the full posterior distribution. The prior and estimation set-up is outlined in Appendix D.

To extract the long-run trends ex-post (i.e., after obtaining the posterior distributions of all parameters in the model), we recast the VAR(p) model in Eq. (3) in its companion form:

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

Here, $\boldsymbol{z}_t = (\boldsymbol{y}_t', \ldots, \boldsymbol{y}_{t-p+1}')'$ denotes an $Mp \times 1$ matrix, $\boldsymbol{J}$ is an $M \times Mp$ selection matrix, selecting the first M rows in $\boldsymbol{z}_t$, $\boldsymbol{C}_t$ is an $Mp \times 1$ vector collecting $\boldsymbol{c}_t$ on the first M elements and is otherwise zero. Moreover, $\boldsymbol{F}_t$ refers to an $Mp \times Mp$ companion matrix that stores the TVP matrices $\boldsymbol{B}_t = (\boldsymbol{B}_{1t}, \ldots, \boldsymbol{B}_{pt})$ 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:

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

where $\boldsymbol{I}_{Mp}$ denotes an $Mp \times Mp$ identity matrix. With this measure the equilibrium value of the variables is driven both by changes in the autoregressive coefficients $\boldsymbol{B}_t$ and by instabilities in the intercepts $\boldsymbol{c}_t$.

3.2 Interest rate accounting framework

For the remaining of the paper we focus on our estimates of long-term trends from the TVP-VAR-SV. As these are estimates of the equilibrium values of the corresponding variables at any given point in time, we can think of them as long-run expectations. We thus omit the expectation notation when performing the decomposition.

We decompose our estimated trends using an interest rate accounting framework. It relies on various equilibrium conditions, and deviations thereof, to identify domestic and international drivers of the Swiss long-term nominal interest rate.

Our first decomposition is the Fisher effect that split the real interest rate between the nominal interest rate and inflation expectations. Specifically, the long-term nominal interest rate (i_t^l) consists of 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 consider the term spread, which is the difference between the long-term and short-term real interest rates. The long-term real interest rate is thus split between the short-term real interest rate (r_t^s) and the term spread ($s_t \equiv r_t^l - r_t^s$):

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

Next, we use our estimates for the rest of the world. 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 ($d_t \equiv r_t^s - r_t^{s,w}$):

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

We finally follow Cumby and Obstfeld (1984) and examine deviations from classical parity conditions. To do so, we split the Swiss short-term real interest rate differential into a deviation from *real* uncovered interest parity ($\text{uip}_t \equiv r_t^s - r_t^{s,w} - \Delta q_t$) and the deviation from relative PPP

($\text{ppp}_t \equiv \Delta q_t \equiv \Delta e_t - \pi_t + \pi_t^w$) which is the trend growth rate of the real exchange rate:[27]

$$i_t^l = \text{uip}_t + \text{ppp}_t + r_t^{s,w} + s_t + \pi_t \ .$$

4 A decomposition Swiss nominal long-term interest rates

4.1 Evolution of the Swiss long-term interest rate

Our estimate for the trend long-term nominal interest rate is presented in Figure 2. The Bayesian framework allows us to calculate credible intervals to evaluate whether the various factors are statistically significantly different from zero. Therefore, in addition to the median point estimate (red lines), we also include and uncertainty intervals (shaded yellow). Finally, the figure also shows monetary regimes as shaded areas.

The 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 World War 1, it remained elevated during the interwar period. The trend reverted during World War 2, with a decrease that persisted during the first half of the Bretton Woods System until the interest rate declined to a level last observed during the 19th century. The interest rate started increasing in the second half of the Bretton Woods period. The path of increase accelerated in the 1970's, and out estimates are volatile in the 1970's and 1980's. This is consistent with higher macroeconomic volatility following the demise of Bretton Woods in 1973 and the move to flexible exchange rates, as well as the oil shocks in 1973 and 1979. In addition to becoming more volatile, our estimates are less precise, suggesting that the long-term interest rate became harder to predict. Since the late 1990's the volatility receded and the long-term interest rate has been moving downward to reach unprecedented low levels in recent years.

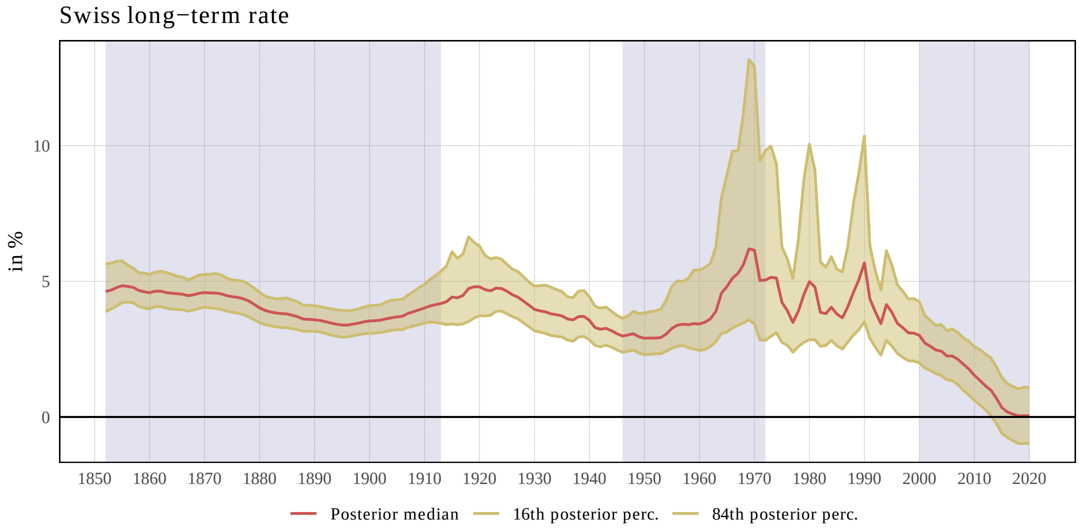
Our approach also provides us with estimates of the short-term interest rate and inflation in Switzerland and abroad, as well as the exchange rate. In the next subsections, we use these variables to decompose the evolution of the Swiss long-term interest rate according to our interest rate accounting framework.

4.2 Inflation and the real interest rate

Figure 3 shows the first decomposition of the long-term nominal interest rate into the real interest rate and inflation (first panel). The second and third panels show the individual

[27] Specifically, $d_t = uip_t + \Delta q_t = \text{uip}_t + \text{ppp}_t$.

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.

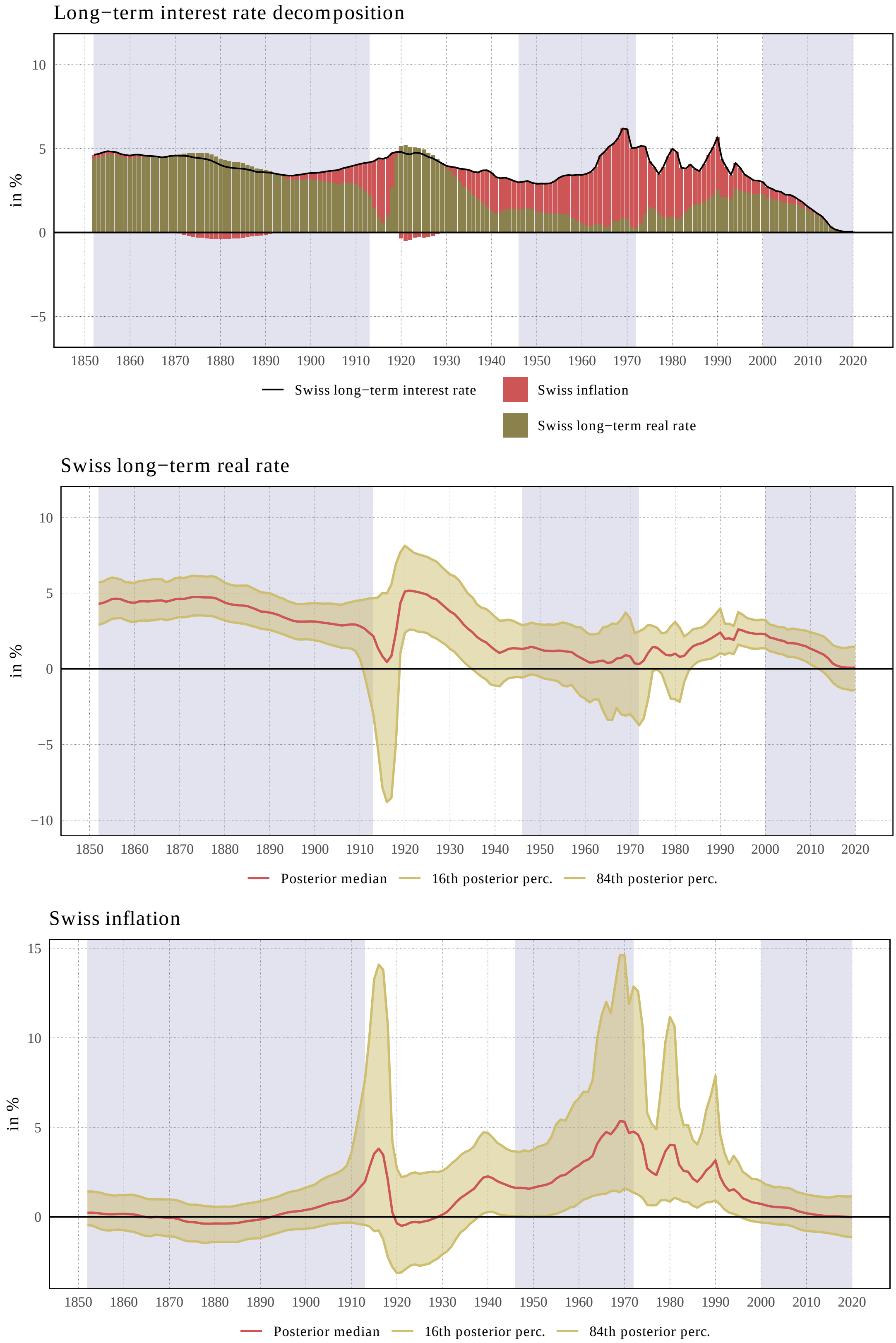
components along with uncertainty intervals.

