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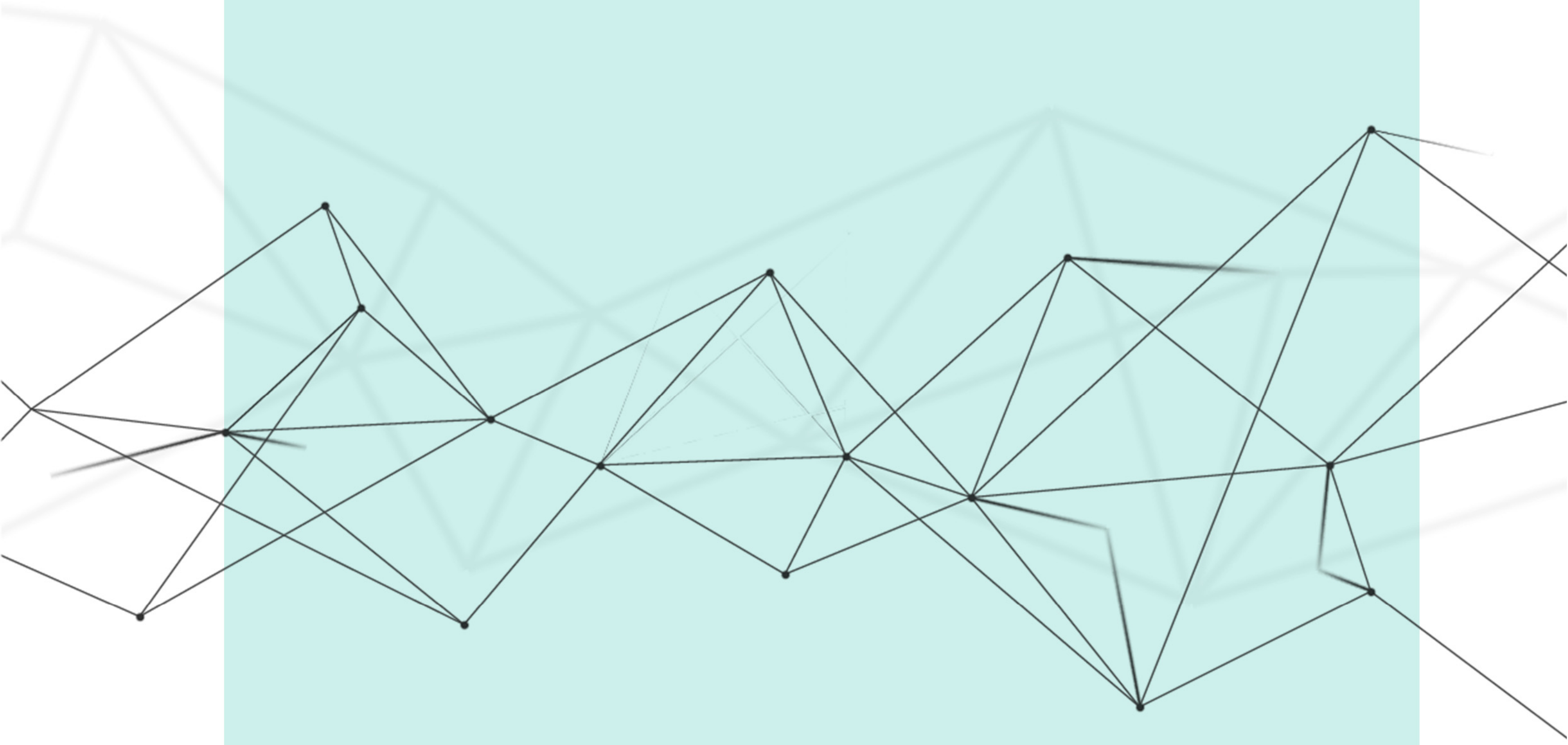

Grundlagen für die
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Anmerkungen
Studie im Auftrag des Staatssekretariats für Wirtschaft SECO.

Der vorliegende Text gibt die Auffassung der Autoren wieder. Diese muss nicht notwendigerweise mit derjenigen des Auftraggebers übereinstimmen.

Interest rates in Switzerland 1852-2020

Summary

The large structural decrease in real interest rates presents challenges for policy makers, for instance hindering the ability of central banks to lower policy rates during recessions. We put this decrease in historical perspective for Switzerland by constructing quarterly data going back to 1852 using novel archival sources and statistical methods. We extract long-term trends for interest rates, inflation, and exchange rate growth, and split the nominal interest rate trend into various components. Using an econometric analysis, we relate the real interest rate to monetary regimes, changes in the pension system, international developments, as well as demographic changes.

Nominal interest rates have reached historical lows since the Global Financial Crisis. The persistent decline in inflation explains only part of this pattern. The real interest rate, which removes changes in inflation developments, went through an up-down cycle since the 1970's, albeit to a lesser extent than in other countries. During the 19th century Swiss interest rates were above foreign ones, as Switzerland was still an emerging economy at the time. An increase in trend inflation after Switzerland left the Gold Exchange Standard in 1936 pushed nominal interest rates higher. Nevertheless, Switzerland became an ‘interest rate island’ after 1945, as Swiss real interest rates included a negative premium compared to other countries. While this specificity became less important since the 1980’s, Swiss nominal interest rates still declined thanks to lower trend inflation and lower foreign interest rates. The decrease was accentuated in 2015, when the term spread between short- and long-term rates vanished after the Swiss National Bank abandoned an exchange rate floor policy and the European Central Bank started a large-scale asset purchase program.

An econometric analysis shows that the Swiss real interest rate reflects global drivers and demographic factors. Specifically, a higher share of the elderly population lowers the real interest rate, with an opposite effect for the share of the young population. Furthermore, over the last 20 years, the interest rate island vanished, pushing up Swiss rates relative to other countries. While this recent increase can appear surprising, it is important to bear in mind that it captures an effect relative to the rest of the world, where central banks have moved towards monetary policy regimes more conducive to price stability. This may have contributed to a convergence of international to Swiss interest rate trends.

While projections are delicate, as long-term interest rate trends can change rapidly, the low inflation trend observed since the Global Financial Crisis, low global real interest rates, and the shift of the age structure of the Swiss population towards a higher share of older people are likely to keep Swiss nominal and real interest rates low. The Covid-19 pandemic may further reinforce this pattern (Jordà et al. 2020). Low interest rates will thus likely remain a challenge for policy makers.

Zinsen in der Schweiz 1852-2020

Zusammenfassung

Der starke strukturelle Rückgang der Realzinsen stellt die politischen Entscheidungsträger vor grosse Herausforderungen. Zum Beispiel behindert das Tiefzinsumfeld die Zentralbanken, in Rezessionen die Leitzinsen zu senken. Wir analysieren den Rückgang der Realzinsen in der Schweiz aus einem historischen Blickwinkel. Dazu konstruieren wir mit primären Quellen und statistischen Methoden vierteljährliche Daten, die bis ins Jahr 1852 zurückreichen. Aus diesen Daten extrahieren wir langfristige Trends für Zinssätze, Inflation und Wechselkurswachstum. Dann zerlegen wir den Trend der langfristigen Nominalzinsen in verschiedene Komponenten. Schliesslich untersuchen wir mit einer ökonometrischen Analyse, ob der langfristige Realzins von monetären Regimen, Veränderungen in der Altersvorsorge, internationalen Faktoren, sowie dem demographischen Wandel abhängt.

Die Nominalzinsen haben seit der globalen Finanzkrise historische Tiefststände erreicht. Der anhaltende Rückgang der Inflation erklärt jedoch nur einen Teil dieser Entwicklung. Tatsächlich durchlief der Realzins, der um die Inflationsentwicklung bereinigt ist, seit den 1970er Jahren eine Auf- und Abwärtsbewegung, wenn auch in geringerem Ausmass als in anderen Ländern. Während des 19. Jahrhunderts lagen die Schweizer Zinssätze über denjenigen im Ausland, da die Schweiz damals noch ein Schwellenland war. Ein Anstieg der Trendinflation nach dem Austritt der Schweiz aus dem Goldstandard im Jahr 1936 liess die Nominalzinsen steigen. Trotzdem wurde die Schweiz nach dem zweiten Weltkrieg zu einer "Zinsinsel", das heisst, die Schweizer Realzinssätze enthielten im Vergleich zu anderen Ländern eine negative Prämie. Während diese Besonderheit seit den 1980er Jahren an Bedeutung verlor, gingen die Schweizer Nominalzinssätze dank der niedrigeren Trendinflation und der niedrigeren ausländischen Zinssätze dennoch zurück. Wir beobachten zudem einen weiteren Rückgang im Jahr 2015, was auf einen Rückgang der Differenz zwischen lang- und kurzfristigen Zinsen zurückzuführen ist. Zur gleichen Zeit gab die Schweizerische Nationalbank eine Wechselkursgrenze auf und die Europäische Zentralbank begann in grossem Still Vermögenswerte zu kaufen.

Die ökonometrische Analyse zeigt, dass der Schweizer Realzins durch globale Faktoren und die demografische Entwicklung beeinflusst wird. Insbesondere senkt ein höherer Anteil der älteren Bevölkerung den Realzins, mit einem gegenteiligen Effekt für den Anteil der jungen Bevölkerung. In den letzten 20 Jahren ist zudem die Zinsinsel verschwunden, was sich in höheren Schweizer Realzinsen im Vergleich zu anderen Ländern widerspiegelt. Dies mag überraschend erscheinen. Jedoch ist es wichtig zu betonen, dass die Analyse den Effekt relativ zum Ausland erfasst. Tatsächlich haben in dieser Zeit viele industrielle Länder ihr geldpolitisches Regime vermehrt auf Preisstabilität ausgelegt, wodurch sich die Zinsentwicklung der Schweiz angenähert haben dürfte.

Zwar sind Projektionen heikel, da sich langfristige Zinstrends schnell ändern können. Mehrere Faktoren weisen jedoch darauf hin, dass das Niedrigzinsumfeld anhalten dürfte. Der seit der globalen Finanzkrise beobachtete niedrige Inflationstrend, die weltweit niedrigen Realzinsen und die Alterung der Schweizer Bevölkerung dürften sowohl die Schweizer Nominal- und Realzinsen niedrig halten. Zudem könnte die Covid-19-Pandemie diese Entwicklung weiter verstärken (Jordà et al. 2020). Niedrige Zinssätze werden daher in naher Zukunft wahrscheinlich eine Herausforderung bleiben.

Taux d'intérêt en Suisse de 1852 à 2020

Résumé

La forte baisse structurelle des taux d'intérêt réels est source de défis pour la politique économique, entravant par exemple la capacité des banques centrales à réduire leurs taux directeurs lors de récessions. Nous offrons une perspective historique pour la Suisse en construisant des données trimestrielles depuis 1852, combinant de nouvelles sources d'archives et approches statistiques. Nous calculons les tendances à long terme pour les taux d'intérêt, l'inflation et les mouvements du taux de change, puis décomposons la tendance des taux d'intérêt nominaux en plusieurs composantes. Notre analyse économétrique montre le lien entre le taux d'intérêt réel et les régimes monétaires, les changements du système de retraites, les développements globaux, ainsi que les changements démographiques.

Les taux d'intérêt nominaux ont atteint des niveaux historiquement bas depuis la crise de 2008. La faible inflation n'explique qu'une partie de cette évolution. Le taux d'intérêt réel – c’est-à-dire corrigé de l’inflation – a connu un cycle d’une hausse suivie d’une baisse depuis les années 1970, mais dans une moindre mesure qu’ailleurs. Au XIXe siècle, les taux d'intérêt suisses étaient supérieurs aux taux étrangers, car la Suisse était alors encore une économie émergente. L’augmentation de l'inflation tendancielle après la sortie de la Suisse de l’étalon-or en 1936 a poussé les taux d'intérêt nominaux à la hausse. Pourtant, la Suisse est devenue une "île de taux d'intérêt" après 1945, avec ses taux d'intérêt affichant une prime négative par rapport aux autres pays. Bien que cette spécificité soit devenue moins importante depuis les années 1980, les taux d'intérêt nominaux suisses ont tout de même baissé du fait de la baisse de l’inflation tendancielle, ainsi que la baisse des taux d'intérêt étrangers. Cette dynamique s'est accentuée en 2015, avec la disparition de l'écart entre les taux à court et à long terme suite à l’abandon du taux de change plancher par la Banque nationale suisse et le programme d'achat d'actifs à grande échelle de la Banque centrale européenne.

Notre analyse économétrique montre que le taux d'intérêt réel suisse reflète les facteurs mondiaux et les aspects démographiques. Plus précisément, une part plus élevée de la population âgée fait baisser le taux d'intérêt réel, avec un effet inverse pour la part de la population jeune. En outre, la disparition de l'îlot de taux d'intérêt a fait augmenter les taux suisses par rapport aux autres pays. Si cette hausse récente peut paraître surprenante, il faut garder à l'esprit qu'elle représente un effet relatif par rapport au reste du monde, où les banques centrales ont renforcé la stabilité des prix. Ceci a pu contribuer à une convergence des taux d’intérêts étrangers vers les niveaux suisses.

Bien que les projections soient délicates, car les tendances à long terme des taux d'intérêt peuvent rapidement changer, il est probable que la faible inflation tendancielle depuis 2008, les faibles taux d'intérêt réels mondiaux, et le changement de la structure de la population suisse vers une part accrue de personnes âgées maintiennent les taux d'intérêt nominaux et réels suisses à un bas niveau. La pandémie de Covid-19 pourrait encore renforcer cette tendance (Jordà et al. 2020). Les taux d'intérêt bas resteront donc probablement un défi pour la politique économique.

Tassi d’interesse in Svizzera 1852-2020

Riassunto

La forte diminuzione strutturale dei tassi di interesse comporta numerose sfide per i policy makers, per esempio ostacolando la capacità delle banche centrali di abbassare i tassi ufficiali in caso di recessione. Questo fenomeno è inserito in una prospettiva storica per la Svizzera attraverso la ricostruzione di una serie storica su base trimestrale a partire dal 1852: tale ricostruzione avviene utilizzando nuove fonti archivistiche e innovativi metodi statistici. In questo contesto, vengono estratti trend di lungo periodo per tassi di interesse, inflazione e crescita dei tassi di cambio. Inoltre, il trend del tasso d’interesse nominale viene suddiviso in diverse componenti. Attraverso un’analisi econometrica, il tasso d’interesse reale viene messo in relazione con regimi monetari, cambiamenti nel sistema pensionistico, sviluppi interazionali, così come cambiamenti demografici.

I tassi di interesse nominali hanno raggiunto oggi il loro minimo storico dalla crisi finanziaria globale. Il costante declino dell’inflazione spiega solo in parte il pattern osservato. Il tasso di interesse reale, che è adeguato ai cambiamenti dovuti all’inflazione, ha attraversato un ciclo ascendente-discendente dagli anni 70, anche se in misura minore rispetto a ciò che è stato osservato in altri paesi. Nel corso del XIX secolo, i tassi di interesse in Svizzera si trovavano al di sopra dei tassi esteri, in quanto la Svizzera era al tempo un’economia in fase emergente. Un aumento nel trend dell’inflazione, dopo che la Svizzera abbandonò la Gold Exchange Standard nel 1936, spinse i tassi di interesse nominali verso l’alto. A partire dal 1945, la Svizzera diventò una cosiddetta “isola dei tassi”, dato che i tassi di interesse reali svizzeri includevano un premio negativo rispetto ad altri paesi. Mentre questa specificità perdeva d’importanza a partire dagli anni 80, i tassi di interesse nominali svizzeri continuavano a diminuire a causa di un inferiore trend dell’inflazione e di più bassi tassi di interesse esteri. La diminuzione si accentuò nel 2015, quando la differenza (o spread) tra i tassi a breve termine e quelli a lungo termine svanì a seguito di due importanti eventi: l’abbandono da parte della Banca Nazionale Svizzera della cosiddetta politica del tasso minimo di cambio e l’inizio di un programma di acquisto di asset su larga scala da parte della Banca Centrale Europea.

L’analisi econometrica mostra che il tasso d’interesse reale svizzero riflette sia tendenze mondiali sia fattori demografici. Nello specifico, una maggiore porzione di anziani (giovani) nella popolazione riduce (aumenta) il tasso di interesse reale. Inoltre, nel corso degli ultimi vent’anni, lo status svizzero di “isola dei tassi” è svanito, spingendo i tassi maggiormente verso l’alto rispetto ad altri paesi. Nonostante questo recente incremento possa risultare sorprendente, è importante tenere a mente che esso coglie un effetto in relazione al resto del mondo, dove le banche centrali si sono allineate alla Svizzera nella gestione della politica monetaria, focalizzandosi maggiormente sulla stabilità dei prezzi. Ciò, infatti, potrebbe aver contribuito alla convergenza dei tassi internazionali nella direzione di quelli svizzeri.