The metallic monetary regimes in place in the 19th and early 20th centuries are associated with an inflation steady and close to zero. The real and nominal interest rates are thus almost identical. The immediate aftermath of World War 1 saw an increase in interest rates as the SNB aimed to return to the Gold Exchange Standard. Subsequently, the nominal interest rate went on a gradual but continuous declining trend from the early 1920's until the 1960s. While this was initially driven by falling inflation after the World War 1 (with a real interest rate that remained high), inflation persistently moved to positive values in during the Great Depression and later, after Switzerland abandoned the peg to gold in 1936. This increase in inflation, along with the ongoing gradual decline in the nominal rates, translated in a steady decrease in the real interest rate.

Although the real interest rate recovered somewhat during the early Bretton Woods period, it remained well below the levels observed in the 19th century. By contrast, while inflation temporarily drifted down in the early Bretton Woods period (as in most advanced economies), it increased markedly in the 1960's and 1970's, as the end of the Bretton Woods system confronted central banks with higher uncertainty in gauging the impact of their policies.

Starting in the early 1980's, central banks improved their conduct of policy and inflation started to decline, leading the Swiss economy to return to a situation of very low inflation since

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.

the mid-1990's. Until the mid-1990s, this decline was partly offset by an increase in the real interest rate, a pattern similar to other countries. This increase in the real interest rate proved temporary, and starting in the late 1990's the real rate has continuously declined to reach 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 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] Despite this, our results are consistent with the cycle of rising real rates in the 1980's, 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. 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. Bacchetta et al. (2021) relies on an approach similar to Del Negro et al. (2019) for Switzerland, and documents a pattern similar to ours, with the latest value of the real interest being even lower than our estimate.

4.3 The term spread

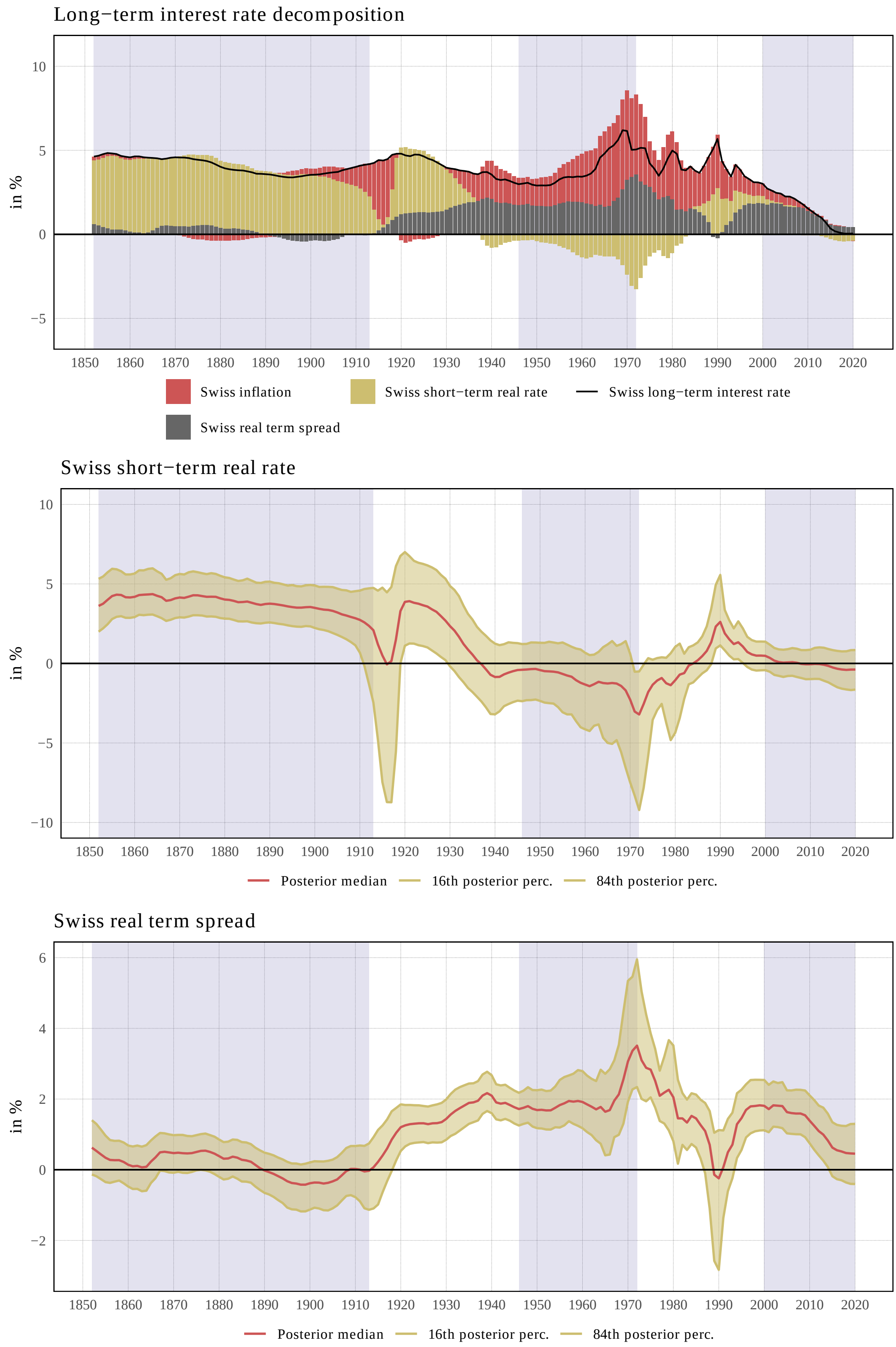
Figure 4 shows our second decomposition of the long-term nominal interest rate into the real short-term interest rate, the term spread, and inflation (first panel). The second and third panels show the individual components along with uncertainty bands (inflation being already presented in Figure 3).

Throughout the 19$^{\text{th}}$ century, short and long-term interest rates were close, as the term spread was not statistically significantly different from zero. The short-term interest rate was steady, but quite elevated at close to 5%, until the early 20$^{\text{th}}$ century. The absence of term spread likely reflected the predictability of interest rates and absence of inflation risk.

The term spread only emerged consistently in the wake of World War 1, possibly due to an increase in inflation risk perceptions after Switzerland left the Gold Standard during the war, following the temporary inflation peak when Switzerland abandoned gold during the conflict. Despite a return to the Gold Standard during the interwar period, risk perceptions remained with the term spread remaining steady at a high level, which increased further once

[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.

Switzerland left gold again in 1936.

The term spread stabilized at a higher level in the aftermath of World War 2. This did no translate into a higher long-term rate, and instead the short-term real rate trend turned negative (although not significantly) in the wake of the Great Depression, remaining close to zero until the late 1980's. The turbulent times following the breakdown of Bretton Woods led to a further increase in the spread in the 1970's, which proved to be short-lived.

The early 1990's saw an increase in the short-term interest rate and a drop in the terms spread as the SNB implemented a rather restrictive monetary policy to curb inflationary pressures (see Peytrignet, 2007). Thereafter, the short-term interest rate fell back to 0% and the term spread rose back when the new monetary policy strategy was introduced in late 1999. The removal of the an exchange rate floor vis-à-vis the euro, at a time when the European Central Bank (ECB) announced a large-scale asset purchase program, pushed the term spread again down to around 0%. The recent drop in the term spread could therefore reflect an environment of very low inflation, or even mild deflation.

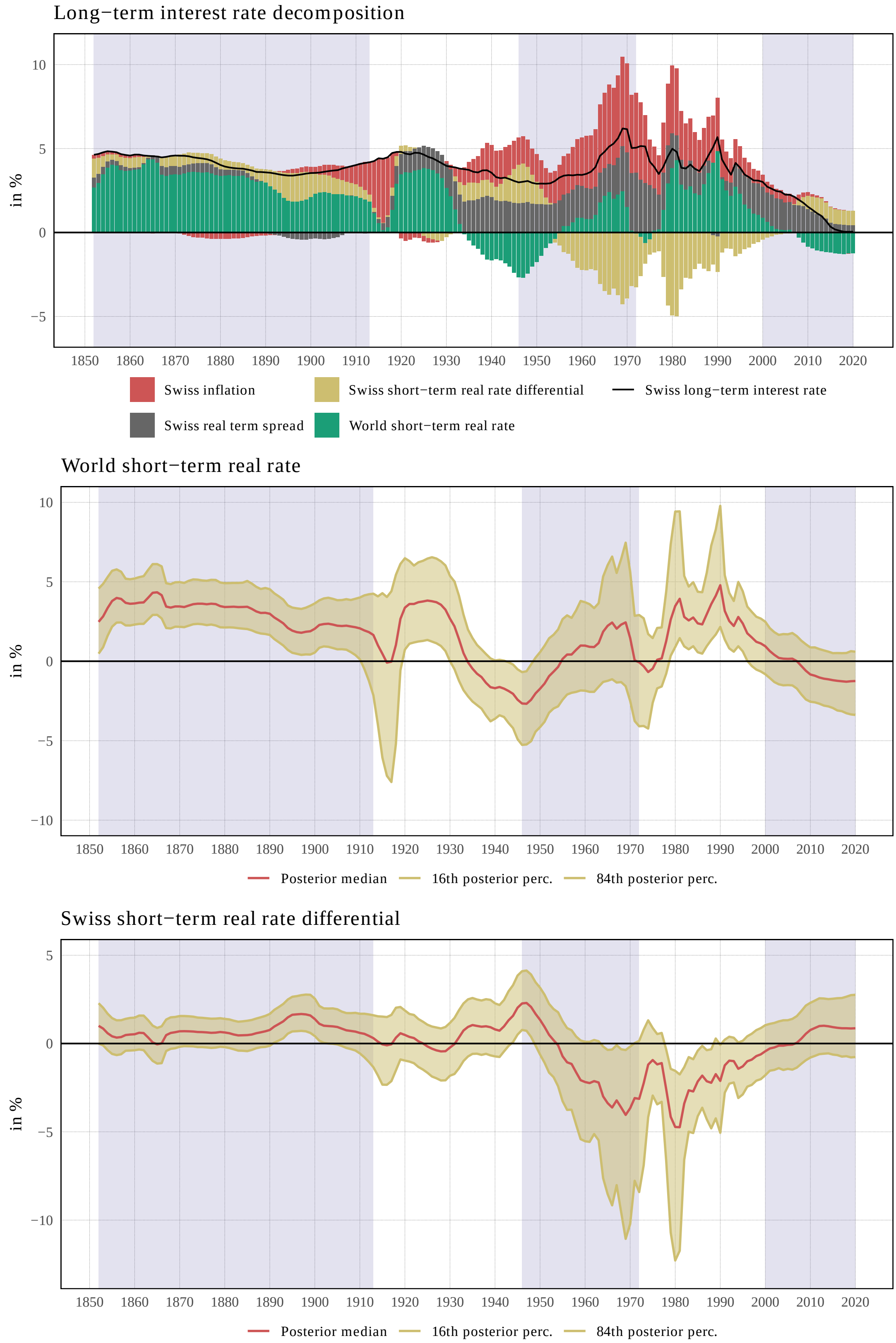
4.4 Swiss-Foreign interest rate differential

Moving to our third decomposition, Figure 6 shows split of the long-term nominal interest rate trend 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 (inflation and the term spread being shown in previous figures).

Note that the pattern for the world short-term real interest rate, shown in the middle panel of Figure 6, is similar to the one documented by Del Negro et al. (2019). The values fluctuated moderately around a steady average until the Great Depression, before falling rapidly until World War 2. The drop was short-lived, and the real interest rate subsequently increased until the 1980's (with a temporary drop after the demise of the Bretton Woods system) reaching levels moderately above the ones prevailing in the early 20^{th} century. Starting in the early 1990's, the real interest rates has been on a downward path that brought it to values that had only been seen during World War 2 and briefly during the mid-1970's.

Turning to our decomposition, the movements of the Swiss real interest rate before World War 2 were primarily driven by the foreign interest, as shown by the steady differential. This is unsurprising as the metallic monetary regimes and free capital mobility before World War 1

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.

(Obstfeld and Taylor, 2005, Bordo and Meissner, 2015) translated into fixed exchange rates.[29] While steady, the differential was not zero and the Swiss interest rate was above the foreign ones, suggesting that investors viewed Switzerland as an emerging economy and demanded a premium to hold Swiss franc assets.

The international monetary landscape change following World War 1, and the period from the Great Depression through to the middle of the Bretton Woods era was characterized by significant capital controls (see, e.g., Eichengreen, 2008). This was associated with a weaker relevance of the foreign interest rate as a driver of the Swiss rates. furthermore, the 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), in line 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.

The fall in the Swiss interest rate observed since the 1980's coincided with a decline in foreign interest rates. However, the decline was not even, as the negative differential between the Swiss and foreign interest rate declined. As a result, the real interest rates abroad became more closer to the Swiss one. 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 made Switzerland less special, and may explain the convergence of interest rates in Switzerland and abroad. The end of the Swiss low interest rate island in recent years is also found by Bacchetta et al. (2021).

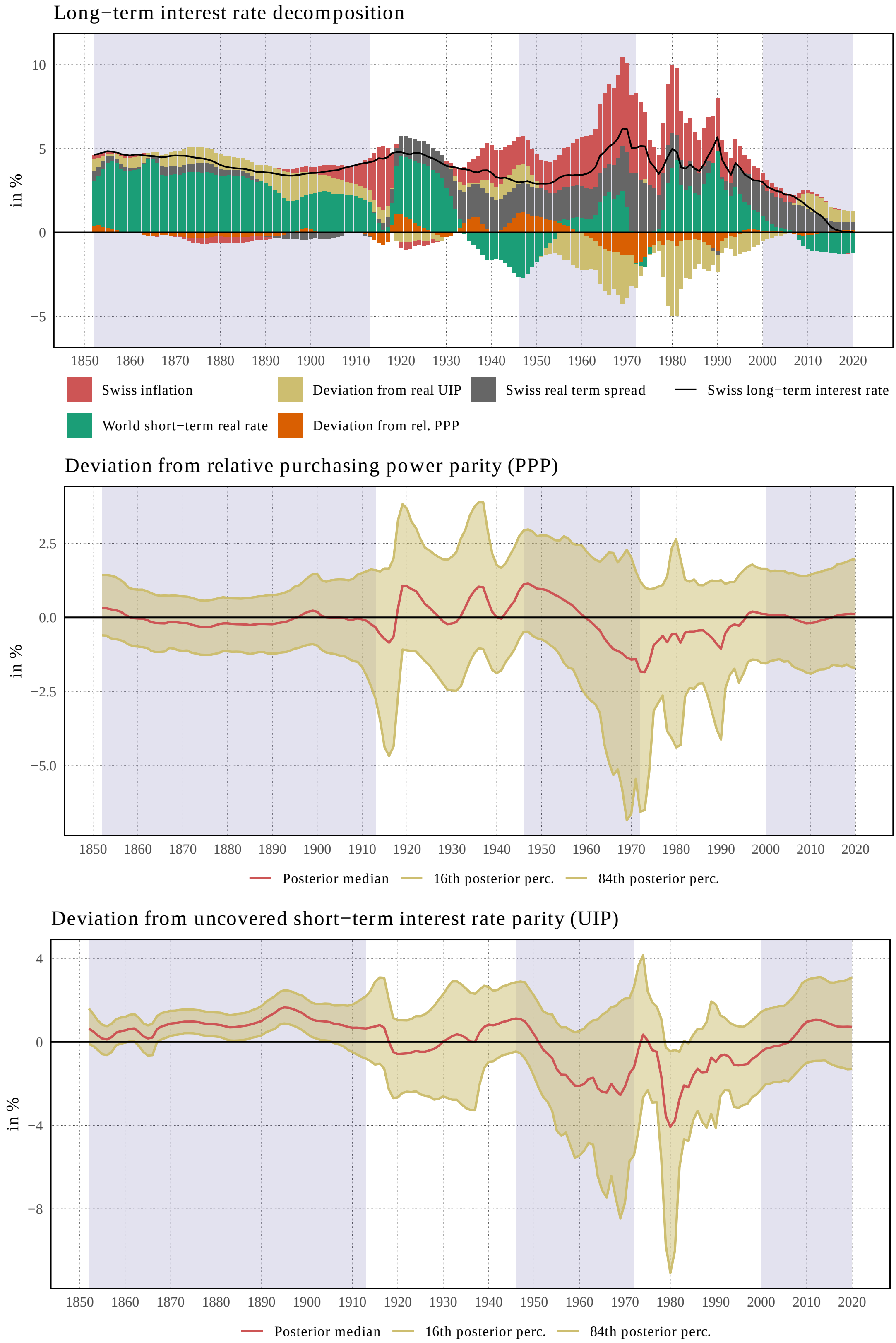
4.5 Deviations from UIP and PPP

Our final decomposition is illustrated in Figure 6 which splits the long-term nominal interest rate into deviations from real UIP, relative PPP (growth of the real exchange rate), the world short-term interest rate, the term spread, and inflation (first panel). The second and third panels show the deviations from PPP and UIP along with uncertainty bands (the other components are presented in previous figures).