Le previsioni sono una materia delicata, in quanto i trend dei tassi di interesse a lungo termine possono cambiare rapidamente. Il modesto trend dell’inflazione osservato a seguito della crisi finanziaria globale, i bassi tassi di interesse reali globali e l’invecchiamento progressivo della popolazione sono fattori che con ogni probabilità tengono bassi i tassi di interesse nominali e reali. La pandemia di Covid-19 potrebbe ulteriormente rinforzare questo pattern (Jordà et al. 2020). Di conseguenza, i bassi tassi di interesse rimarranno probabilmente una sfida per i policy makers.

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Abbreviations

BIS Bank for International Settlements

CHF Swiss franc

CPI Consumer price index

ECB European Central Bank

GBP Pound Sterling

GDP Gross Domestic Product

NOK Norwegian krone

SFSO Swiss Federal Statistical Office

SNB Swiss National Bank

TVP-VAR Time-varying parameter vector-autoregression

UK United Kingdom

US United States

USD US Dollar

VAR Vector-autoregression

WPI Wholesale price index

1 Introduction

Declining nominal and real interest rates have been a major feature of the global macroeconomic environment over the last twenty years.[1] This has been documented not only for the United States (Laubach and Williams, 2016), but also for other advanced economies (Del Negro et al., 2019, Jordà et al., 2020). Lower interest rates raise substantial challenges, for instance for pension funds due to legally imposed minimum returns, as well as for central banks due to the effective lower bound (Andrade et al., 2021). While earlier contributions focused on the period since the late 20th century, several recent studies have extended the sample period backwards to put recent trends in a long perspective.

In this paper we contribute to the understanding of the evolution of interest rates in Switzerland in a historical perspective. Our contribution is fourfold. First, we construct quarterly time series for interest rates, inflation, and the exchange rate going back to the introduction of the Swiss franc in 1852. Second, we extract long-term trends from these series using an approach that allows for structural shifts, even sudden ones, in the economy. Third, we contrast the behavior of the Swiss real interest rate trend against the rest of the world. Finally, we link the real interest rate trend to demographic factors, the evolution of the Swiss pension system, and the various Swiss monetary regimes.

An analysis over a long sample, such as ours, is faced with the usual challenges of historical data that are often measured at low frequency and subject to measurement errors (see, e.g., Kaufmann, 2020). This issue is particularly pervasive for macroeconomic indicators, while financial variables are better measured. In addition, existing historical data for Swiss interest rates and exchange rates at a frequency higher than annual are not available for most of the 19th century.

We extend the coverage of financial data for 19th century Switzerland by constructing short-term interest rates, long-term interest rates and exchange rates from a variety of archival sources.

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[1] We cordially thank Teodoro Bevilacqua, Marc Burri, Rui Esteves, Patrick Halbeisen, Martin Lüpold, and Aronne Watkins, for invaluable discussions and help with historical data.

While Swiss price data exist over the entire period, they only cover (wholesale) prices at an annual frequency until the early 20th century, which is the starting date for the Swiss Federal Statistical Office's (SFSO) official price indexes. We disaggregate the annual data to quarterly frequency, and clean them from measurement error, by relying on the observed co-movement between quarterly inflation, interest rates, and exchange rate growth after 1922, using a mixed-frequency vector autoregressive model (Schorfheide and Song, 2015). We then use this model to predict the missing quarterly inflation series before 1922.

From these quarterly data, we extract estimates of the long-term trend for interest rates, inflation and exchange rate growth. The standard approach for estimating the long-term real interest rate trend relies on restrictions from a theoretical model imposed on observed data (Laubach and Williams, 2016). While this approach has the advantage of relying on insights from economic theory, it assumes a stable structure of the economy across time. This is questionable when taking a long-term view, as we do. The international monetary regime went through several changes, with times of fixed and floating exchange rates. Globalization and capital mobility have also gone through, sometimes rapid, changes. To account for such structural changes we use a time-varying parameter vector autoregressive (TVP-VAR) model. In the spirit of Beveridge and Nelson (1981), we extract long-term trends that represent the values at which variables will stabilize once temporary fluctuations have dissipated.

Our method provides us with long-term trends of nominal interest rates and inflation in Switzerland and abroad. These trends indicate that until World War 1 the Swiss nominal interest rate was higher than abroad. Because inflation in Switzerland was quite similar to foreign inflation under the metallic currency regimes of the 19th century, this implies that the real interest rate was relatively high as well. This pattern was subsequently reversed during the interwar period as Switzerland gained a safe haven status, and the Swiss interest rate proved less volatile than foreign rates. During the 20th century real interest rates declined in Switzerland, as in the rest of the world. A clear decrease is observed before World War 2, after which real rates remained steady and low for several decades. They increased in the 1970's and 1980's, before moving down to reach the current low values. While the up-down trend since the 1970's is observed both in Switzerland and abroad, its magnitude was smaller in Switzerland.

While providing a thorough assessment of the drivers of real interest rates goes beyond our report, we assess the role of the world real interest rate trend, demographic factors, as well as the influence of monetary policy regimes and the structure of the retirement system. We find that the Swiss long-term real interest rate trend is strongly influenced by global factors, reflected in the foreign real interest rate trend. On top of these, we show that population aging (higher share of older people, and lower share of younger people) lowers the Swiss real interest rate. The shift to the new monetary policy framework since 2000 and the introduction of the capitalization leg of the pension system have coincided with a higher real interest rate trend rate. While this last finding is surprising, it could reflect that other countries have focused more and more on stabilizing inflation, and therefore became more similar to the Swiss monetary environment.

The rest of the paper is structured as follows. Chapter 2 reviews the related literature. Chapter 3 presents and explains existing and newly constructed data. We then analyze the long-term trends in Chapter 4. Chapter 5 presents the econometric analysis on the drivers of Swiss real interest rate trends. Chapter 6 concludes.

2 Related literature

2.1 Historical estimates of prices and interest rates

Historical data are frequently imperfect. In a series of papers, Romer (1986, 1989, 1994) cautions against the widely held view that US macroeconomic indicators became less volatile in the post-War period, as this result might reflect measurement errors in the earlier data rather than structural changes in economic cycles or policy. Similarly, Kaufmann (2020) shows that previously held views on the largely benign impact of deflationary periods on output may actually arise from measurement errors in historical price data. These studies point out that many economic time series are constructed retrospectively using underlying data which were not collected for that purpose. Working with historical data therefore presents challenges which are often overlooked because they are not relevant for recently compiled data.

Since the underlying data were not collected with the purpose of constructing time series, indicators that are retrospectively constructed often include errors. Price indices are a case in point. Kaufmann (2020) investigates a number of ways in which they can be mis-measured. These include the use of wholesale prices to approximate retail prices, as wholesale commodity prices were frequently published in newspapers while retail prices were less likely to be recorded. A similar lack of records affects the prices of services which, as a result, often comprise only a small share of the overall basket.[1] In addition, price indices for small geographical areas are often used to represent prices for a country as a whole. Data may be collected in the main cities, but not in large towns or the countryside. Given that the urbanization of populations proceeded over time, this generalization may be particularly egregious in historical data. Finally, a small number of individual price quotes are often used to construct broader price indices, leading to substantial sampling error in historical price data.

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[1] This also reflects the changing structure of the economy, whereby services have increased in importance in the consumer basket over time. This issue is particularly relevant to the measurement of rent, which is frequently not collected at all, or only at a very low frequency.

Interest rate data also present issues. In some countries, governments did not issue long-term debt until, from a historical perspective, fairly recently. Even in the US, the only available bond yield series for much of the 19th century is based solely on railway bonds (Bordo and Haubrich, 2008a,b). In other countries, such as Sweden, long-dated debt was issued but short-term debt was not. As a result, a discount rate is used as a proxy of the short-term risk-free rate (Waldenstrom, 2014). Moreover, compiling data on bond yields presents several challenges. Historically, the number of listed bonds was much smaller than today, markets were less liquid, and bonds were less homogeneous with a variety of call options, repayment plans, seniority clauses, lottery bonds, etc. (see, e.g., Velde, 2018). All of these factors complicate the compilation of historical bond yields.

Another issue facing researchers using historical data is their frequency. This may reflect the limited resources of the compiler, rather than the availability of data: recent technological improvements have enabled researchers to compile more detailed databases.[2] Still, historical data sometimes simply are not available at a high frequency. This is particularly the case for macroeconomic data, for instance GDP or CPI inflation, as they were less closely observed at the time (Stuart, 2018). By contrast historical financial data are often available at a high frequency because they were closely watched by market participants and published in newspapers. As a result, many historical macroeconomic series can only be constructed at a much lower frequency than more recent series and must therefore be interpolated.

Despite these challenges, several historical macro-finance history databases have been compiled in recent years. Perhaps the most widely known is the Jordà-Schularick-Taylor database, which compiles annual data since 1870 for national income and its components, public debt, money, interest rates, bond yields, bank balance sheet information, exchange rates quotes and exchange rate regimes, as well as housing and equity returns (Jordà et al., 2017). The geographical scope of the database has recently been expanded and now includes eighteen advanced economies.

The Jordà-Schularick-Taylor database is largely collected from secondary sources – that is, the authors collect data that has already been compiled by other scholars. This can lead to differences in the methodology underlying the series in the database. In contrast, the database compiled by Flandreau and Zummer (2004) and subsequently extended by Accominotti et al.

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[2] Increasing the frequency of data can change our understanding of historical events. One example relates to the impact of the Latin Monetary Union (LMU), of which Switzerland was a founding member, on trade patterns. Flandreau (2000) used data at a 10-year frequency to study the impact of LMU membership on trade and found no statistically significant relationship. However, Timini (2018) studied a similar question using annual data and found that LMU membership had a significant impact on trade during the period 1865-1874.

(2010), builds annual data from 1880 to 1913 from primary or intermediate sources, ensuring comparability across the countries in the sample.[3]

2.2 The natural real interest rate

Over the last decade, a large literature has analyzed the so-called natural or equilibrium real interest rate (usually denoted by R^*), which is the real interest rate that would prevail in an economy where prices and wages adjust freely. It can be understood as the interest rate when inflation is zero and the business cycle is neutral – or more exactly cyclical fluctuations of economic activity are exclusively driven by efficient responses to shocks. Put differently, R^* is the real interest rate that prevails once temporary fluctuations dissipate, i.e. the long-run forecast of the real interest rate.

2.2.1 Estimating the natural real interest rate

The standard approach for estimating the natural rate filters the data to identify the unobserved underlying state, a procedure that requires imposing restrictions from a macroeconomic model (see Laubach and Williams, 2003). This approach has the advantage that it imposes restrictions from economic theory and may therefore yield more precise estimates. The downside is, however, that these theoretical relationships are assumed to accurately represent the true economic structure, and this structure has to be stable over time.

To account for time-variation in the underlying structure, TVP-VARs are increasingly adopted to estimate the natural rate of interest. Del Negro et al. (2017) use flexible TVP-VARs to estimate R^* for the US, and Del Negro et al. (2019) use a similar model to estimate the global R^* using a long panel over several countries. These models allow for structural changes but assume that they happen gradually. Such gradualism can be at odds with the data, as some changes, such as changes in exchange rate regimes and wars, can lead to more sudden changes in the structure of the economy. Therefore, Giordani and Kohn (2008) account for rapid changes in the US natural real interest rate by allowing for some large structural breaks.

Reduced-form approaches, that is approaches that do not impose economic restrictions, to estimate long-term trends have a long tradition in macroeconomics. For instance, Lucas (1980), uses linear filtering techniques to extract the persistent component of money growth and investigates how it relates to trend inflation. More recently, Cogley et al. (2010) rely on

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[3] See also, the database of Albers (2018), which collects macro data for 28 countries, primarily at a quarterly frequency, during the interwar period.

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).

2.2.2 How has the natural real interest rate evolved?

Laubach and Williams (2016) use an approach following Laubach and Williams (2003) and present updated estimates of the natural rate of interest that impose restrictions from economic theory for the US and conclude that the natural rate has been on a decreasing trend since the 1980's, with the trend falling more strongly during the Global Financial Crisis of 2008-2009.

Several papers have extended the estimates to longer samples and a broader range of countries, all reaching the conclusion that the natural rate has decreased over the last 30 to 40 years. Del Negro et al. (2017) construct estimates based on a theoretical model for the United States since 1960, and also compute estimates using a reduced-form approach. They document a clear decrease since the late 1980's. Del Negro et al. (2019) assess the natural rate for seven advanced economies over a long sample starting in 1870. They find that the 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. These changes occurred very gradually over time. The common element of the natural rate for the various countries has become stronger in recent decades, pointing to the presence of a global factor.

Fiorentini et al. (2018) also consider a long sample starting in 1890 for 17 countries, improving the method by Laubach and Williams (2003) to handle periods with underlying changes in the structure of the economy. They find a similar path as other studies with an increase in the natural rate from 1960 to the late 1980's, followed by a decrease. 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. Jordà et al. (2020) estimate the natural real interest rate for France, Germany, Italy, Netherlands, Spain and the UK using annual data starting, in some cases, as early as the 14th century. Focusing on the effect of pandemics, they argue that the impact on the natural real interest rate can last for decades.

Several studies include 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.

2.2.3 What drives the recent decrease in the natural real interest rate?

A central equilibrium relation in dynamic macroeconomic models is the so-called Euler condition, which relates the real rate of return on assets to macroeconomic conditions and the characteristics of the assets (see Box 1 for a technical discussion).

Box 1: The Euler condition

The Euler condition states that the expected real return on an asset k between periods $t-1$ and t, denoted by $E_{t-1}r_t^k$, reflects the expectation of the growth rate of consumption, $E_{t-1}g\left(c_t\right)$, the impatience of agents $impatience_t$ (related to the time discount factor in the utility), and the covariance between consumption and the real return on the asset, $Cov_{t-1}\left(c_t; r_t^k\right)$:

$$E_{t-1}r_t^k = E_{t-1}g\left(c_t\right) + impatience_t + Cov_{t-1}\left(c_t; r_t^k\right)$$

The expected real return is high when consumption grows rapidly, agents are impatient, or the asset is a bad hedge for consumption risk, with a low return when consumption is low (a positive covariance).

The real rate of return on asset k can further be split between the rate of return on a reference asset (such as a safe and liquid government bond) and a spread: $r_t^k = r_t^{reference} + spread_t^k$. The spread includes a risk premium, as well as any non-pecuniary convenience that the reference asset can bring, such as being traded on a more liquid market.

Specifically, the rate of return on all assets is higher in a fast-growing economy, or when investors are impatient and put little weight on the future. In addition, an asset earns a lower return if it is useful for insuring against fluctuations in consumption. Finally, an asset that is less risky or traded on more liquid markets offers a lower return.

A first potential source of the reduction in the natural rate of interest can be a reduction in the long-term growth rate. Gordon (2015) argues that a decreasing pace of innovation has translated into a lower growth rate in the United States. While growth has slowed in advanced economies since the Global Financial Crisis, its role as a driver of the reduction of the natural rate of interest remains a subject of debate. Rachel and Summers (2019) argue that lower growth played a material role. Pescatori and Turunen (2016) find evidence for the impact of a lower growth rate, as do Del Negro et al. (2017) for the US. However, they also estimate that growth has not been the main factor. Fiorentini et al. (2018) only find a secondary impact of growth on their large geographic sample. The impact of growth on the real interest rate operates through the demand for investment from firms. Gruber and Kamin (2016) find that investment has decreased because of lower growth expectations and cheaper capital goods.

The literature has found changes in the discount factor to be more relevant, coming from several sources. A major one is demographic change, as savings are relatively high in a country with a low share of young people relative to middle aged people. Gagnon et al. (2016) use a multi-generation model calibrated to the US economy and find that the life cycle of the baby boom generation played a major role in the initial increase in the natural interest rate and its subsequent decrease. Fiorentini et al. (2018) put demographic change at the heart of the rise and fall cycle of the natural interest rate in advanced economies, especially in Europe. Fuhrer and Herger (2021) show that a higher population growth rate raises the real interest rate, provided it is driven by natural growth rather than immigration. Further papers finding demographic change influences the real interest rate include Favero et al. (2016), Rachel and Summers (2019), Rachel and Smith (2017), and Marx et al. (2019). Although, the latter point to a limited impact.

A second source of change in the discount factor is an increase in the propensity to save. Pescatori and Turunen (2016) point to higher global savings as a contributing factor, and Lo and Rogoff (2015) stress the role of a long deleveraging process after the Global Financial Crisis. These can reflect the larger share of high savings countries in the world economy. Marx et al. (2019) point to precautionary savings from non-insurable idiosyncratic risk as a central element in the fall of the return on safe assets.

The evidence on the recent decrease in the natural rate of interest focuses on long-term government bonds, which in many countries are relatively safe and liquid. By contrast, the return on capital has not shown a clear downward trend (Marx et al., 2019). Recent studies have thus focused on the special nature of government bonds. A first feature is that they offer a safe asset, and households usually prefer to invest their precautionary savings in such a safe asset (Marx et al., 2019). Del Negro et al. (2019) and Del Negro et al. (2017) put the convenience yield, which is the discount that investors accept to be able to hold safe and liquid assets, offered by government bonds at the heart of their analysis, and they estimate that the increased advantage of these assets in terms of safety and liquidity are the driving factor in the decrease of their return in recent years. Pescatori and Turunen (2016), Fiorentini et al. (2018), and Rachel and Smith (2017) also find a role for a rising risk premium on non-government bonds, which is the mirror image of the convenience yield. Engel and Wu (2018) construct estimates of the convenience yield for a broad range of countries, and show its relevance for exchange rate fluctuations. A point of particular interest in our analysis is that their estimate shows a decrease in the convenience yield for Switzerland, relative to other countries, since the late 2000's.