Relative purchasing power parity held until the breakdown of the Bretton Woods system, with the exception of the World Wars during which estimates are highly uncertain as shown by the wide 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 pattern markedly changes with the end of Bretton Woods, as the sharp appreciation of the Swiss franc translated into negative deviations from relative PPP (although this period is again measured

[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.

with uncertainty). The magnitude of the deviations gradually shrank, and have been close to zero since the mid-1990's.

The deviation from real uncovered interest parity was steady and marginally positive until World War 1, reflecting the fact that Switzerland was essentially an emerging economy during this period, leading investors to require a premium to invest in the country. The pattern abruptly shifted in the aftermath of World War 2, with the deviation becoming clearly negative with the emergence of the Swiss interest rate island. The estimates are however associated with substantial uncertainty. The deviation was particularly negative during the early 19has shrunk and disappeared, consistent with the end of the Swiss interest rate island.

5 Inflation uncertainty and spreads

5.1 Measures of uncertainty

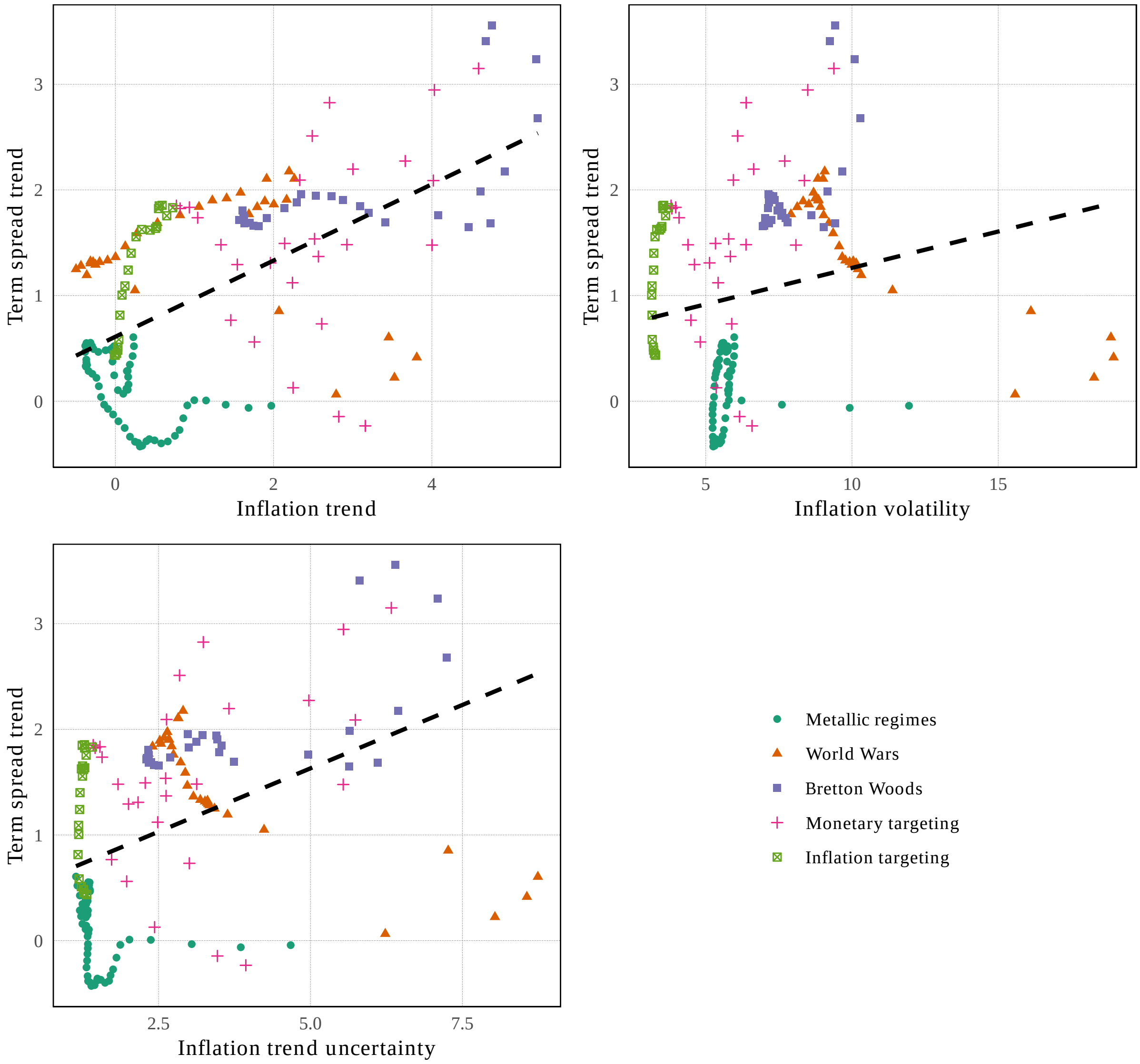
The previous section indicates that the trends in the term spread, the interest rate differential, and the deviation from UIP emerged at times of (relatively) high inflation uncertainty. We take a closer look at this aspect by computing several measures of inflation uncertainty, and then assess their comovements with the various spreads through charts and an econometric analysis.

We measure inflation uncertainty in three ways. We first consider the inflation level, as higher inflation is often associated with more inflation uncertainty. Second, we use our TVP-VAR-SV to compute a time-varying measure of the unconditional volatility of inflation. Third, we take the interquartile range of the posterior distribution of the long-run inflation trend. When considering variables that contrast Switzerland with the rest of the world, we take relative versions of these uncertainty measures (namely the difference in trend inflation, the difference in the unconditional volatility of inflation, and the difference in the interquartile range of the posterior distribution).

5.2 Comovements of spreads and uncertainty

We start with the domestic Swiss term spread. Figure 7 shows scatter plots with linear regression lines of the term spread trend against the three different measures of inflation uncertainty. We observe a positive relationship with all uncertainty measures. The various colors denote the main monetary regimes that Switzerland experienced. The scatter plots distinguish between various monetary regimes. The metallic regimes of the 19^{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, although, the term spread trend remained higher than during the metallic regimes.

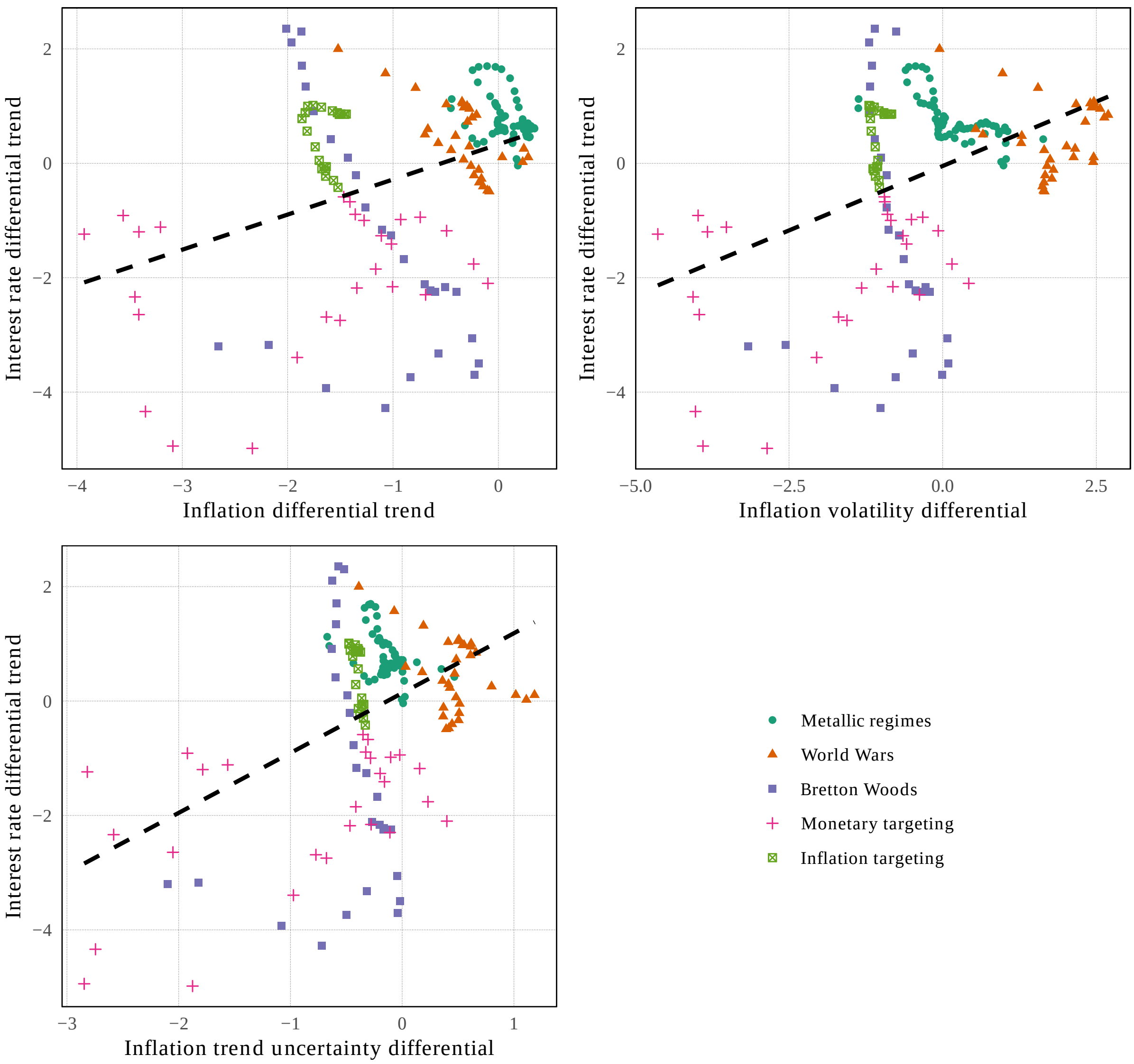
Fig. 7: Term spread trend and inflation uncertainty



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-SV. Inflation trend uncertainty is the interquartile range of the posterior distribution of trend inflation in the TVP-VAR-SV.

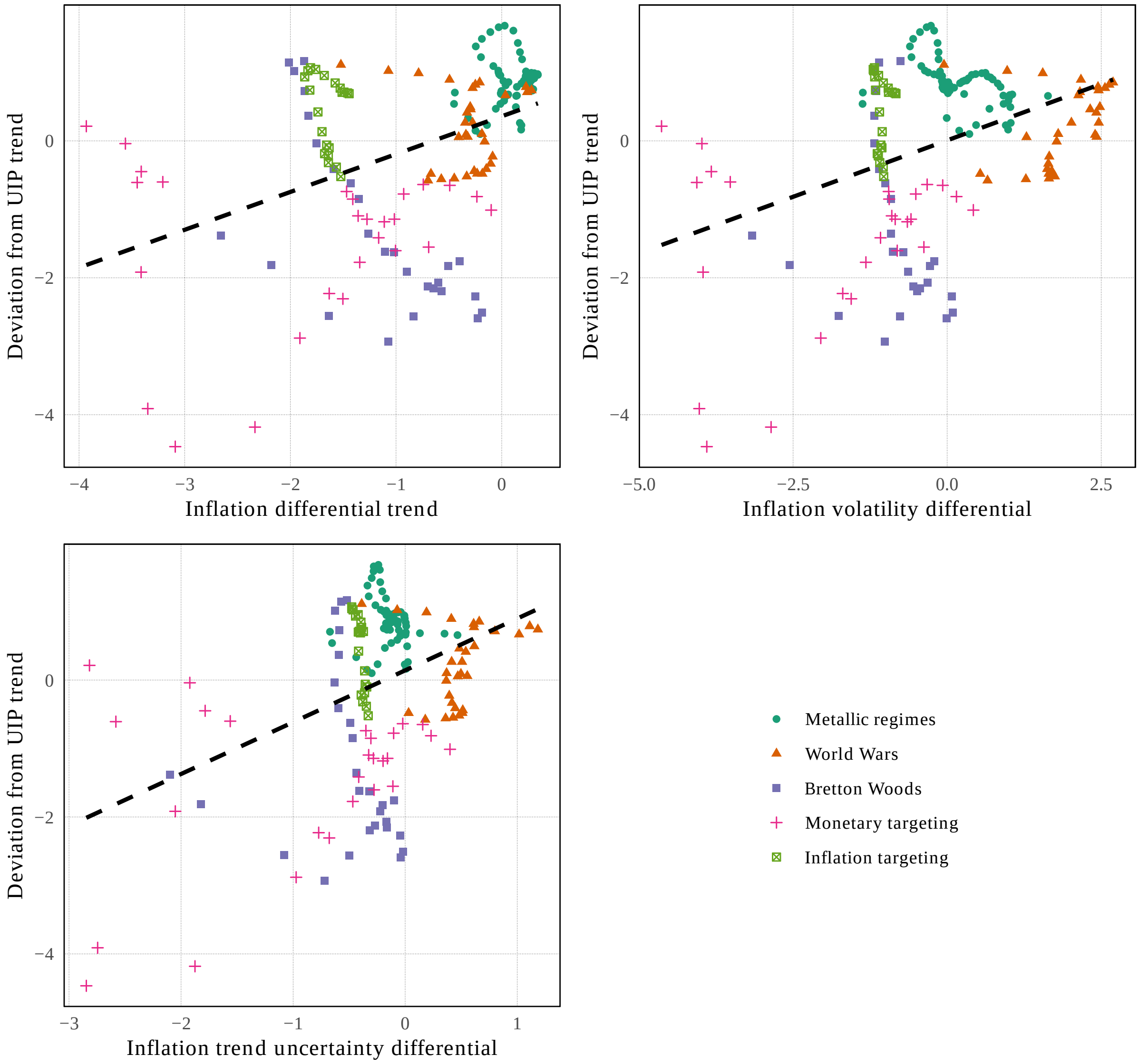
We next consider the international dimension with the Swiss-foreign interest rate spreads and the deviations from real UIP. The measures of uncertainty are expressed in international differences, as explained above. Figure 8 shows the scatter plot of the interest rate differential with the uncertainty measures. We expect higher inflation uncertainty in Switzerland to

Fig. 8: Interest rate differential and inflation uncertainty



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-SV. The inflation trend uncertainty in Switzerland and abroad are the interquartile ranges of the posterior distribution of trend inflation in the TVP-VAR-SV.

Fig. 9: Deviation from UIP and inflation uncertainty



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-SV. The inflation trend uncertainty in Switzerland and abroad are the interquartile ranges of the posterior distribution of trend inflation in the TVP-VAR-SV.

translate into a positive interest rate differential. We indeed observe a positive relationship between the real interest rate differential and all three relative inflation uncertainty measures. The differential was particularly negative during the Bretton Woods period and monetary targeting, times at which inflation was more volatile abroad than in Switzerland. Furthermore, relative inflation uncertainty and the interest rate differential are lower during inflation targeting and the metallic monetary regimes.

The relationship is similar when we consider the deviation from UIP (Figure 9). Recall that the difference between the deviation from real UIP and the real interest rate differential is the real exchange rate growth trend. The most pronounced negative deviations from UIP occured during monetary targeting and Bretton Woods era, which were periods with relatively low inflation uncertainty in Switzerland compared to the rest of the world. Under inflation targeting, the deviation from UIP became smaller in absolute size, in line with the idea that inflation uncertainty was roughly equal in Switzerland than in the rest of the world.

5.3 Econometric assessment

We conduct a more formal assessment of the pattern discussed in the previous section by estimating linear regressions of the various spreads on the three inflation uncertainty measures. This more formal approach has two benefits. First, we can base inference on HAC-robust standard errors that account for the highly persistent nature of the data. Second, we can exploit variation within various monetary regimes to examine which period drives the correlation between uncertainty and the spreads most.