Financial constraints also affect the equilibrium interest rate, and enter the Euler condition through the shadow value of borrowing limits. Eggertsson and Mehrotra (2014) show that a persistent tightening of borrowing constraints in an overlapping generations model reduces the demand for borrowing and raises the supply of savings by different agents, exerting a persistent downward pressure on the real interest rate. In a global economy capital flows transmit this 'secular stagnation' across countries (Eggertsson et al., 2016). Gourinchas and Rey (2019) show that periods of rising asset prices, which raise the wealth to consumption ratio, can lead to the build-up of financial fragility. A subsequent financial crisis leads to a long deleveraging cycle, as happened in the 1930's and after the Global Financial Crisis, with a persistent decrease in the natural interest rate. Borio et al. (2017) argue that the global financial cycle should be included in estimating the natural rate. They find that doing so leads to a higher level of the rate currently, and moderately dampens the decrease in the recent past.

Fiscal policy can also impact the interest rate through its effect on consumption. Rachel and Summers (2019) find that higher government debt, health spending and retirement expenses have led to a steady increase in the natural rate of interest. This increase was, however, dominated by the strong decreasing trend driven by low growth and demographic change.

2.2.4 The Swiss 'interest rate island'

The literature has identified Switzerland to be a special case because its interest rates, and possibly the natural real interest rate, are particularly low in international comparison – that is, Switzerland appears to be an 'interest rate island'. Cunat (2003) notes that low interest rates might arise because the Swiss population has a high degree of patience, or because distortions in certain sectors reduce the growth rate of productivity and of GDP, both factors lowering the interest rate as indicated in Box 1.[4] Kugler and Weder di Mauro (2005) find that this phenomenon emerged sometime after World War 1, and argue that it reflects an insurance premium against very rare catastrophic events outside Switzerland, such as a major war. They evaluated this hypothesis in a series of papers, largely focusing on the period from the early-1980's to the late-1990's (Kugler and Weder di Mauro, 2002, 2004). An analysis of more recent data indicated that the Swiss interest rate island was no longer present in the 21st century, but it is difficult to pin down the exact point in time when it vanished (Kugler and Weder di Mauro, 2009).

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[4] Specifically, Cunat (2003) points to strong government protection in the agricultural sector.

3 Data

Existing macro-finance data bases, such as Jordà et al. (2017) or Flandreau and Zummer (2004), have two main disadvantages: They are at annual frequency and only start in 1870. Because we aim to analyze the evolution of Swiss interest rates since the creation of the Swiss franc, we compile a new quarterly data set starting in the 1850s for Switzerland and its main trading partners. We cover interest rates, inflation, exchange rates, and demographics.

This chapter first presents the international and then the Swiss data. As the Swiss data present several gaps, we describe how we address them with newly sourced financial market data for the 19th century. We also discuss our statistical techniques to construct Swiss inflation and demographic variables at quarterly frequency. The chapter concludes with a presentation of the most important time series. Table 3.1 provides an overview. More information is given in Appendix A.1.

3.1 International data

We construct long international time series for prices and interest rates, and aggregate these data in a 'rest-of-the-world' measure from the perspective of Switzerland. Until 1914, we only use data for the UK because it was at the center of the monetary system and probably the most advanced economy (in addition, the historical statistics are of high quality). At the turn of the century, the US gradually replaced the UK as the leading economy, becoming the center of the Bretton Woods System after 1945. There is a debate on when this transition exactly took place (O'Brien and Pigman, 2010, Kirby, 1981). Because the transition date is unclear, and because the US and UK were roughly equally important trading partners for Switzerland in the mid-20th century, we equally weigh the UK and US statistics between 1914 and 1963.

Starting in 1964 we construct trade-weighted statistics representative of Switzerland's most important trading partners. The reason is that it is the earliest year for which we were able to obtain a trade-weighted exchange rate from the BIS (2021). However, the BIS weights for the

Tab. 3.1: Data description

(a) World

Variable	**Frequency**	**Comments**
Prices	Quarterly	UK WPI before 1914. Equally weighted US and UK CPI until 1963. Trade-weighted CPI thereafter. Seasonally adjusted
Short-term interest rate	Quarterly	Discount rate on short-term paper before 1970. UK before 1914. Equally weighted US and UK until 1963. Trade-weighted thereafter. Seasonally adjusted before 1914
Long-term interest rate	Quarterly	UK consol yield before 1935, then long-term government bond yields (typically 10-year maturity). UK before 1914. Equally weighted US and UK until 1963. Trade-weighted thereafter

(b) Switzerland

Variable	**Frequency**	**Comments**
Prices	Annual, Quarterly	Annual WPI before 1921. CPI afterwards. Disaggregation to quarterly frequency and correction for measurement error with mixed-frequency model. Seasonally adjusted
Exchange rate	Quarterly	CHF/GBP until 1914. Equally weighted CHF/GBP and CHF/USD until 1963. Trade-weighted thereafter
Short-term interest rate	Quarterly	Average discount rate in various cities (ZH, SG, GE, BS), consortium of note-issuing banks before 1907. Discount rate of SNB and overnight lending rate thereafter. Seasonally adjusted before 1907
Long-term interest rate	Quarterly	Confederation and cantonal bonds before 1904. Bonds of Confederation and/or federal railways thereafter. Seasonally adjusted before 1907
Dependency ratios	Annual, Quarterly	Swiss inhabitants aged less than 20 years as a proportion of population aged 20-65 years. Swiss inhabitants aged over 65 years as a proportion of population aged 20-65 years. Interpolated for 1852-1859 and 2020. Disaggregation to quarterly frequency without mixed-frequency model

Notes: The sample ranges from 1852-2020 because the Swiss franc replaced the existing local currencies in 1851 and 1852 (Niederer, 1965). Most foreign data and Swiss prices are available before 1852. Moreover, we use quarterly data, because the disaggregation method for prices works better at quarterly frequency, even though many financial market variables are available monthly.

exchange rate index stem from the 1990s and are therefore likely to be less representative. Therefore, for weighting foreign interest rate data, we use the annual trade-weights from the Swiss National Bank's (SNB) exchange rate index that start in 1973 (see Müller, 2017, SNB, 2021), and use the 1973 weights backwards for the first decade.

We collect data for each of the three time segments from various sources. Until 1914, the UK data are from Thomas and Dimsdale (2017). We use a wholesale price index because consumer prices are only available annually for the 19th century. We use the discount rate on prime commercial paper as the measure for short-term interest rate. The long-term government bond yield is a consol rate, linked with a 10-year government bond yield in 1935.[1]

US data are mostly from the NBER macrohistory data base (NBER, 2021) and FRED (2021). We use a cost-of-living index linked in 1947 with the official US CPI. The short-term interest rate is a commercial paper rate in New York linked with the Federal Funds Rate in 1954. The long-term interest rate stems from railway bonds, linked with a treasury bond yield in 1941 and the long-term government bond yield from the OECD (2021a) in 1960.

After 1964 short- and long-term interest rate data are sourced from the OECD Main Economics Indicators database, and are used from December 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 nine of the most important trading partners for which we were able to collect data.[2] We then calculate a weighted average using the SNB's exchange rate index weights.[3]

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. 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).

We then link the various segments for each variable. We make sure that price indices have the same base year and are seasonally adjusted before linking them. For interest rates, we

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[1] Consol is short for consolidated annuity. These are perpetual government bonds with no fixed maturity data but, usually, an option for redemption.

[2] Specifically, Austria, France, Germany, India, Italy, Japan, The Netherlands, the UK and the US. Appendix A.1 provides more information on the selection and weights of individual countries.

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

seasonally adjust the series only for the 19th and early 20th century.[4]

3.2 Swiss data

3.2.1 Existing data and limitations

In addition to interest rate, inflation, exchange rate, and demographic data, we rely on information pertaining to the monetary regime in place in Switzerland and changes in the pension system. The monetary regimes are captured by a series of non-overlapping dummies from Kaufmann (2019). The pension rules are also segmented through time based on information from Die Pensionskasse (2021). The various periods are shown in Table 3.2.

Existing data for short-term interest rates start in the early 20th century. We use data from the SNB's historical interest rate data base (SNB, 2007), focusing on short-term money market rates. To make it comparable with the historical data we collect, we use the end-of-month value of the discount rate of the SNB starting in 1907. We then use Euromarket interest rates in Zurich (call money starting in 1948, tomorrow/next starting in 1971) until 1999, and from then on use the SARON, a secured overnight rate.[5]

Existing data on long-term interest rates start in 1899. We use yields of a 3.5% federal railway bond from SNB (2007),[6] which also provides us with the average yield on federal railway and Confederation bonds with maturity of 5 years starting in 1924. We link this series with OECD data on long-term government bond yields in 1955 (OECD, 2021a) and with the SNB's 10-year government bond yield in 1988 (SNB, 2021).

The price data stem from the historical statistics data base of the SFSO (2021a). Starting in 1921, we use the official monthly consumer price index from the SFSO. Before 1921, we use annual wholesale prices for two reasons. First, existing estimates of consumer prices are often rough computations based on wholesale prices.[7] Second, the monthly 19th century indicator available for the UK is a wholesale price index as well. The series based on wholesale prices are linked with the official monthly consumer price index in 1921.[8]

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[4] Mankiw and Miron (1991) discuss that, before the emergence of central banks, interest rates displayed a seasonality because money supply was relatively fixed, but money demand seasonally fluctuated with agriculture and business activity.

[5] To make the series as consistent as possible over time, we do not use the 3M Libor, the SNB's operational interest rate target from 1999-2019, but rather the retrospectively computed SARON.

[6] As for many other countries, these data are missing during World War 1.

[7] See Kaufmann (2020). Moreover, there is statistical evidence that these prices are measured with substantial error (Kaufmann, 2019).

[8] We index the monthly series so that the overlapping observation is on average equal to the annual series. Also, we seasonally adjust the monthly index.

Tab. 3.2: Time dummies on monetary regimes and major changes in pension system

(a) Monetary regimes

Regime	**From**	**To**	**Comments**
Bimetallism	1852Q1	1873Q4	Swiss franc fully replaced existing currencies during 1852
Classical Gold Standard	1874Q1	1907Q1	
Foundation SNB	1907Q2	1914Q2	
World War 1	1914Q3	1918Q4	
Interwar-period	1919Q1	1939Q3	Gold Exchange Standard and Great Depression
World War 2	1939Q4	1945Q3	
Bretton Woods (with capital controls)	1945Q4	1958Q4	
Bretton Woods (capital mobility)	1959Q1	1972Q4	
Monetary targeting	1973Q1	1999Q4	Start date corresponds to break-down of Bretton Woods. Monetary targeting was introduces somewhat later
Flexible inflation targeting	2000Q1	2011Q2	New SNB strategy introduced at the end of 1999
Exchange rate floor	2011Q3	2014Q4	Exchange rate floor at CHF/EUR 1.20
Flexible inflation targeting	2015Q1	2020Q4	Negative interest rates without official exchange rate floor

(b) Pension system

Regime	**From**	**To**	**Comments**
Optional old age insurance	1852Q1	1947Q4	Employers provide optional pensions
Old age insurance	1948Q1	1984Q4	Old age and survivors' insurance law is implemented
Three-pillar system	1985Q1	2020Q4	Old age and survivors' insurance and occupational pension law is implemented

Notes: These segments are defined according to information provided by Kaufmann (2019) and Die Pensionskasse (2021).

Existing exchange rate data (other than at annual frequency) are available from 1914 on. From 1914 to 1963 we compute a trade-weighted exchange rate using an equally weighted average between the CHF/GBP and CHF/USD using data from the SNB (2021). From 1964 to November 1973, 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).[9]

Demographic data are sourced from the SFSO (2021b), with annual data available from 1860-2019 on the number of inhabitants by age. We then calculate the young dependency ratio (the population under 20 as a proportion of the population aged 20-65), and the old dependency ratio (the population over the age of 65 as a proportion of the population aged 20-65).

We identify several gaps and limitations in the available Swiss data. First, to the best of our knowledge, high-frequency short-term interest rates and long-term interest rates are missing before 1907 and 1899, respectively. Second, price data before 1921 is available only at an annual frequency. What is more, there is evidence that these price series are measured with substantial error. Third, consistent high-frequency exchange rate data start only in the 20th century. Finally, demographic data is missing before 1860 and for 2020, and available only at an annual frequency. We now discuss the steps followed to deal with each of these issues.

3.2.2 Filling the gaps: Swiss interest rates and exchange rates for the 19th century

We obtain high-frequency interest rates and exchange rates from a range of primary sources. These additional data are spliced with the existing series covering more recent years to construct series starting in 1852. This section presents the most important features of the data collection and construction.[10]

The data are collected mainly from primary archival sources. These include information from the *Basler Börse*, *Bourse de valeurs de Genève*, the *Neue Zürcher Zeitung*, and many others.[11] For example, Figure 3.1 provides financial market information for the *Basler Börse* on 28 April 1870.

These sources provide us with end-of-month values on the prevailing discount rate in various cities, exchange rates, as well as information on prices of cantonal and Confederation bonds. Overall, we have collected in excess of 15,000 observations from all sources.

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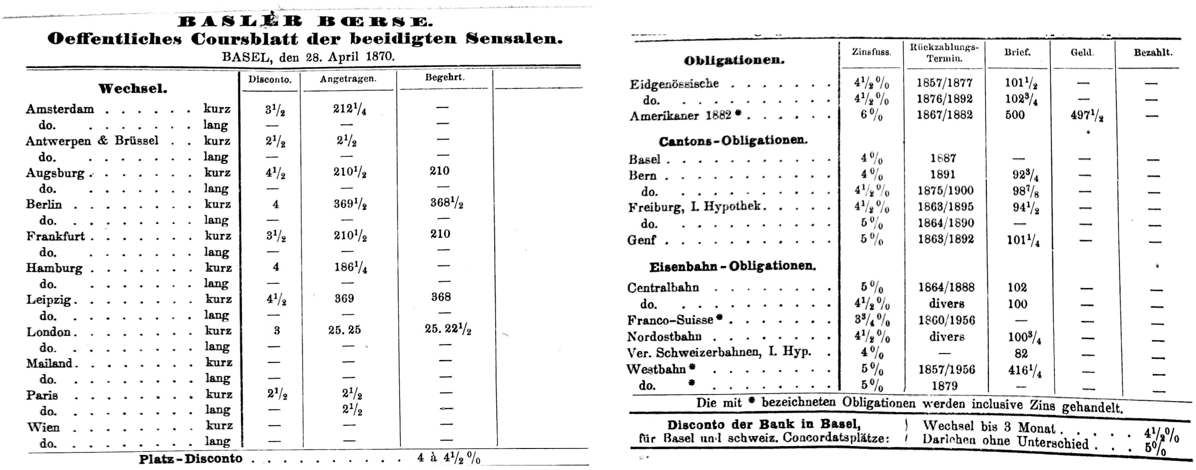
[9] See Müller (2017) for a methodological description.

[10] More information is given in Appendix A.1.

[11] Most of our data is obtained through the *Wirtschaftsarchiv Basel* and the *Bibliothèque de Genève*. Some of the additional data are obtained via digitalized documents available, for example, on impresso-project.ch.

Fig. 3.1: *Kursblatt der Basler Börse*, 28 April 1870



BASLER BŒRSE.

Oeffentliches Coursblatt der beeidigten Sensalen.

BASEL, den 28. April 1870.