Table 1 shows the results. Panel (a) presents the specifications over all years, without controlling for monetary regimes. The dependent variables are given in the first row. For each we present three columns, corresponding to the different uncertainty measures as independent variables: trend inflation, unconditional inflation volatility, and the interquartile range of trend inflation. The Swiss uncertainty measures are used for the terms spread (columns 1 to 3), while the analysis of the interest rate differential (columns 4 to 6) and deviation from UIP (columns 7 to 9) rely on the Swiss-foreign difference of the respective volatilities. We observe that while the coefficients have the expected signs, no uncertainty measures has a statistically significant impact based on the HAC-robust standard errors. This indicates that the highly persistent data leads to high standard errors and uncertain inference.

The lack of significance could result from an heterogeneous relation across the various monetary regime. We thus interact the uncertainty measures with monetary regime dummies

Tab. 1: Spreads and inflation uncertainty

(a) Without interaction terms

	Term spread			Interest rate differential			Deviation from UIP		
	INF	IQR	UCV	INF	IQR	UCV	INF	IQR	UCV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Uncertainty	0.36*	0.24	0.07	0.61	1.05	0.45	0.55	0.76	0.33
	(0.21)	(0.35)	(0.23)	(0.74)	(0.64)	(0.34)	(0.51)	(0.48)	(0.29)
Constant	0.61	0.43	0.57	0.33	0.14	−0.05	0.36	0.14	0.01
	(0.81)	(0.98)	(1.68)	(0.85)	(0.90)	(0.85)	(0.79)	(0.62)	(0.81)
N	169	169	169	169	169	169	169	169	169
R^2	0.34	0.19	0.04	0.15	0.20	0.19	0.19	0.16	0.15
Adjusted R^2	0.34	0.19	0.04	0.15	0.20	0.18	0.18	0.15	0.15

(b) With interaction terms

	Term spread			Interest rate differential			Deviation from UIP		
	INF	IQR	UCV	INF	IQR	UCV	INF	IQR	UCV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Uncert. x Metallic reg.	−0.58**	−0.60**	−0.17	0.46	−2.94	−0.10	1.33	−2.69	0.08
	(0.27)	(0.29)	(7.84)	(1.65)	(1.83)	(0.57)	(1.59)	(2.13)	(0.77)
Uncert. x World Wars	0.29	0.02	0.01	−1.10	0.56	0.12	−0.06	0.44	0.02
	(0.50)	(0.14)	(3.92)	(1.05)	(0.87)	(0.33)	(0.93)	(1.04)	(0.48)
Uncert. x Bretton Woods	0.43***	0.22*	0.11	0.57	1.44	0.97	0.67	1.13**	0.86*
	(0.16)	(0.12)	(7.91)	(1.35)	(1.33)	(1.04)	(0.92)	(0.56)	(0.45)
Uncert. x Monetary targ.	0.37	0.15	0.07	0.93	1.27**	0.82	0.71	0.91	0.60
	(0.23)	(0.17)	(10.08)	(0.64)	(0.61)	(0.56)	(0.65)	(0.70)	(0.53)
Uncert. x Inflation targ.	2.18**	0.07	0.02	−0.19	−1.39	−0.23	−0.13	−1.28	−0.20
	(0.96)	(24.04)	(254.46)	(0.61)	(2.45)	(0.91)	(0.60)	(2.60)	(1.09)
Constant	0.58	1.14**	1.17	0.15	−0.07	0.20	0.23	−0.04	0.22
	(0.41)	(0.45)	(61.78)	(0.64)	(0.60)	(0.62)	(0.65)	(0.81)	(0.97)
N	169	169	169	169	169	169	169	169	169
R^2	0.54	0.64	0.64	0.32	0.38	0.32	0.31	0.35	0.28
Adjusted R^2	0.52	0.62	0.63	0.30	0.36	0.30	0.29	0.33	0.26

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.

in Panel (b). We find statistical significance in some regimes for the Swiss term spread. This is the case under the metallic regimes, albeit with the wrong signs of coefficients. Recall however that the term spread showed little variations during these years, which makes the economic interpretation of the coefficient delicate. We find evidence of a relation with the expected sign during the Bretton Woods era, and during the inflation targeting regime. The coefficients are however significant only when we take the inflation level, and (less so) when we consider the interquartile range.

Turning to the cross-country dimension, the results are weaker. We find some evidence of a link with the interest rate differential during the monetary targeting period, and with the UIP deviation during the Bretton Woods era. Statistical significance is only achieved when considering the interquartile range measure of uncertainty. This broadly confirms the results of the previous visual analysis, but underscores a high degree of uncertainty due to the high persistence of the underlying data.

6 Conclusion

Our analysis provides a novel assessment of Swiss interest rates and their drivers starting from the inception of the Swiss franc in 1852, and make four main contributions. First, we construct a novel data set of long-term interest rates and exchange rates for Switzerland from archival sources during the 19$^{\text{th}}$ century. Second, we apply a time-varying parameter vector autoregressive (TVP-VAR) model with stochastic volatility (SV) to extract the trends. Moroever, we introduce flexibility by allowing for mixture innovations in the state equation of the TVPs (see, McCulloch and Tsay, 1993, Gerlach et al., 2000, Giordani and Kohn, 2008). In contrast to other approaches in the literature, this modeling technique effectively allows for coefficients that are constant or evolve gradually, but that can also exhibit a few occasional abrupt structural breaks. Third, we document the patterns of interest rates and decompose the long-term nominal interest rate in its various domestic and international components using an interest rate accounting framework.

We show that Swiss interest rates were higher than abroad during the 19$^{\text{th}}$ century, as investors demanded a premium to hold assets in the still marginal Swiss franc. The Swiss franc gained its stature during the World Wards, and the premium reversed during the Bretton Woods and the Great Inflation eras. This indicates that the relatively lower inflation risk in Switzerland contributed to relatively low Swiss real interest rates. Trend inflation was as a main factor during World War 1, and even more so for the increase of nominal interest rates during the

Bretton Woods years and under monetary targeting. At the same time, a positive term spread trend emerged. The role of inflation and the term spread both declined since the 1990s and the Global Financial Crisis, respectively. One interpretation is that inflation risk contributed to the emergence and demise of the positive term spread trend. An econometric assessment of the link between inflation uncertainty and the term spread, interest rate differential, as well as the deviation from UIP shows coefficients with the expected sign. The estimates are however imprecise and rarely statistically significant.

Our paper emphasizes that, besides real factors driving the natural rate of interest, inflation risk may have partly contributed to the movements since the Bretton Woods years. According to this view, new monetary regimes focusing on stable inflation have contributed to the decline in the natural real rate of interest. Conversely, if the recent inflation increase were to affect expectations, it may lead to an increase in the real interest rate.

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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 between Confederation and cantonal bond yields.