Wechsel.		Disconto.	Angetragen.	Begehrt.
Amsterdam	kurz	$3\frac{1}{2}$	$212\frac{1}{4}$	—
do.	lang	—	—	—
Antwerpen & Brüssel	kurz	$2\frac{1}{2}$	$2\frac{1}{2}$	—
do.	lang	—	—	—
Augsburg	kurz	$4\frac{1}{2}$	$210\frac{1}{2}$	210
do.	lang	—	—	—
Berlin	kurz	4	$369\frac{1}{2}$	$368\frac{1}{2}$
do.	lang	—	—	—
Frankfurt	kurz	$3\frac{1}{2}$	$210\frac{1}{2}$	210
do.	lang	—	—	—
Hamburg	kurz	4	$186\frac{1}{4}$	—
do.	lang	—	—	—
Leipzig	kurz	$4\frac{1}{2}$	369	368
do.	lang	—	—	—
London	kurz	3	25. 25	25. $22\frac{1}{2}$
do.	lang	—	—	—
Mailand	kurz	—	—	—
do.	lang	—	—	—
Paris	kurz	$2\frac{1}{2}$	$2\frac{1}{2}$	—
do.	lang	—	$2\frac{1}{2}$	—
Wien	kurz	—	—	—
do.	lang	—	—	—
Platz-Disconto				4 à $4\frac{1}{2}$ %

Obligationen.	Zinsfuss.	Rückzahlungs-Termin.	Brief.	Geld.	Bezahlt.
Eidgenössische	$4\frac{1}{2}$ %	1857/1877	$101\frac{1}{2}$	—	—
do.	$4\frac{1}{2}$ %	1876/1892	$102\frac{3}{4}$	—	—
Amerikaner 1882 *	6 %	1867/1882	500	$497\frac{1}{2}$	—
Cantons-Obligationen.					
Basel	4 %	1887	—	—	—
Bern	4 %	1891	$92\frac{3}{4}$	—	—
do.	$4\frac{1}{2}$ %	1875/1900	$98\frac{7}{8}$	—	—
Freiburg, I. Hypothek	$4\frac{1}{2}$ %	1863/1895	$94\frac{1}{2}$	—	—
do.	5 %	1864/1890	—	—	—
Genf	5 %	1863/1892	$101\frac{1}{4}$	—	—
Eisenbahn-Obligationen.					
Centralbahn	5 %	1864/1888	102	—	—
do.	$4\frac{1}{2}$ %	divers	100	—	—
Franco-Suisse *	$3\frac{3}{4}$ %	1860/1956	—	—	—
Nordostbahn	$4\frac{1}{2}$ %	divers	$100\frac{3}{4}$	—	—
Ver. Schweizerbahnen, I. Hyp.	4 %	—	82	—	—
Westbahn *	5 %	1857/1956	$416\frac{1}{4}$	—	—
do. *	5 %	1879	—	—	—

Die mit * bezeichneten Obligationen werden inclusive Zins gehandelt.

Disconto der Bank in Basel, für Basel und schweiz. Concordatsplätze:	
Wechsel bis 3 Monat	$4\frac{1}{2}$ %
Darlehen ohne Unterschied	5 %

Source: *Wirtschaftsarchiv Basel*

We collect exchange rates vis-à-vis the GBP starting in 1852 (see Appendix A.1 for a figure of the resulting series). By that time, the replacement of the predecessor currencies to the Swiss franc was mostly complete (see Niederer, 1965) and exchanges started quoting Swiss franc exchange rates. Therefore, we avoid converting the exchange rates of predecessor currencies into Swiss franc. Tables from the primary sources often comprise two values, one for demand (*Gesucht*) and one for supply (*Angebot*), in which case we take the average of the two.

The earliest monthly discount rates start in the late 1840s and relate to banks in various Swiss cities.[12] We use a simple average of these discount rates, ignoring missing values for some cities during some periods.[13] We then link this average with the discount rate for note-issuing Swiss banks (*Emissionsbanken*) in July 1893. After the introduction of the Swiss franc, there was some heterogeneity of discount rates across various cities. Within 20 years of the introduction of the new currency, these discount rates converged to similar levels and show a strong co-movement (see Appendix A.1).

Turning to long-term bonds, price data for Confederation bonds start in 1857. The specific information for bonds is shown in Figure 3.1, including the coupon interest rate, the repayment dates, and the price quotes. We rely on widely used bond pricing equations to compute the yield-to-maturity for each individual cantonal and Confederation bond (see Appendix A.1 for technical details). This information changes over time, however. In particular, the maturity date

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[12] The often used data from Jöhr (1914) are only available on an annual frequency. However, he documents that there were up to 200 discount rate changes per decade. We therefore found it worthwhile to collect monthly data.

[13] For a short period in the 1870's, we only obtained discount rates of the *Konkordatsbanken* instead of Basel, Zurich and St. Gallen. By this time, however, the interest rates were quite similar in all cities. Therefore, we calculated a simple average of the discount rate in Geneva and the *Konkordatsbanken*.

is not known for some bonds in the early sample period. If the maturity date is missing, we calculate the current yield as an approximation.[14] Moreover, some bonds were callable and subject to (random) repayment plans. We ignore that there was a possibility that a bond was repaid before maturity date. In Appendix A.1 we show that we therefore likely underestimate the long-term bond yield. Intuitively, callable bonds and bonds subject to random repayment plans are, on average, repaid earlier than the reported maturity date. We do not think that this substantially distorts our analysis, for two reasons. First, Appendix A.1 shows in a simulation exercise that these biases are likely to be modest. Second, our long-term interest rates show broadly similar trends and are actually somewhat higher than long-term interest rates in the UK (see Figure 3.4).

Another challenge is that there are many missing values in Confederation bond data until the 1860's. We complete the missing Confederation bond yield data with information on cantonal bonds. First, we calculate average bond yield series for both cantonal and Confederation bonds. We then replace missing values of the Confederation bond yields with yields on cantonal bond, after adjusting the cantonal bond yield series so they have the same mean as the Confederation bond yields. This adjustment is done because cantonal bond yields usually carry a positive liquidity or risk premium (see Appendix A.1 for a comparison of the two series).[15]

3.2.3 Filling the gaps: Swiss demographic data

The earliest census with age information was taken in 1860, with the 1850 census giving only the overall population size. Data for the period from 1852 to 1860 are therefore interpolated.

We do so by calculating the attrition rate in the population reflecting death, as well as emigration and (less important during this period) immigration. Specifically, we calculate the average attrition rate from 1860 to 1869 and apply this backwards to the pre-1860 data.[16] This backwards computation means that the oldest age category drops out of the sample each year. We therefore make the assumption that the number of people in the oldest age category (99 and older) is equal to the average over the 1860-1869 period. As might be expected, this number is very small: on average in the 1860s there were just 7 people aged 99 and older out of a population of almost 2.4 million. Applying the attrition rate and assuming a constant number of people in the oldest age category, we compute estimates of the population by age

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[14] The current yield is the yield-to-maturity for a bond with infinite time to maturity. Therefore, we assume that a bond without maturity date has similar properties as a consol.

[15] We therefore assume that the risk or liquidity premium stayed constant during this early sample period.

[16] In Appendix A.1 we discuss an alternative method and the checks we carried out which led us to select this method.

group before 1860.

Demographics data are available up to 2019, and we use a similar methodology to obtain dependency ratios for 2020. We apply the attrition rates in the 10 years from 2010-2019 to the 2019 data to obtain estimates for 2020.[17] As this leaves us with no children aged 0 years in 2020, we use the average number of children aged 0 years in the previous 10 years.

The demographics data is only available at annual frequency. For disaggregation, we use a reduced-form model that assumes gradual changes in the underlying unobserved quarterly data.[18]

3.2.4 Filling the gaps: Swiss inflation data

The biggest shortcomings of the existing data are for Swiss inflation, in two forms. First, only annual data are available. Second, they are likely subject to measurement errors. Therefore, we use a statistical approach to disaggregate inflation to quarterly frequency and correct the data for uncorrelated measurement error. As we later model the relationship between interest rates and inflation, rather than the price level, we disaggregate the inflation series.

We construct quarterly estimates of Swiss year-on-year inflation prior to 1922 by treating the annual data as being observed in the last quarter of the year, with missing observations in the other quarters.[19] The missing observations are replaced by estimates where we use information from interest rates and exchange rates, as well as inflation in the UK. We have quarterly observations for these variables, for which measurement errors are of limited concern as financial variables were easily observed and estimates of 19th century UK wholesale prices are considered reliable. We then exploit these observations, in addition to the co-movement observed between the post-1922 quarterly data, to predict the missing quarterly year-on-year inflation in Switzerland before 1922.

For this prediction we use the mixed-frequency VAR model originally proposed in Schorfheide and Song (2015). The model assumes that year-on-year inflation is the average of (unobserved) quarterly year-on-year inflation rates. The quarterly inflation series are then estimated using Bayesian estimation techniques. Our estimates assume that quarterly inflation

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[17] By the 2010s, the term ‘attrition rate’ is less accurate: due to immigration the attrition rate is sometimes positive for certain age cohorts.

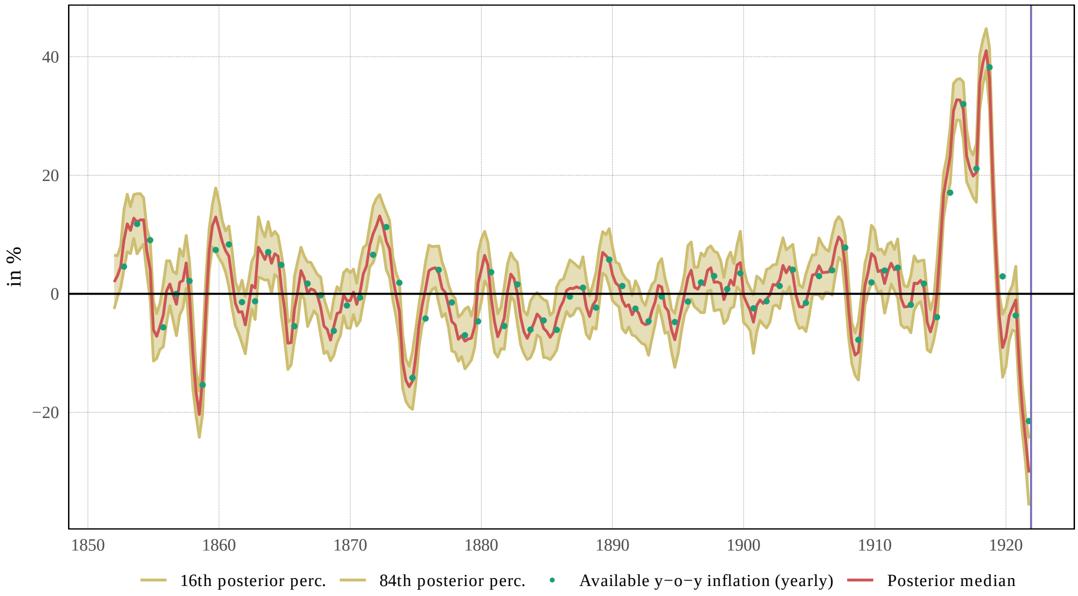
[18] More technically, we use a local level model which we estimate using the Kalman filter to obtain quarterly estimates. Such a model may be less accurate during periods with large changes in deaths or births, such as during a pandemic or a major war.

[19] Recall that the Swiss prices series is on an annual basis before 1921, implying that the year-on-year growth rate of this series (i.e., Swiss inflation) is observed annually prior to 1922.

depends on its lags – capturing potential persistence in inflation – as well as on the lags of the other, higher frequency variables. Exploiting the post-1921 co-movements between quarterly year-on-year inflation and the other variables reduces the uncertainty associated with the prediction of the unobserved quarterly inflation series during the 19th century.

In addition, the approach cleans the prediction of potential measurement errors in the observed historical inflation series. We assume that inflation based on official statistics starting in 1922 is measured accurately, while retrospectively constructed historical inflation before 1922 is measured with error. As uncorrelated measurement errors are unpredictable, our prediction of quarterly year-on-year inflation will be cleaned of these measurement errors.

Fig. 3.2: Quarterly estimate of Swiss inflation



Notes: Actual annual and estimated quarterly year-on-year inflation (in %). Point estimate of quarterly inflation (in red), with one standard error uncertainty intervals (in yellow), and observed annual inflation (in green).

Figure 3.2 shows the result of the exercise, presenting quarterly estimates of Swiss year-on-year inflation. The annual values are attributed to the last quarter (green dots), and the red line shows the posterior median estimate at a quarterly frequency, along with one standard error band of confidence (the 16th and 84th posterior percentiles). We can see that our estimates are close to the annual values. On average the two coincide, even though they are not identical in a specific year, as can be expected in the presence of unpredictable and uncorrelated measurement errors.

We are confident that the model provides accurate estimates of quarterly inflation. First, using information from foreign inflation in our estimates for Swiss inflation is motivated by historical evidence that inflation rates were highly correlated during the 19th century (Gerlach and Stuart, 2021). Second, we apply our procedure to the case of Norway (see Appendix A.1.5). Norwegian data are available at a quarterly frequency throughout the sample. We aggregate them to annual frequency, apply our approach to these values, and examine how well our model predicts the quarterly values. We find that our method provides a solid fit, and substantially improves the prediction compared to time series approaches relying solely on domestic variables and ignoring the available international information.

3.3 Interest rates and inflation 1852-2020

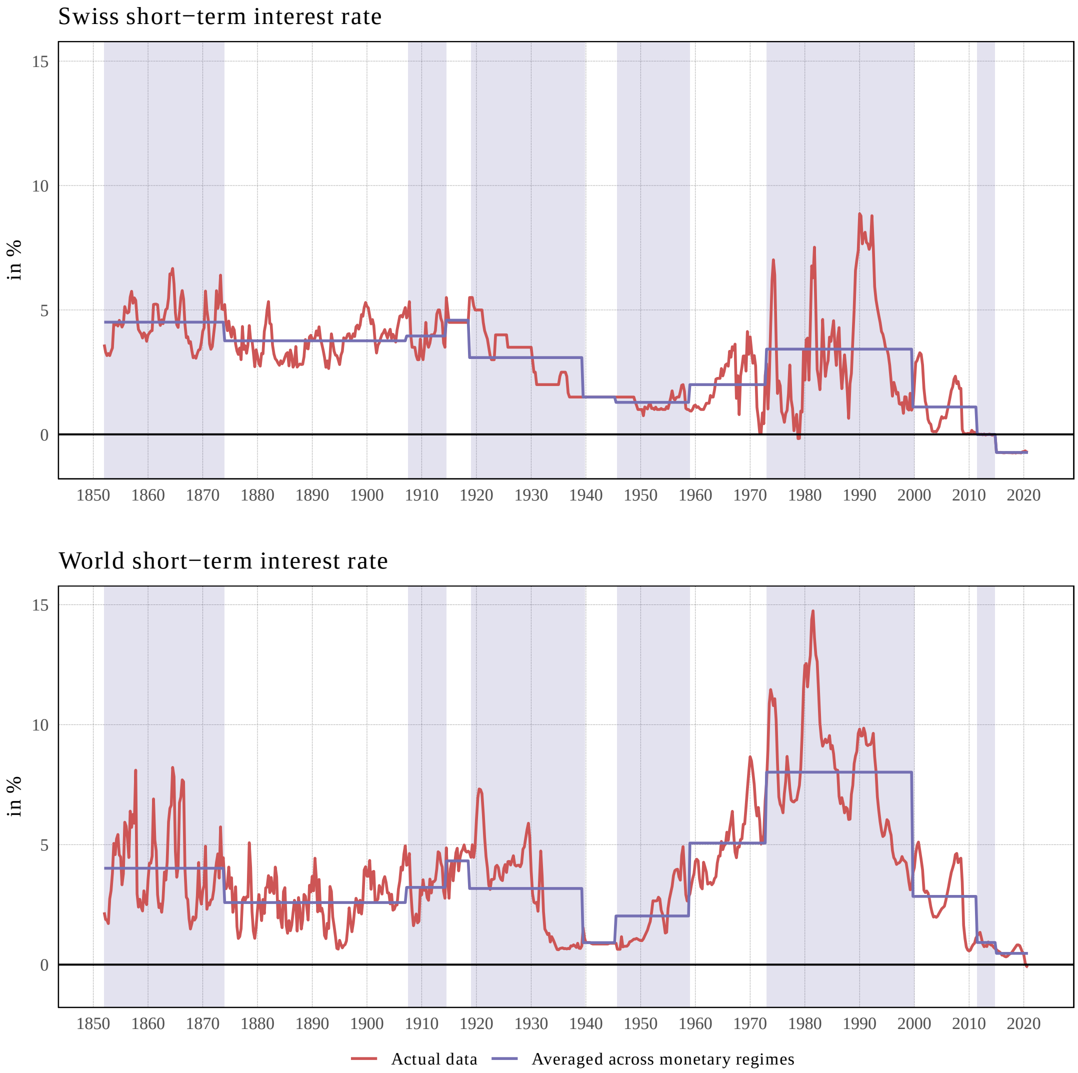
This section presents interest rates and inflation computed following the steps presented above for Switzerland and the rest of the world (UK before 1914, US and UK until 1964, trade-weighted average thereafter).

Figure 3.3 shows the short-term interest rate at a maturity of one month or less for Switzerland (top panel) and the rest of the world (bottom panel). In addition to the quarterly data (red lines), we show the average over various Swiss monetary regimes (blue lines). Several features are visible. First, until the end of World War 1 the Swiss interest rate is higher than the foreign one, with the pattern reversing subsequently. This reflects the fact that Switzerland's safe-haven status only emerged during the interwar period. Second, the Swiss interest rate was less volatile than the foreign one until the Great Depression. Finally, the large increase in foreign rates in the 1960's, 1970's, and 1980's is not observed to the same extent in Switzerland.

Figure 3.4 is built along the same lines as Figure 3.3 and displays the interest rate at a maturity of 5 years or more. We also observe the relatively high level of the Swiss interest rate until the 1930's, and the smaller increase during and after the Bretton Woods System. In terms of volatility, the Swiss series is no less volatile than the foreign one in the first part of the sample.

One factor behind the difference between the nominal interest rates in Switzerland and abroad is the different level of inflation (the so-called Fisher effect, see Box 2). While this can explain the interest rate differential in the 1970's and 1980's to some extent, it played a smaller role, if any, during the 19th century.

Fig. 3.3: Short-term interest rates



Notes: This figure presents quarterly short-term interest rates (in %) with a maturity of one month or less for Switzerland (top panel) and the rest of the world (bottom panel). The blue line shows the average across the various monetary regimes of Switzerland (shaded and non-shaded areas).

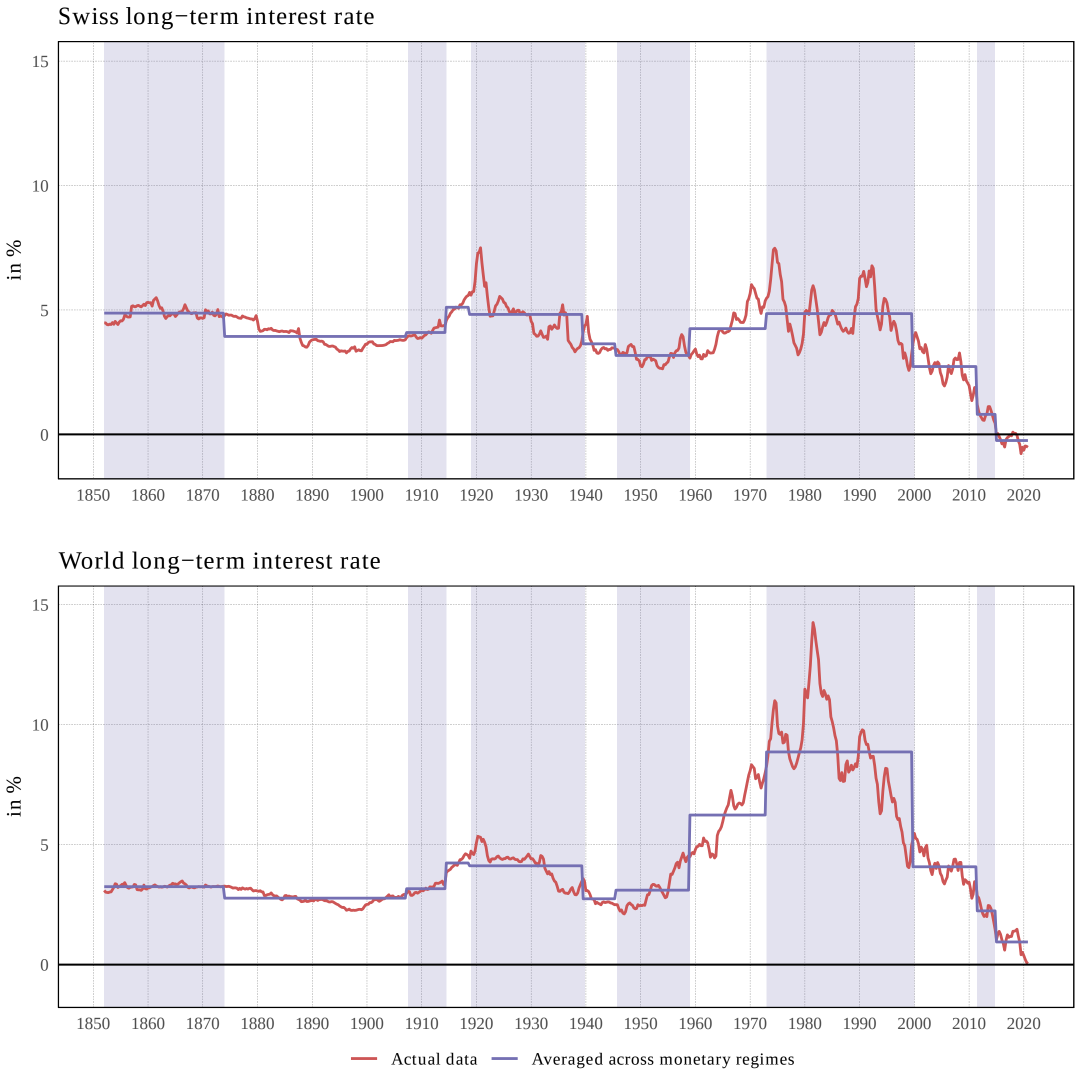


Fig. 3.4: Long-term interest rates

Notes: This figure presents quarterly long-term interest rates (in %) with a maturity of 5 years or more for Switzerland (top panel) and the rest of the world (bottom panel). The blue line shows the average across the various monetary regimes of Switzerland (shaded and non-shaded areas).

Box 2: The Fisher effect

The Fisher effect decomposes the nominal interest rate into a contribution of the real interest rate and inflation expectations:

$$\text{Nominal interest rate} = \text{Real interest rate} + \text{Expected inflation}$$

The nominal interest rate is therefore high if (expected) inflation is high. Intuitively, if lenders expect the price level to increase until a loan is repaid, they demand a compensation, that is a higher nominal interest rate, to offset the fall in purchasing power of the lent funds.

Figure 3.5 shows the behavior of inflation in Switzerland (top panel) and the rest of the world (bottom panel, actual data). Several points emerge. First, Swiss and foreign rates of inflation are equally volatile until World War 1. Moreover, the average inflation rate was almost identical in that period, in line with the findings by Gerlach and Stuart (2021). Second, Switzerland experienced larger increases in inflation during both World Wars than other countries did.[20] Third, while Switzerland experienced an increase in inflation in the 1970's, it proved to be smaller and less persistent than abroad. Finally, Swiss inflation since the 1990's has been persistently lower than in the other countries.

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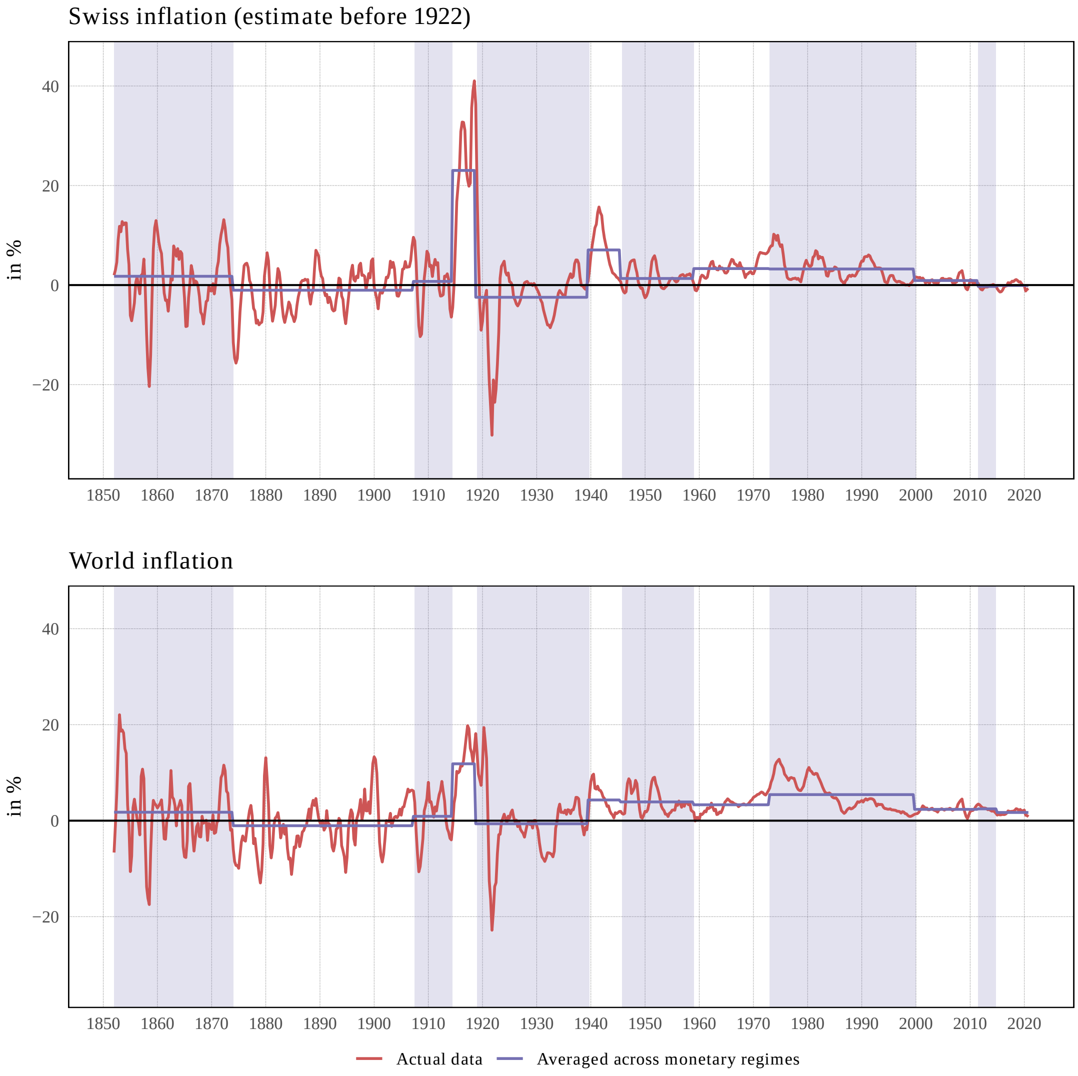
[20] This also reflect the fact that our foreign sample does not include countries in continental Europe that were most heavily affected by the conflicts.

Fig. 3.5: Inflation



Notes: This figure presents quarterly year-on-year inflation (in %) for Switzerland (top panel) and the rest of the world (bottom panel). The blue line shows the average across the various monetary regimes of Switzerland (shaded and non-shaded areas).

4 Trends in inflation and interest rates

Having constructed long time series of interest rates (short- and long-term) and inflation in Switzerland and abroad, we now turn to estimating the nominal and real interest rate trends. We first present the methodology, then the results for Switzerland and the rest of the world, and finally assess the main drivers of Swiss interest rate trends.

4.1 Methodology

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

The standard approach relies on restrictions from economic theory to extract the underlying trends. This approach is not well suited when considering a long sample with several, possibly sudden, structural changes. 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.

We therefore opt for a reduced-form model to identify the long-term trends in the variables. Because the data cover a long time period our method needs to allow for structural shifts in the dynamic relationships between the variables. We therefore estimate a TVP-VAR model including quarterly values of the short-term interest rates, the long-term interest rate, inflation, and the quarter-on-quarter growth rate of the exchange rate for Switzerland, as well as the rest of the world. The TVP-VAR allows us to estimate the long-term trends, defined as the best long-term forecast at any given point in time (i.e. the Beveridge Nelson trend, see Box 3). Because all coefficients in the model are allowed to change over time, these trends may evolve as well.

Box 3: Time-varying parameter VARs and the Beveridge Nelson trend

The TVP-VAR allows us to compute the long-term trends by decomposing the time series into a trend component and a gap component. This procedure is similar to a Beveridge and Nelson (1981)-type decomposition that has also been used by, e.g., Cogley et al. (2010) and Kliem et al. (2016).

To illustrate this technique, assume that y_t is the nominal interest rate. For simplicity, we assume that y_t evolves according to:

$$y_t = c_t + \rho_t y_{t-1} + u_t$$

with c_t being a time-varying intercept, ρ_t a time-varying autoregressive parameter and u_t an independently and identically distributed random shock. The unconditional mean at time t is equal to:

$$\mathbb{E}(y_t) = \mu_t = \frac{c_t}{1 - \rho_t}$$

which can be interpreted as the best long-run forecast of the interest rate at time t. Note that the variation of the model parameters (c_t, ρ_t) determines the variation of the unconditional mean. Therefore, restricting the model parameters to evolve smoothly over time will tend to yield smooth changes in the unconditional mean. By contrast, allowing for sudden changes in the model parameters will allow the long-term trends to change rapidly as well.

The TVP-VAR is a multivariate model, such that y_t is a vector of our variables, and μ_t is a vector comprising the long-run trends. For instance, if the first two elements of y_t are inflation and long-term interest rates, the first element of μ_t will be our estimate of trend inflation while the second element represents the long-term interest rate trend.

We can then compute linear combinations of these trends. For instance, the difference between the nominal interest rate trend and trend inflation yields the real interest rate trend.

TVP-VAR models typically restrict the coefficients to evolve slowly over time in order to handle the large number of coefficients that have to be estimated from the data (see, e.g., Primiceri, 2005). This leads to estimates of the long-term trends that evolve slowly over time as well (see Box 3). 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. We therefore opt for the model proposed by Huber et al. (2019) which allows for constant model coefficients, gradual changes, but also, for a few abrupt structural breaks. These structural breaks, in turn, allow for sudden large changes in the the long-term trend estimates.

4.2 Trend estimates of interest rates and inflation

4.2.1 Estimates for Switzerland

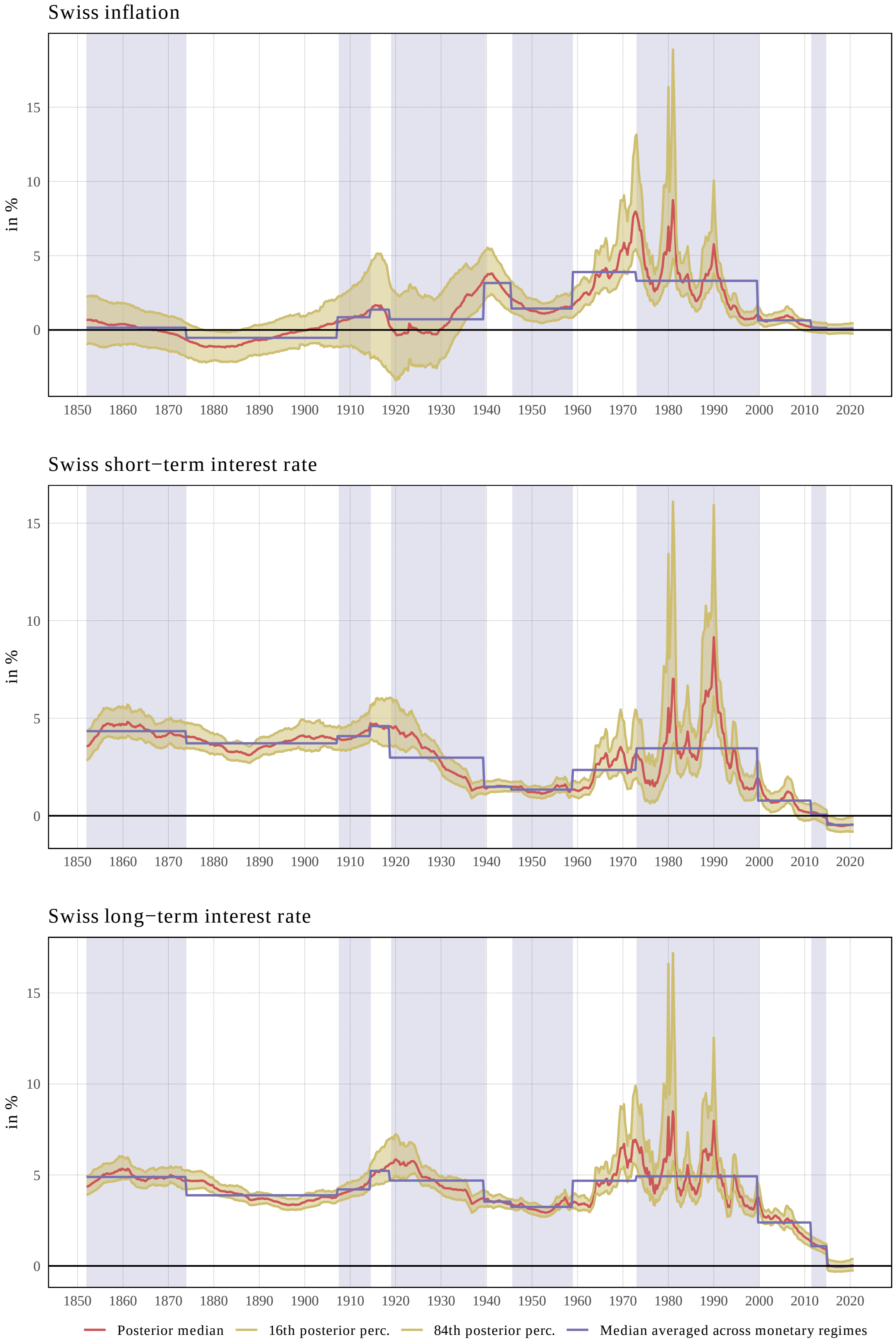
Figure 4.1 shows our time-varying estimates of the trend values of Swiss inflation, the short-term nominal interest rate, and the long-term nominal interest rate. In addition to the median point estimate (red lines), the figure also includes uncertainty intervals (shaded yellow) and the average of the posterior median over various monetary regimes (blue lines).

The top panel shows that Switzerland was characterized by long-run price stability until the early 1870's, and a deflationary period during the early Classical Gold Standard (1874-1907). The two World War's lead, for the first time in the history of the Swiss franc, to a positive inflation trend (although estimates are very imprecise during World War 1). After World War 2 trend inflation temporarily drifted down. Like in most other advanced economies, trend inflation went up in the 1960's and 1970's, and remained at a high level until the beginning of the 1990's. This can reflect deep changes in the structure of the world economy, with the end of the Bretton Woods system leading central banks to face more uncertainty (at least initially) in gauging the impact of their policies. Since the mid-1990's, the Swiss economy has returned to a situation of long run price stability.