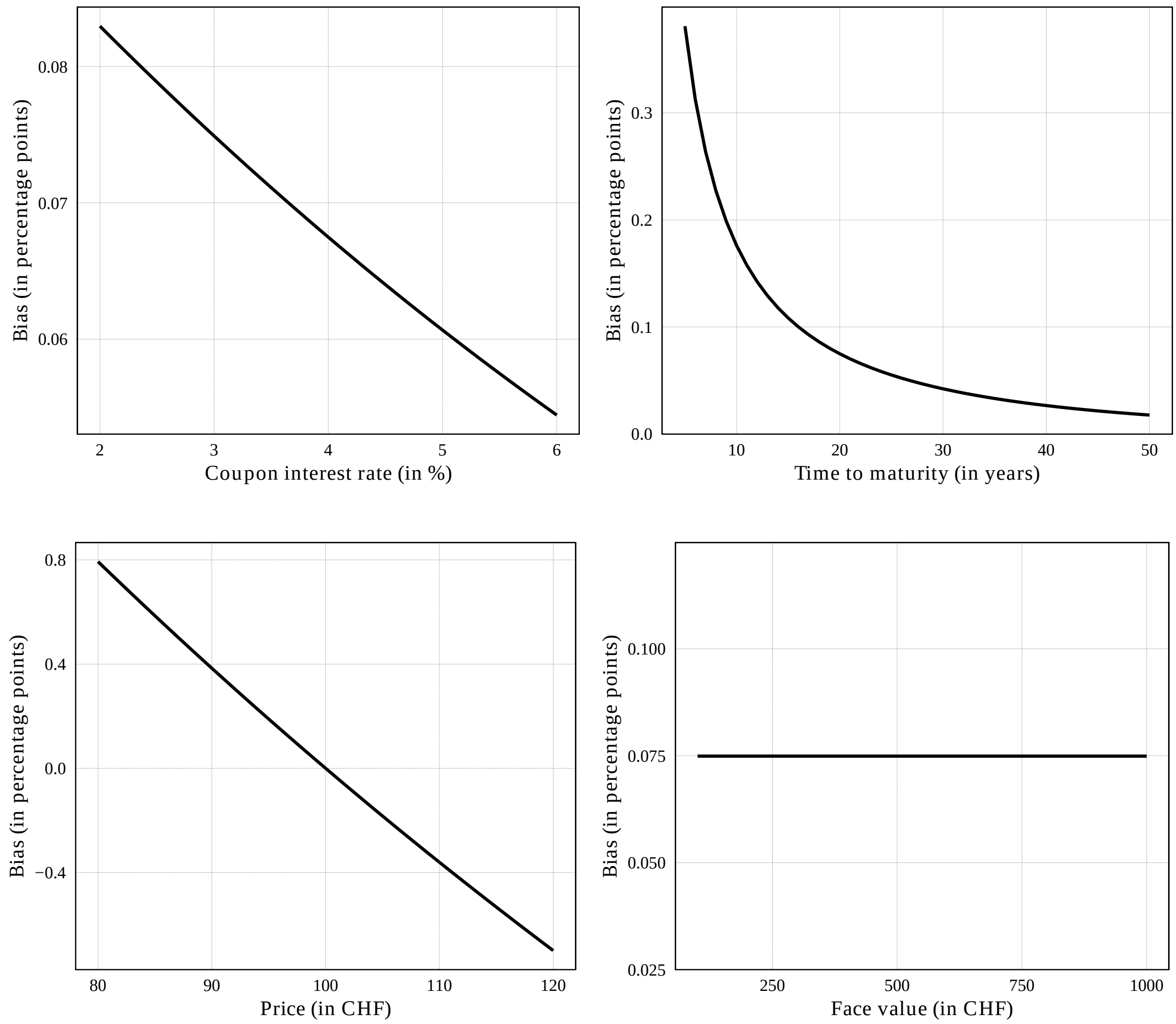
A.1 Simulation exercise

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

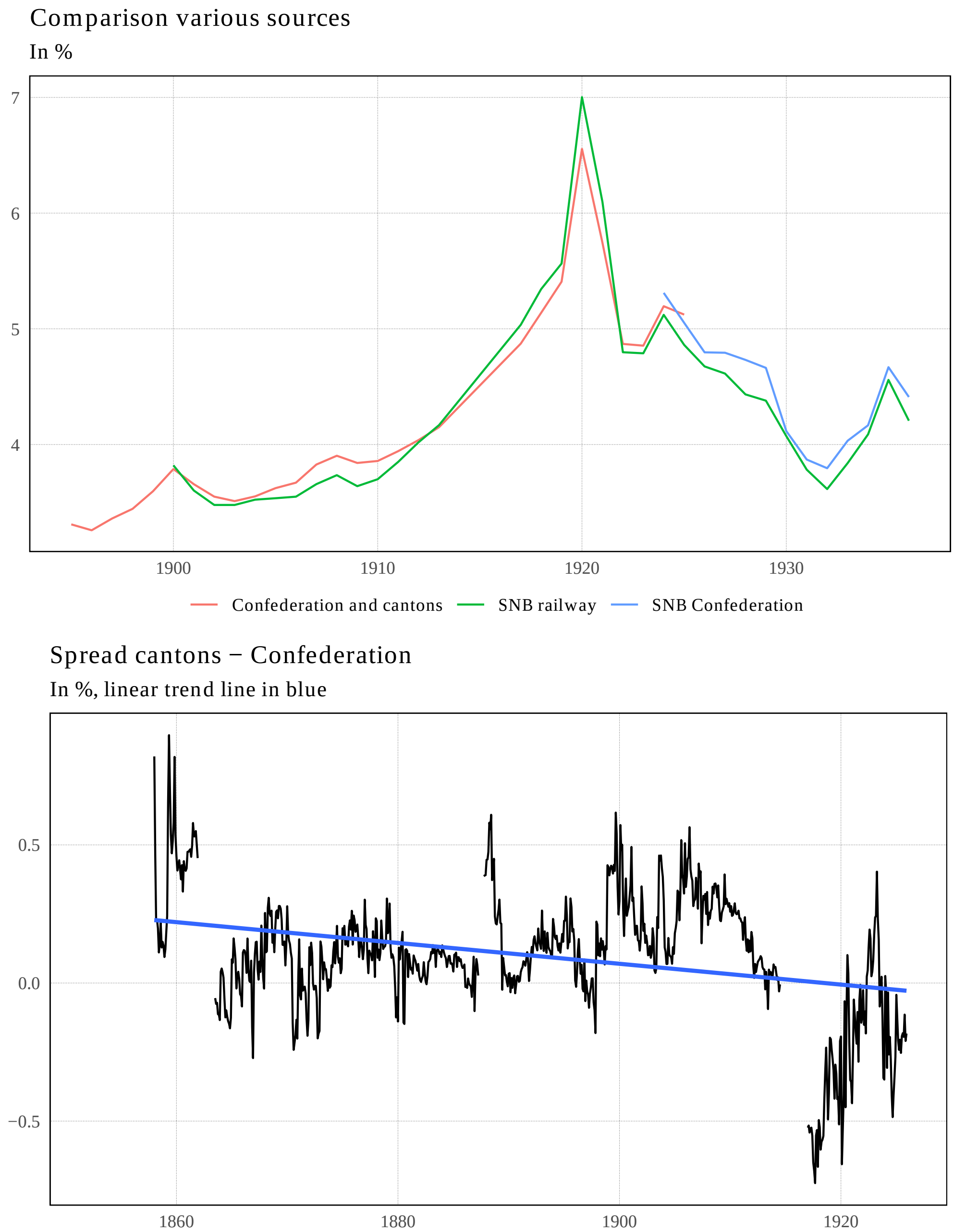


Notes: The figure shows the bias when using the current yield instead of the yield-to-maturity formulas. We assume that the true bond has a coupon interest rate of 3%, a time to maturity of 20 years, a price of CHF 98, and a face value of CHF 100. We then vary each of these characteristics for a range 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 World War 1. 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 (1915)	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).

D Technical appendix

This appendix provides technical details on the estimation of a time-varying parameter vector autoregressive (TVP-VAR) with stochastic volatility (SV) on an equation-by-equation basis, the equation-specific prior set-up, and a sketch of the Markov Chain Monte Carlo (MCMC) algorithm. In all these aspects, the structure of the model is closely related to the one proposed in Huber et al. (2019).

D.1 Equation-by-equation estimation

In this sub-section, we outline the estimation of the TVP-VAR model in Eq. (3). As noted in Sub-section 3.1, $\boldsymbol{\Sigma}_t$ can be decomposed as $\boldsymbol{\Sigma}_t = \boldsymbol{D}_t \boldsymbol{H}_t \boldsymbol{D}_t'$. We exploit this Cholesky SV specification of the variance-covariance matrix and re-write the TVP-VAR in its structural-form:

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

with $\tilde{\boldsymbol{c}}_t$ denoting an $M \times 1$ vector of structural intercepts, $\tilde{\boldsymbol{B}}_{it}$ an $M \times M$ matrix of structural coefficients, and $\tilde{\boldsymbol{D}}_t$ an $M \times M$ lower triangular matrix with zero main diagonal, measuring the contemporaneous relations between elements in $\boldsymbol{y}_t$. Furthermore, we collect all the structural coefficients related to the lags of $\boldsymbol{y}_t$ in an $M \times Mp$ matrix $\tilde{\boldsymbol{B}}_t = (\tilde{\boldsymbol{B}}_{1t}, \dots, \tilde{\boldsymbol{B}}_{pt})$. Since $\boldsymbol{H}_t$ is an $M \times M$ diagonal matrix, this model denotes a set of M unrelated TVP regressions, which can be straightforwardly estimated in an equation-by-equation manner (see, e.g, Huber et al., 2019, Hauzenberger, 2021, Lopes et al., 2021).