The trend short-term interest rate was steady, but quite elevated at close to 5%, until the 1920's. Thereafter, it declined as Switzerland became a safe haven (see also Baltensperger and Kugler, 2016). It increased in the 1960's and 1970's, and remained at a higher level with sizable volatility until the late 1990's.

The trend long-term interest rate has proved quite steady during the 19th century too, and stood at a similar level as the short-term interest rate trend. During World War 2 and the first half of the Bretton Woods System, the long-term interest rate declined to a level last observed during the 19th century. Note that during this period, substantial capital controls were in place. After lifting capital controls during the second half of the Bretton Woods system, and especially after its demise in 1973, we observe a clear increase in the level and volatility of the interest rate.

Fig. 4.1: Swiss trend estimates



Notes: The figure shows the estimates of long run trend of Swiss inflation, short-term nominal interest rate, and long-term nominal interest rate (in %). The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. The blue line shows the average of the median across the various monetary regimes (shaded and non-shaded areas).

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 estimates of long run trends in Figure 4.1 display a volatile pattern in the 1970's and 1980's, suggesting that the changing macroeconomic environment, with the demise of Bretton Woods and the move to flexible exchange rates, as well as the oil shocks in 1973 and 1979 and subsequent high inflation period led to higher macroeconomic volatility. In addition, this made it harder to precisely estimate long run trends, which is reflected in wider uncertainty intervals.

Using the results of Figure 4.1 we compute estimates of trend real interest rates by removing trend inflation from nominal interest rate trends. Figure 4.2 displays the resulting estimates for short- and long-term interest rates, as well as the term spread (the difference between the two).

The Swiss trend real interest rates have been on a clear downward trend, not only in recent years but also compared to the 19th century. Both short- and long-term real interest rates evolved around a steady value until 1930, before experiencing a sharp decrease until World War 2. The real rates remained at low values until 1980 (with a temporary drop of the short-term rate in the 1970's), and gradually increased until the 1990's. This increase proved temporary, and real interest rate trends have subsequently moved down until today, reaching a negative value for the short-term rate and zero for the long-term one after the removal of the minimum exchange rate at CHF/EUR 1.20 in January 2015.

Our estimates of the trend real interest rate are more volatile than those found in other studies. This is a consequence of our flexible model that allows for rapid changes in the real interest rate trend. Note that we do not impose smooth changes in the real interest rate trend, as for example Del Negro et al. (2019). Therefore, our findings suggest that the smooth real interest rate trends found in the literature are an artifact of tightly restricted model parameters that rule out rapid shifts.[1]

Our estimates 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. The magnitudes are however different than for Switzerland. Specifically, Del Negro et al. (2019) estimate that the natural real interest rate in 1980 was at a level above the pre-1920 one (also within the band of confidence), while our estimates indicate that it remained lower than during the early 20th century.

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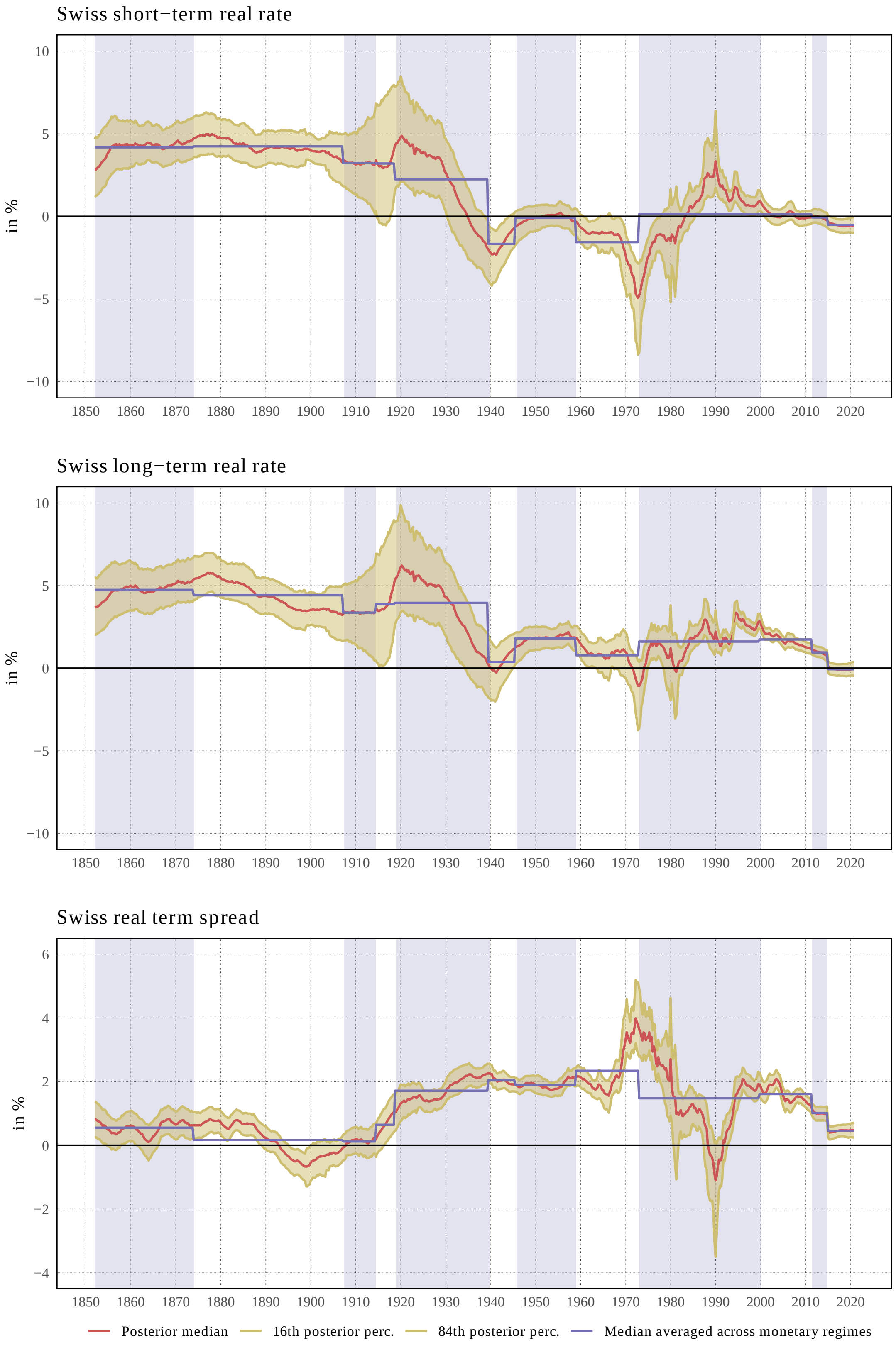
[1] There is no particular theoretical reason that the natural rate of interest should evolve gradually, in particular, during periods with rapid structural changes.

Fig. 4.2: Swiss real interest rate trends



Notes: The figure shows the estimates of trend of Swiss short-term real interest rate, long-term real interest rate, and the term spread (in %). The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. The blue line shows the average of the median across the various monetary regimes (shaded and non-shaded areas).

The decrease of the trend real interest rate in the interwar period was most pronounced for the short-term rate, as shown by the increase in the spread that was essentially zero until World War 1. As that time marked the first period where inflation was persistently positive, the rising term premium could reflect inflation risk, which was not a concern under the Gold standard. The spread remained quite steady until the first decade of the 21st century (excluding a temporary increase in the 1970's and a temporary drop in the 1980's-1990's), and has since decreased to a level similar to the one of a century ago. The recent drop could reflect an environment of very low inflation, or even mild deflation, since the end of the minimum exchange rate regime, and the beginning of the European Central Bank's (ECB) large-scale asset purchase program.

4.2.2 Estimates for the rest of the world

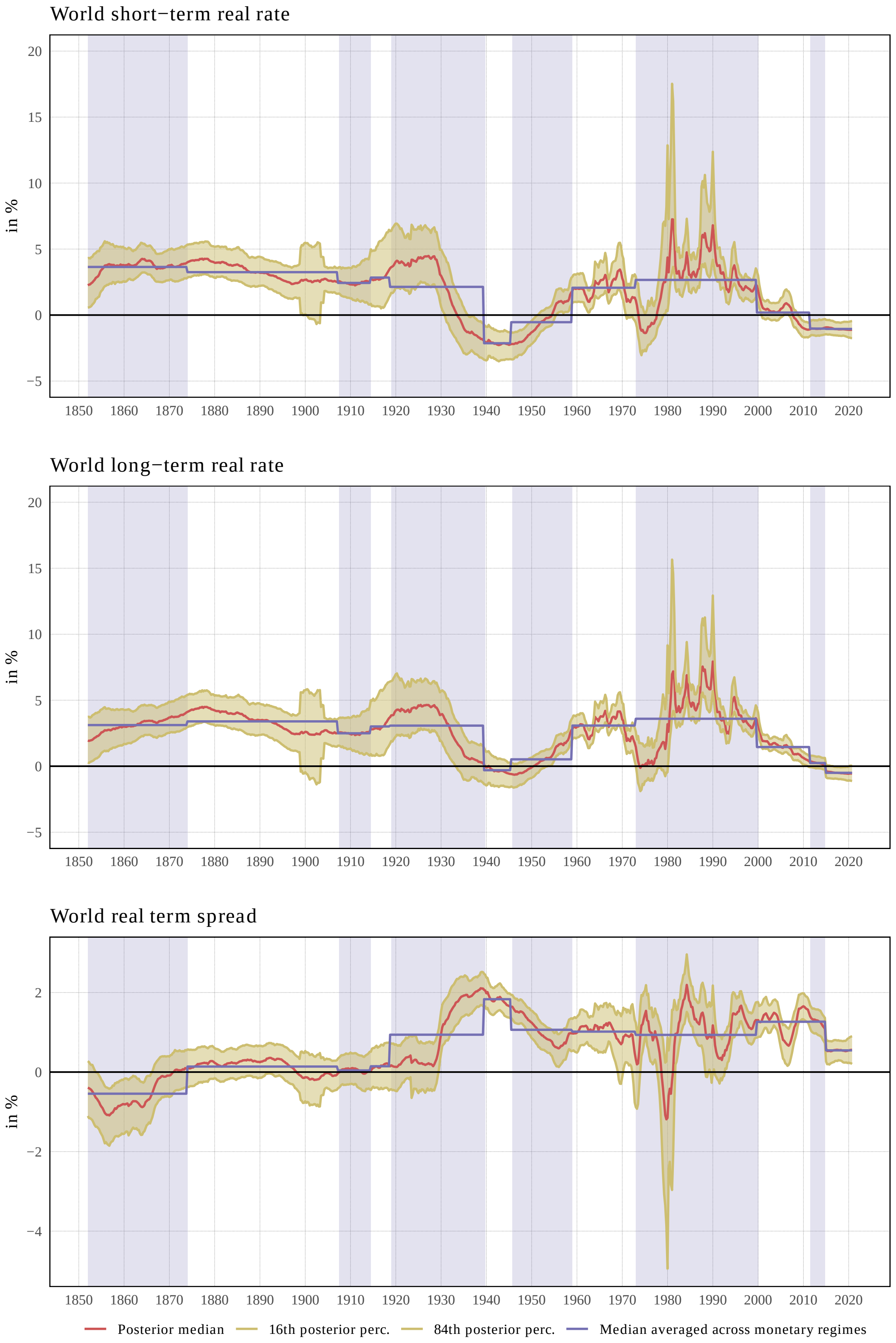
In addition to the estimates of trend values for Switzerland, our approach provides us with similar estimates for the rest of the world. Figure 4.3 displays the values for the real interest rates and term spread, and is built in a similar way as Figure 4.2.

The pattern for real interest rates are similar to the ones 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 temporary, and real interest rates subsequently increased until the 1980's (with a temporary drop when the Bretton Woods System disintegrated) to levels moderately above the ones prevailing in the early 20th century. Starting in the early 1990's, real interest rates have been on a downward path that brought them to values that had only been seen at the time of World War 2 and briefly during the mid-1970s.

While short- and long-term real interest rates followed similar patterns, they did not exactly track each other, leading to movements in the term spread. This spread was essentially zero until the Great Depression. Interestingly, this spread increased later than for Switzerland, which is consistent with the idea that World War 1 inflation was less of an issue in the sample of countries included in the rest of the world. However, with the decoupling of their currencies from gold during the Great Depression, the inflation risk rose as well. Since then, it fluctuated around a steady average (except for a short drop in 1980) until recently, when it decreased following the start of the ECB's large-scale asset purchase program in 2015.

The pattern for the foreign term spread presents three interesting contrasts with the one observed for Switzerland. First, it was lower than in Switzerland during the 19th century. This could reflect the fact that Switzerland was an emerging economy at the time, with the possibility that its commitment to the Gold Standard and low inflation was seen as less certain than in

Fig. 4.3: Foreign real interest rate trends



Notes: The figure shows the estimates of trend of foreign short-term real interest rate, long-term real interest rate, and the term spread (in %). The red line shows the median estimate and the yellow area displays a one standard error uncertainty interval. The blue line shows the average of the median across the various monetary regimes (shaded and non-shaded areas).

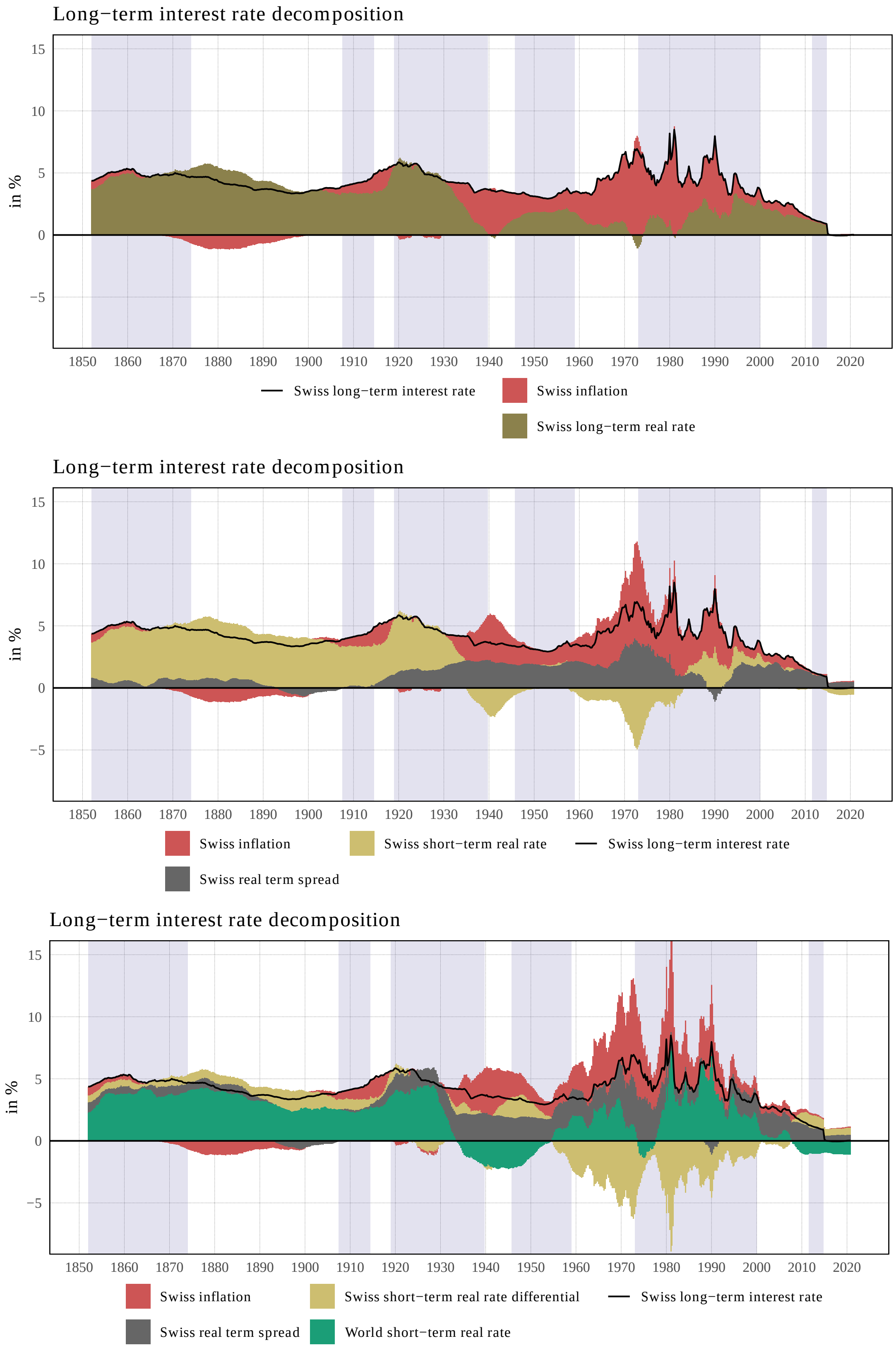
other countries. Second, the increase took place later than in Switzerland, with the earlier Swiss shift possibly driven by higher perceived inflation risk after the surge in Swiss inflation during World War 1. Third, the magnitude of the increase was larger in Switzerland, with the spread fluctuating around 2 percentage points from 1920 to 2010, compared to half as much in the rest of the world.

4.3 A decomposition of Swiss nominal long-term interest rates

Our estimates of trends for the various variables in Switzerland and abroad allow us to decompose the evolution of the Swiss nominal interest rate trend into various components (see Box 4 for details). Figure 4.4 shows this exercise for the trend Swiss long-term nominal interest rate, taking three different perspectives, namely between inflation and the real long-term rate (top panel), inflation, the real short-term rate and the term spread (middle panel), and inflation, the real foreign short-term rate, the real short-term interest differential, and the Swiss term spread (bottom panel).

The top panel splits the nominal interest rate trend (black line) into our trend estimates of inflation (red area) and the real interest rate (dark green area). Recall that, in our model, trend inflation is equivalent to long-term inflation expectations. Therefore, we can assess the role that inflation expectations played in the evolution of the nominal interest rates (Fisher effect, see Box 2). We see that the nominal interest rate was steady until the 1990's. The real interest rate was also steady over the early part of the sample up to the 1930's. During this time, inflation expectations played little to no role: inflation was generally close to zero throughout this period. After the Great Depression, however, the real interest rate declined strongly because of an increase in inflation expectations. These inflationary pressures then lingered during the Bretton Woods System and from 1972-1995. Only when inflation expectations were subsequently brought under control in the mid-1990's did inflation stop playing an important role in driving nominal interest rates. From 1980-2000, however, this decline in trend inflation was partly offset by an increase in the long-term real interest rate during the late-1980's and early-1990's.

Fig. 4.4: Decomposition of the Swiss long-term nominal interest rate



Notes: The figure decomposes the trend values of the Swiss nominal long-term interest rate (in %) between a) inflation and real long-term rate b) inflation, real short-term rate and term spread, and c) inflation, real foreign short-term rate, real short-term interest differential and Swiss term spread. The shaded and non-shaded areas represent Swiss monetary regimes.

Box 4: Decomposing the long-term nominal interest rate

Following the literature on so-called 'growth accounting' we decompose the Swiss nominal long-term interest rate into various components (all variables in this box represent the corresponding long-term trend estimates).

First, the real interest rate is the nominal interest rate corrected for inflation expectations (see Box 2), and long-term inflation expectations are given by the inflation trend. Therefore, we decompose the long-term nominal interest rate (i_t^l) into the long-term real interest rate ($r_t^l \equiv i_t^l - \pi_t$) and inflation ($\pi_t$):

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

Second, the term spread is the difference between the long-term and short-term real interest rates. So we further decompose the long-term real interest rate into the short-term interest rate (r_t^s) and the term spread ($s_t \equiv r_t^l - r_t^s$):

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

Third, we decompose the Swiss short-term real interest rate into the world short-term real interest rate ($r_t^{s,w}$) and the interest rate differential vis-à-vis the rest of the world ($d_t \equiv r_t^s - r_t^{s,w}$):

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

The second panel extends the analysis by further splitting the long-term real interest rate into the short-term real rate (yellow area) and the term spread (gray area). Throughout the 19th century, the term spread and inflation expectations were approximately zero, such that the real long-term interest rate was largely driven by the real short-term rate. Interest rates during this period were significantly less volatile than in more recent periods. The predictability of interest rates and zero inflation risk perhaps explains the fact that there was little or no spread between real short- and long-term rates. During the interwar period we observe two factors driving up long-term interest rates. First, the short-term interest rate increased as the SNB aimed to return to the Gold Exchange Standard at the pre-war parity to gold, requiring a relatively restrictive monetary policy. Second, the term spread increased at the end of World War 1. After a decade, the short-term real rate dropped without any offset by the term spread. The movement of the real long-term rates during the interwar period thus reflected offsetting changes in term spread and short-term rate. Our analysis hence shows an increase in risk perceptions in the interwar period, possibly due to the fact that inflation rose to unprecedented levels during World War 1, that first manifested itself through the term spread. These risk perceptions were then confirmed through higher inflation expectations during the Great Depression. It is notable that inflation expectations begin to pick-up after the first countries left the Gold Standard in the early 1930's even though Switzerland's commitment to the Gold Standard was considered firm for several years thereafter.[2] However, there was a sharp rise in inflation expectations once Switzerland finally left the gold anchor in 1936.[3] Both variables only decreased after the 1990s. Abstracting from temporary movements, the term spread remained high until the early 21st century, before decreasing. Interestingly, the short-term interest rate was relatively high, and the term spread negative, around the 1990's when the SNB implemented a rather restrictive monetary policy which curbed inflationary pressures (see Peytrignet, 2007).

The final panel includes the role of foreign variables by splitting the Swiss short-term real interest rate between the foreign short-term real rate (green area) and the spread of the Swiss rate over the foreign value (gray area). The movements of the Swiss real rate until World War 2 were primarily driven by the foreign real interest rate. This is not surprising, perhaps, because there were few capital controls in place before World War 1 and exchange rates were fixed via the Bimetallic Regime (1852-1873) and the Classical Gold Standard (1874-1914). Indeed, the period from the mid- to late-19th Century is widely recognized as one in which capital flowed freely across international borders (Obstfeld and Taylor, 2005, Bordo and Meissner, 2015).[4] With the Great Depression, World War 2, and the first half of the Bretton Woods System, the importance of the world real interest rate declined. This was a period with substantial capital controls in place (see, e.g., Eichengreen, 2008). When capital controls were lifted in the second half of the Bretton Woods System, the world real interest rate again contributed positively to Swiss interest rate fluctuations, although inflation expectations and the positive term spread were more important.

Starting in the late 1950's, the Swiss real rate differential turned negative, and remained so until the late 1990's (abstracting from a temporary change in the late 1970's). This safety premium in the Swiss short-term interest rate limited the increase in the long-term interest rate until the

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[2] See Hsieh and Romer (2006) for a discussion of perceived Swiss commitment to the Gold Standard in the early 1930's.

[3] For an analysis of Swiss economic performance during this period see Zurlinden (2003). For an analysis of the decision to remove the gold anchor, see Bordo et al. (2007).

[4] For a history of monetary regimes in Switzerland, see Baltensperger and Kugler (2017) and Kaufmann (2019).

1980's, explaining why the Swiss real rates never rose as much compared to other countries during the 20th century. This is consistent with the Swiss interest rate island documented by Kugler and Weder di Mauro (2002, 2004, 2005).

4.4 Deviations from long-term equilibrium conditions

The trend estimates allow us to assess deviations from theoretical long-run equilibrium conditions, such as the uncovered interest rate parity (UIP), or relative purchasing power parity (PPP). Boxes 5 and 6 provide the details on these concepts. If these deviations are zero, the exchange rate evolves in line with the corresponding domestic and foreign interest rates (UIP) and inflation rates (PPP). A positive deviation from UIP indicates that investors are willing to forego some return to hold their savings in Swiss franc (and conversely for a negative deviation). A positive deviation from relative PPP implies that the Swiss franc depreciates in real terms, and the economy becomes more competitive compared to the rest of the world.

Box 5: Deviations from uncovered interest rate parity

The uncovered interest rate parity (UIP) condition states that, with free capital mobility, arbitrage implies that the expected return on domestic bonds should be the same as on foreign bonds. Because saving in foreign assets requires a conversion from domestic to foreign currency, the expected return has to be adjusted by the expected rate of depreciation of the domestic currency. The UIP condition is thus written as:

$$\text{Return domestic} = \text{Return foreign} + \text{Expected depreciation}$$

It is well known that this condition may be violated if, for instance, capital controls are in place or investors demand risk premia to hold assets denominated in foreign currency. We can use our model to estimate trend deviations from the UIP condition:

$$\text{Deviation}_t = \Delta e_t - i_t + i_t^w$$

where Δe_t is the trend growth rate of the exchange rate, i_t is the short-term or long-term Swiss interest rate, and i_t^w is the corresponding interest rate abroad. A positive value of the deviation indicates that the Swiss interest rate is lower than implied by the UIP, or equivalently, the Swiss franc depreciates more than implied by the interest rate differential.

Box 6: Deviations from relative purchasing power parity

The relative purchasing power parity (PPP) condition states that, with free trade of goods and services, arbitrage implies that goods prices inflation should be the same in all countries, once expressed in the same currency. Because foreign inflation is measured in the foreign currency, it has to be adjusted by the rate of depreciation of the domestic currency. The relative PPP condition is written as:

$$\text{Domestic inflation} = \text{Foreign inflation} + \text{Depreciation}$$

It is well known that this condition may be violated, e.g., if some goods and services are not tradeable or prices are slow to adjust. We use our model to estimate trend deviations from the relative PPP condition:

$$\text{Deviation}_t = \Delta e_t - \pi_t + \pi_t^w$$

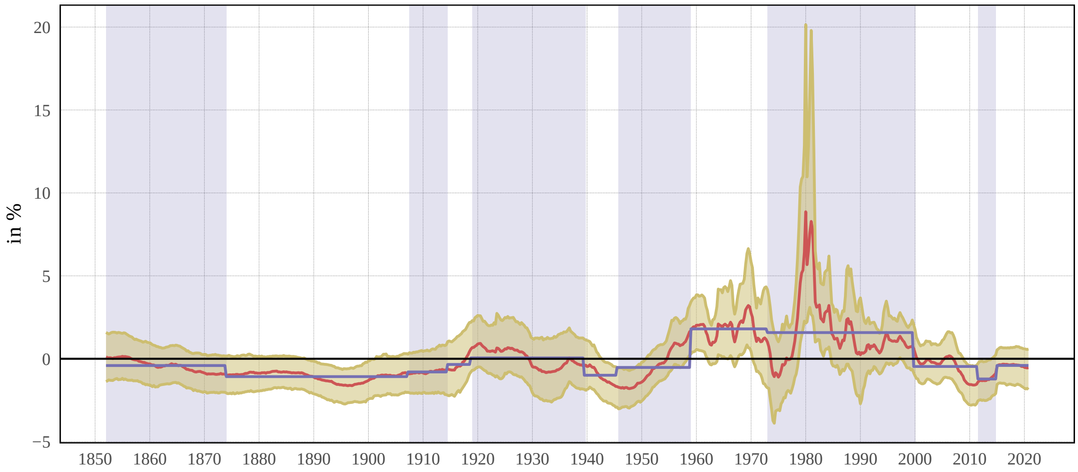
where Δe_t is the trend growth rate of the exchange rate, π_t is Swiss trend inflation, and π_t^w is foreign trend inflation. A positive value indicates that Swiss inflation is lower than implied by the PPP condition.

Note that the real exchange rate is defined as prices abroad (expressed in Swiss francs) relative to prices in Switzerland. Therefore, the deviation from relative PPP measures the growth rate of the real exchange rate. A positive (negative) deviation thus represents a trend depreciation (appreciation) of the Swiss franc.

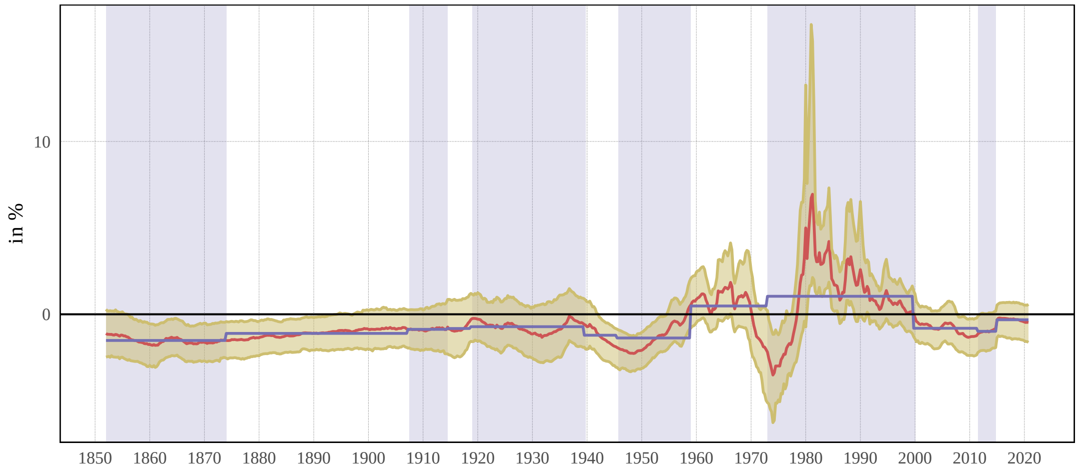
The first two panels of Figure 4.5 present the deviation from UIP using short- and long-term interest rate trends, respectively. A positive value indicates that the Swiss interest rate is lower than implied by UIP. During the 19th century, investors demanded a premium to hold Swiss francs (the deviation was negative). In the post-war period, the deviations fluctuated more strongly but were on average positive. Interestingly, Swiss interest rates were low in international comparison in the late 1970's. This coincides with the decision to introduce a minimum exchange rate with respect to the German Mark, which led with some delay to renewed inflationary pressures (see Peytrignet, 2007, p.193). It may be surprising that the point estimate of the deviation from UIP has been negative in recent years. However, the uncertainty intervals highlight that this deviation is not statistically significant from zero. This is

Fig. 4.5: Trend deviations from UIP and relative PPP

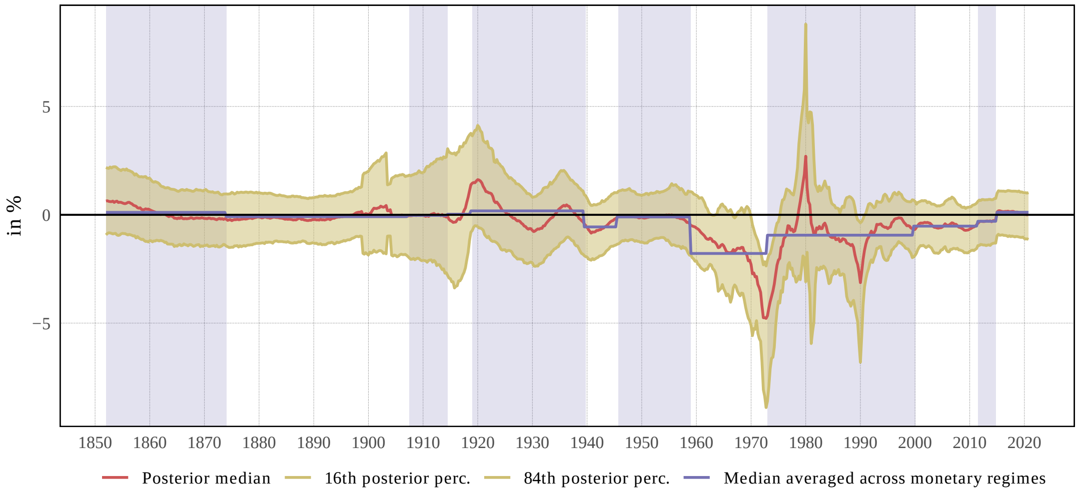
Deviations from uncovered short−term interest rate parity



Deviations from uncovered long−term interest rate parity



Deviations from relative purchasing power parity



Notes: The figure shows the gap between the relative trend interest rates (foreign minus Swiss) and the expectations of exchange rate movements (top two panes), as well as gap between the relative inflation and exchange rate movements (bottom panel). The blue line shows the average values over the various monetary regimes (shaded and non-shaded areas).

in line with the observation that the Swiss interest rate island has disappeared recently (Kugler and Weder di Mauro, 2009).

The last panel of Figure 4.5 indicates the deviation from relative PPP based on the trend estimates of inflation and the trend growth rate in the exchange rate. A positive value indicates that the nominal exchange rate depreciates by more than what the relative inflation rates suggest, i.e. that Switzerland faces a trend real depreciation of its currency. For most of the sample, the deviation from relative PPP is not statistically different from zero, which suggests that the Swiss franc does not exhibit a real trend appreciation or depreciation. There are two exceptions. First, when many countries turned to a more expansionary monetary policy towards the end of the Bretton Woods System, we observe a sharp negative deviation, implying a real trend appreciation of the Swiss franc. Second, for a short period in the early 1990's, there is a significantly negative deviation as well. During both periods, the SNB conducted a relatively more restrictive monetary policy than other countries, resulting in relatively lower inflation.

5 Econometric assessment

Can we link the pattern of trend real interest rates discussed above to economic fundamentals? While a detailed econometric assessment of the various fundamentals would go beyond the scope of this paper, we focus on international factors and demographic change, identified as major drivers in the literature, as well as on the various monetary policy regimes and the pension system legislation.

Specifically, we regress our estimate of the long-term real interest rate trend on the old and young dependency ratios (old or young population, relative to working age population), the dummies for the monetary regimes, and the dummies for the various stages of the pension system. In most specifications, we also control for our estimate of the world long-term real interest rate trend. Our analysis can therefore be seen as focusing on the determinants that are specific to Switzerland: although demographic change and monetary regimes also matter for other countries, these should be absorbed by the world real interest rate trend.