For $j = 1, \dots, M$, that is:

$$y_{jt} = \boldsymbol{x}_{jt}' \tilde{\boldsymbol{\beta}}_{jt} + \tilde{\epsilon}_{jt}, \quad \tilde{\epsilon}_{jt} \sim \mathcal{N}(0, h_{jt}),$$

with $\boldsymbol{x}_{jt}$ denoting a $K_j (= Mp + j) \times 1$ vector of equation-specific covariates, $\tilde{\boldsymbol{\beta}}_{jt}$ a $K_j \times 1$ vector of equation-specific time-varying coefficients, and h_{jt} the j^{th} diagonal element of $\boldsymbol{H}_t$. In particular, for the first equation ($j = 1$), $\boldsymbol{x}_{1t} = (1, \boldsymbol{y}_{t-1}', \dots, \boldsymbol{y}_{t-p}')'$ and $\tilde{\boldsymbol{\beta}}_{1t} = (\tilde{c}_{1t}, \tilde{\boldsymbol{B}}_{1\bullet,t})'$ with $\tilde{c}_{1t}$ denoting the first element in $\tilde{\boldsymbol{c}}_t$ and $\tilde{\boldsymbol{B}}_{1\bullet,t}$ the first row of $\tilde{\boldsymbol{B}}_t$, while for equation $j = 2, \dots, M$, $\boldsymbol{x}_{jt} = (1, \boldsymbol{y}_{t-1}', \dots, \boldsymbol{y}_{t-p}', \{y_{kt}\}_{k=1}^{j-1})'$ and $\tilde{\boldsymbol{\beta}}_{jt} = (\tilde{c}_{jt}, \tilde{\boldsymbol{B}}_{j\bullet,t}, \{\tilde{D}_{jk,t}\}_{k=1}^{j-1})'$ with $\tilde{c}_{jt}$ denoting the j^{th} element in $\tilde{\boldsymbol{c}}_t$, $\tilde{\boldsymbol{B}}_{j\bullet,t}$ the j^{th} row of $\tilde{\boldsymbol{B}}_t$, and $\tilde{D}_{jk,t}$ the $(j,k)^{\text{th}}$ element of $\tilde{\boldsymbol{D}}_t$. In what follows, we assume that the i^{th} element in $\tilde{\boldsymbol{\beta}}_{jt}$, $\tilde{\beta}_{ij,t}$, evolves according to the law of motion defined in Eq. (4) and (5). That is,

$$\tilde{\beta}_{ij,t} = \tilde{\beta}_{ij,t-1} + \tilde{u}_{ij,t}, \quad \tilde{u}_{ij,t} \sim \mathcal{N}(0, \kappa_{ij,t}),$$

where $\kappa_{ij,t} = \bar{\kappa}_{1,ij}$ with probability p_{ij} and $\kappa_{ij,t} = \bar{\kappa}_{0,ij}$ with probability $1 - p_{ij}$. Note that this implies exactly the same law of motion for the free elements in $\tilde{\boldsymbol{D}}_t$ as for $\tilde{\boldsymbol{B}}_t$.

Moreover, each diagonal element of $\boldsymbol{H}_t = \text{diag}(\{h_{jt}\}_{j=1}^{M})$ follows an independent SV process. That is, for $j = 1, \ldots, M$, the logarithm of the structural error variances $\log(h_{jt})$ is assumed to evolve according to an AR(1) process:

$$\log(h_{jt}) = \mu_j + \rho_j \left(\log(h_{jt-1}) - \mu_h\right) + \eta_{jt}, \quad \eta_{jt} \sim \mathcal{N}(0, \varsigma_j), \tag{6}$$

where μ_j denotes the unconditional mean, ρ_j the autoregressive parameter, and η_{jt} the state innovations with mean zero and state innovation variance ς_j.

D.2 Equation-specific prior set-up

For each equation ($j = 1, \ldots, M$), we use exactly the same prior set-up. In general, this set-up captures the notion of avoiding excessive over-fitting in an highly parameterized model, reducing estimation uncertainty of the coefficients, and thus obtaining more accurate estimates of the long-term trends.

Priors for the TVPs. On the initial state $\tilde{\boldsymbol{\beta}}_{j0}$ we use a Normal-Gamma prior (Brown and Griffin, 2010). By introducing sufficient shrinkage, this global-local shrinkage prior has been shown to be particularly useful for TVP models (see, e.g., Bitto and Frühwirth-Schnatter, 2019).

For the i^{th} element of $\tilde{\boldsymbol{\beta}}_{j0}$, $\tilde{\beta}_{ij,0}$, that is:

$$\tilde{\beta}_{ij,0} \sim \mathcal{N}(0, \theta_{ij}), \quad \theta_{ij}|\psi_j \sim \mathcal{G}(\lambda, \lambda\psi_j/2), \quad \psi_j \sim \mathcal{G}(e_0, e_1).$$

Here, θ_{ij} denotes a local scaling parameter that serves to detect important signals and ψ_j refers to a global shrinkage parameter used primarily to reduce estimation uncertainty. In the application, we set $\lambda = 0.1$ and $e_0 = e_1 = 0.01$.

By introducing a binary indicator $\delta_{ij,t}$ as an auxiliary variable, we can recast the mixture distribution for the state innovation variance as follows:

$$\kappa_{ij,t} = \delta_{ij,t}\bar{\kappa}_{1,ij} + (1 - \delta_{ij,t})\bar{\kappa}_{0,ij},$$

with $Pr(\delta_{ij,t} = 1) = p_{ij}$. These mixture indicators allow us to discriminate between a high variance and a low (almost zero) variance state. However, to obtain these discrete mixture indicators filtering techniques are required to integrate out the latent states, rendering the computation of this step burdensome (Gerlach et al., 2000, Giordani and Kohn, 2008). We therefore use the proposed latent threshold mechanism in Huber et al. (2019) to facilitate computation and approximate these auxiliary mixture indicators. Intuitively, the main mechanism of this approximation works as follows. If the change in a coefficient, $\Delta\tilde{\beta}_{ij,t} = \tilde{\beta}_{ij,t} - \tilde{\beta}_{ij,t-1}$, is sufficiently large and thus above a certain threshold r_{ij}, we set $\delta_{ij,t}$ to one; otherwise $\delta_{ij,t}$ is set to zero. On the threshold r_{ij}, moreover, we use a Uniform prior of the form: $r_{ij} \sim \mathcal{U}(\xi_{0,ij}, \xi_{1,ij})$, with $\xi_{0,ij} = 0.1\bar{\kappa}_{1,ij}$ and $\xi_{1,ij} = 1.5\bar{\kappa}_{1,ij}$.[33] Since the mixture indicators already sufficiently control the degree of dynamic sparsity and shrinkage, we use a relatively uninformative inverse Gamma prior on $\bar{\kappa}_{1,ij} \sim \mathcal{IG}(\zeta_{0,ij}, \zeta_{1,ij})$, with shape $\zeta_{0,ij} = 3$ and scaling $\zeta_{1,ij} = 0.03$.

Priors for SV. To complete the prior set-up, we use relatively standard choices for SV. Following Kastner and Frühwirth-Schnatter (2014), we specify a Gaussian prior on the unconditional mean $\mu_j \sim \mathcal{N}(0, 10)$ as well as on the initial state $\log(h_{j0}) \sim \mathcal{N}\left(\mu_j, \varsigma_j/(1-\rho_j^2)\right)$, a Beta prior on the (transformed) autoregressive parameter $(\rho_j + 1)/2 \sim \mathcal{B}(5, 1.5)$ and a Gamma prior on the state innovation variance $\varsigma_j \sim \mathcal{G}(0.5, 0.5)$.

D.3 Equation-specific posterior simulation

In this sub-section we briefly summarize our posterior simulation algorithm. The exact forms of the full conditional posterior distributions can be found in Huber et al. (2019). To simulate from the joint posterior distribution of the M flexible equation-specific TVP regressions, we use Markov Chain Monte Carlo (MCMC) methods with most steps being relatively standard. Specifically, for the j^{th} equation, we rely on a Gibbs Sampler that iterates through the following steps:

1. **Sample the full history of the TVPs $\{\tilde{\beta}_{ij,t}\}_{i=1}^{K_j}$, for $t = 0, \ldots, T$.** Conditional on all other parameters of the model, the TVPs can be drawn with a forward-filtering backward-sampling Carter and Kohn (1994) and Frühwirth-Schnatter (1994) algorithm.

2. **Sample auxiliary parameters of the Normal-Gamma prior for the initial states $\tilde{\beta}_{j0}$ of the TVPs.** Following Brown and Griffin (2010), we sample the local scaling parameters $\{\theta_{ij}\}_{i=1}^{K_j}$ independently from a generalized inverse Gaussian distribution and the global shrinkage parameter ψ_j from a Gamma distribution.

3. **Sample the latent thresholds $\{r_{ij}\}_{i=1}^{K_j}$ and define the binary mixture indicators.** We simulate the approximated discrete mixture indicators by using a Griddy Gibbs. We

[33] For a thorough discussion on this choice, see Huber et al. (2019).

therefore define a discrete grid of size 150 for the threshold r_{ij} bounded between $\xi_{0,ij}$ and $\xi_{1,ij}$. For each proposed value, we evaluate the posterior of r_{ij} by combining the likelihood of $\Delta\tilde{\beta}_{ij,t}$, for $t = 1, \ldots, T$, with the Uniform prior on r_{ij}. Based on these latent thresholds, we straightforwardly obtain the mixture indicators $\{\delta_{ij,t}\}_{i=1}^{K_j}$ for each point in time.

4. **Sample the time-varying log-volatilities of the structural error variance** $\log(h_{jt})$**.** We sample latent log-volatility process and the parameters of the SV state equation with the algorithm implemented in Hosszejni and Kastner (2021).

For each equation, we repeat this steps 50,000 and discard the first 10,000 draws as a burn-in. Of the retained 40,000 draws, we keep every other draw for posterior inference.