The results are presented in Table 5.1. The first column includes demographic factors and the various monetary regimes. The second column adds the world real interest rate trend. The third column splits the sample across the periods of the pension system, instead of the monetary regimes. All variables are combined in the final column, where we only consider selected phases of the monetary regime and pension system to avoid a collinearity problem.

We observe a clear effect of demographics. The real interest rate trend is lower when the share of old people is high, and when the share of young people is low. In terms of magnitude, an increase of 1 percentage point in the ratio of old to working age people reduces the real interest rate by 20-30 basis points (i.e. 0.2-0.3 percentage points), while a decrease of 1 percentage point in the ratio of young to working age people reduces the real interest rate by 4-6 basis points. This is in line with the findings of the literature that an aging population lowers the real interest rate. Specifically, in demographic models working age people save more when they expect to be in retirement for a longer period (a situation where the ratio of old to working age people is high), leading to a lower interest rate. The (smaller) effect of the ratio of young people occurs when working age people make transfers to their children who do not yet earn any income. These transfers limit the amount of savings of working age people, and we thus have a high interest rate when the ratio of young to working age people is high. The pattern is robust to the various specifications.

The first column shows that the trend real interest rate has evolved across regimes, with higher values before and after World War 2. These results are however sensitive to controlling for the real interest rate in the rest of the world (column 2). Including the real interest rate trend abroad in the regression removes the significance of the early monetary regimes. This is not surprising, as in the early decades of the sample nearly all countries were part of metallic currency regimes, which implied fixed exchange rates, and capital moved relatively freely. Therefore, real interest rate trends should be similar across countries and absorbed by the world interest rate (see also our discussion of the interest rate decomposition presented in the previous chapter). By contrast, the dummy remains significant for more recent periods: the Swiss real interest rate has been higher than abroad since the beginning of the Bretton Woods period, and especially since the adoption of the new policy regimes in 2000.[1] Interestingly, the temporary exchange rate floor against the euro is not associated with a different value.

The third column assesses the impact of the characteristics of the pension system through three dummies, controlling for demographics and the world real interest rate trend. The adoption of the pay-as-you go component of the system in 1948 did not lead to a change of the real interest rate trend, but we observe a clear increase in 1984 when the capitalization component was introduced. This result is striking, as we would expect the higher savings to lower the interest rates. Recall, however, that these coefficients do not have a causal interpretation as other events may have happened at the same time.

The final column considers all variables jointly, with only selected periods of the monetary regimes and pension system. We observe that the effect of the monetary regimes is robust to controlling for the pension system. Moreover, the demographic variables and the world real interest rate trend keep the expected sign.

Our econometric analysis shows that the Swiss real interest rate has been higher in recent decades than before, which can seem puzzling. It is however important to keep in mind that we control for the world real interest rate, as well as demographic change. The dummies therefore

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[1] More precisely, the real interest rate trend is higher in Switzerland in more recent periods conditional on demographics and the world real interest rate.

Tab. 5.1: Explaining Swiss long-term real interest rate trend fluctuations

Demographics				
Old dependency ratio (in %)	-0.305^{***}	-0.233^{***}	-0.222^{***}	-0.352^{***}
	(0.067)	(0.049)	(0.020)	(0.029)
Young dependency ratio (in %)	0.045^{***}	0.052^{***}	0.039^{***}	0.064^{***}
	(0.013)	(0.010)	(0.005)	(0.006)
World long-term real rate (in %)		0.491^{***}	0.307^{***}	0.372^{***}
		(0.021)	(0.020)	(0.021)
Monetary regimes				
Bimetallism	4.043^{***}	1.397		
	(1.372)	(1.013)		
Classical Gold Standard	3.831^{***}	0.950		
	(1.475)	(1.089)		
Foundation SNB	2.886^{**}	0.454		
	(1.464)	(1.079)		
World War 1	3.568^{**}	0.919		
	(1.411)	(1.042)		
Interwar-period	4.468^{***}	1.827^{*}		1.067^{***}
	(1.283)	(0.948)		(0.109)
World War 2	2.088	0.970		
	(1.353)	(0.994)		
Bretton Woods (capital controls)	3.961^{***}	2.290^{**}		1.441^{***}
	(1.487)	(1.094)		(0.118)
Bretton Woods (free capital mobility)	3.544^{**}	0.414		
	(1.679)	(1.239)		
Monetary targeting	6.317^{***}	2.694^{**}		2.138^{***}
	(1.833)	(1.354)		(0.151)
Flexible inflation targeting	7.534^{***}	4.828^{***}		3.651^{***}
	(1.929)	(1.420)		(0.223)
Exchange rate floor	7.490^{***}	5.245^{***}		4.198^{***}
	(2.051)	(1.508)		(0.293)
Flexible inflation targeting	6.970^{***}	4.974^{***}		4.032^{***}
	(2.150)	(1.580)		(0.314)
Institutional regimes				
Optional old age insurance			2.552^{***}	
			(0.445)	
Old age insurance			2.371^{***}	0.477^{***}
			(0.513)	(0.169)
Three-pillar system			4.857^{***}	2.145^{***}
			(0.578)	(0.230)
Constant				1.678^{**}
				(0.660)
Observations	676	676	676	676
Adjusted R^2	0.938	0.967	0.947	0.902

Notes: The table shows regressions of the Swiss long-term real interest rate trend on Swiss demographic factors, the world real interest rate trend, monetary regimes, and pension legislation dummies (see Table 3.2). Standard errors are given in parentheses and */**/*** denote statistical significance at the 10%/5%/1% level.

capture the pattern of the Swiss interest rate relative to the value in the rest of the world and conditional on demographic change. The estimates indicate that since the 2000's the Swiss real interest rate trend has been higher than what we would expect given demographic change and given the world real interest rate. Thus, Switzerland has become less special and the interest rate island has disappeared in line with Kugler and Weder di Mauro (2009). This is also consistent with the estimates of Engel and Wu (2018) who find the convenience yield for Swiss government bonds has become lower than the one in other countries since 2000.

6 Conclusion

Our analysis provides a long view of Swiss interest rates by constructing a novel data set for the 19th century, and by using a novel estimation approach to capture fluctuations in long-term trends. We draw on new archival sources and existing data for other countries to compute quarterly time series of Swiss short- and long-term interest rates, exchange rate growth, and inflation, going back to 1852.

We show that, while Swiss interest rates have been relatively low in international comparison since World War 1, the opposite pattern was observed in prior decades. Although real interest rates abroad explain a relevant share of Swiss interest rate fluctuations, we also identify various Swiss-specific patterns. First, Swiss nominal interest rates remained lower than foreign interest rates during the 1970's and 1980's, which can be at least partly attributed to lower trend inflation. Second, a decomposition shows that the Swiss (real) interest rate island emerged during the Bretton Woods system, became more relevant after the demise of the Bretton Woods system, and became less important when the inflationary environment stabilized during the 1990's. In addition, Swiss demographic change plays a significant role in driving the real interest rate trend, whereas, the new monetary policy regime in 2000 and the introduction of the capitalization component of the pension system coincided with a higher real interest rate relative to other countries.

Our finding that the monetary regime of the last two decades is associated with a higher real rate, suggesting that Swiss real interest rates rose relative to other countries, is the most surprising. Bearing in mind that it captures an effect relative to the rest of the world, and that most world central banks have moved towards some sort of inflation targeting regime, our finding could reflect foreign countries adopting regimes more conducive to price stability, thereby becoming more similar to Switzerland.

We have to be careful with predicting recent trends into the future. Indeed, our estimates show that long-term interest rate trends may change rapidly at times. Nevertheless, we believe that the low inflation trend observed since the Global Financial Crisis will keep nominal interest rates low, at least in the short-term. Furthermore, global developments, which point to a sustained period of low real interest rates, can be expected to continue to put downward pressure on Swiss real interest rates. In addition, according to Jordà et al. (2020), the Covid-19 pandemic may be an additional factor that keeps the natural rate of interest down. Finally, the aging of the Swiss population will likely exert a downward effect on the real rate. Therefore, we conclude that low interest rates will remain a challenge for policy makers.

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Appendix

A Appendix

A.1 Data

A.1.1 Trade-weights

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.[1]

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 China, and it is therefore not included. Thus, our final sample comprises nine countries as follows: Austria, France, Germany, India, Italy, Japan, The Netherlands, the UK and the US. According to the SNB's weights, these countries represent 85% and 63% 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 A.1).

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[1] 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.

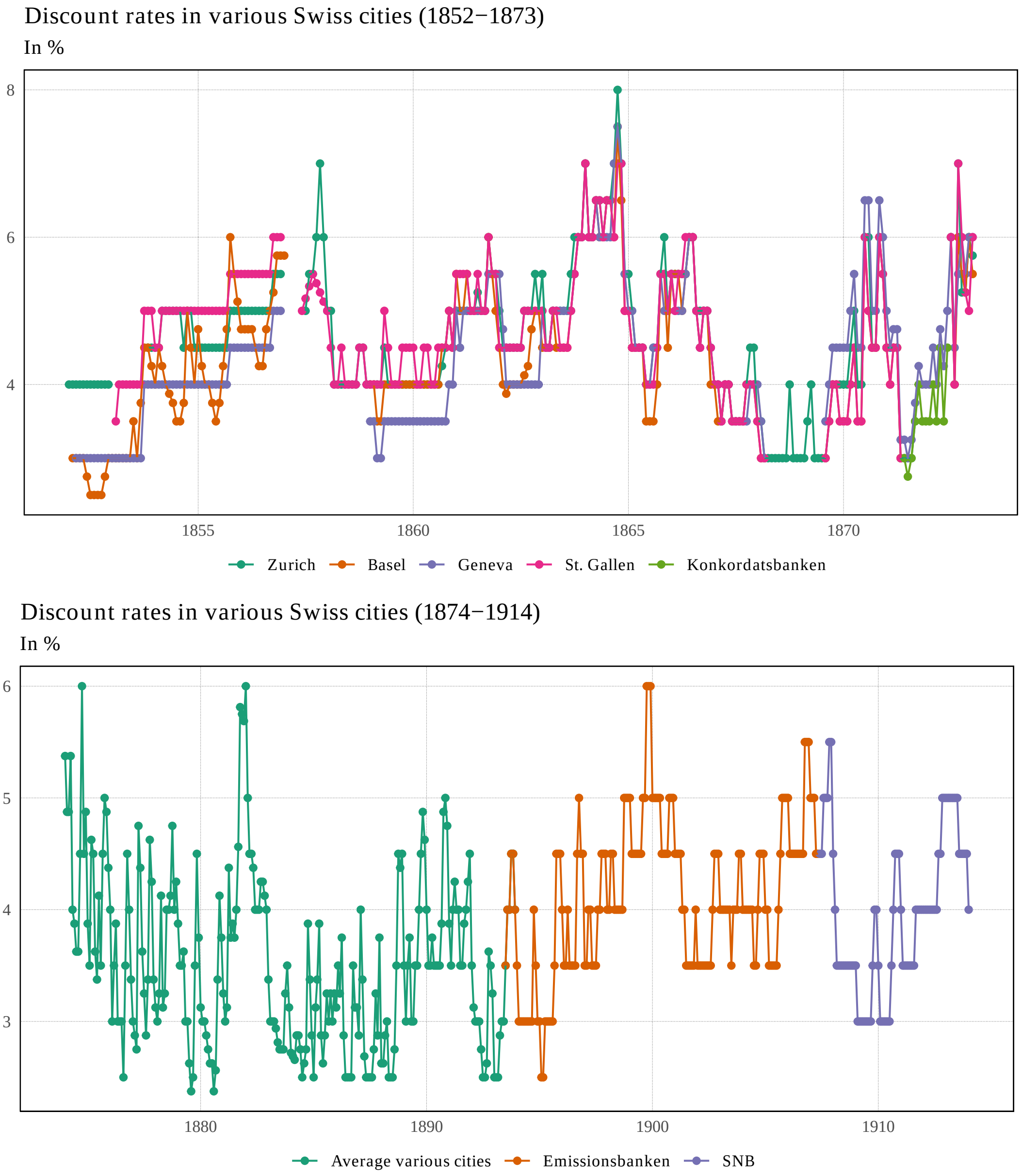
Tab. A.1: Sample periods international interest rate data (1964-2020)

Country	Weight 1973	Weight 2020	Short interest rate	Long interest rate
Austria	6.2	2.6	1964Q1-2020Q4	1964Q4-2020Q4
France	13.8	6.8	1964Q1-2020Q4	1964Q1-2020Q4
Germany	26.3	17.2	1964Q1-2020Q4	1964Q1-2020Q4
India	0.0	3.3	2011Q4-2020Q4	NA
Italy	9.7	6.2	1964Q1-2020Q4	1980Q1-2020Q4
Japan	3.8	2.8	1964Q1-2020Q4	1989Q1-2020Q4
Netherlands	3.9	2.6	1982Q1-2020Q4	1964Q1-2020Q4
United Kingdom	11.5	6.9	1964Q1-2020Q4	1964Q1-2020Q4
United States	10.5	14.6	1964Q1-2020Q4	1964Q1-2020Q4
Total	85.6	63.0		

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).

A.1.2 Data for Switzerland during the 19th century

Fig. A.1: Monthly discount rates for the 19th century

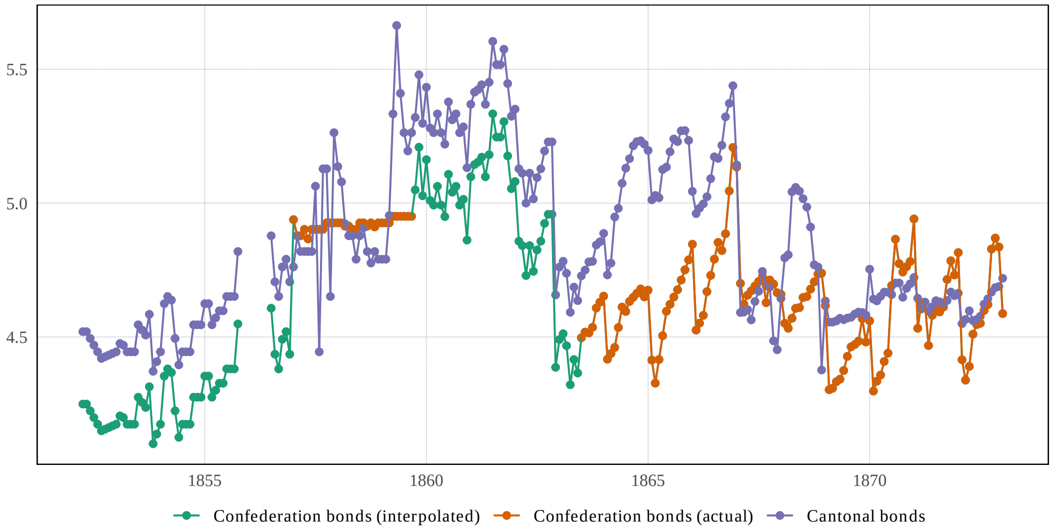


Notes: The figure shows monthly discount rates for various cities (in %).

Fig. A.2: Monthly long-term bond yields for the 19$^{\text{th}}$ century

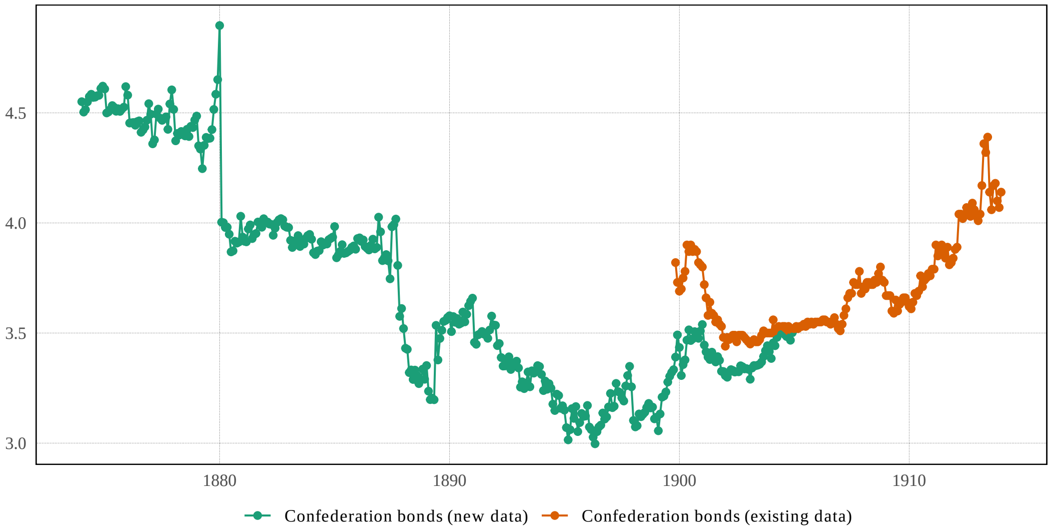
Long−term bond yields (1852−1873)

In %



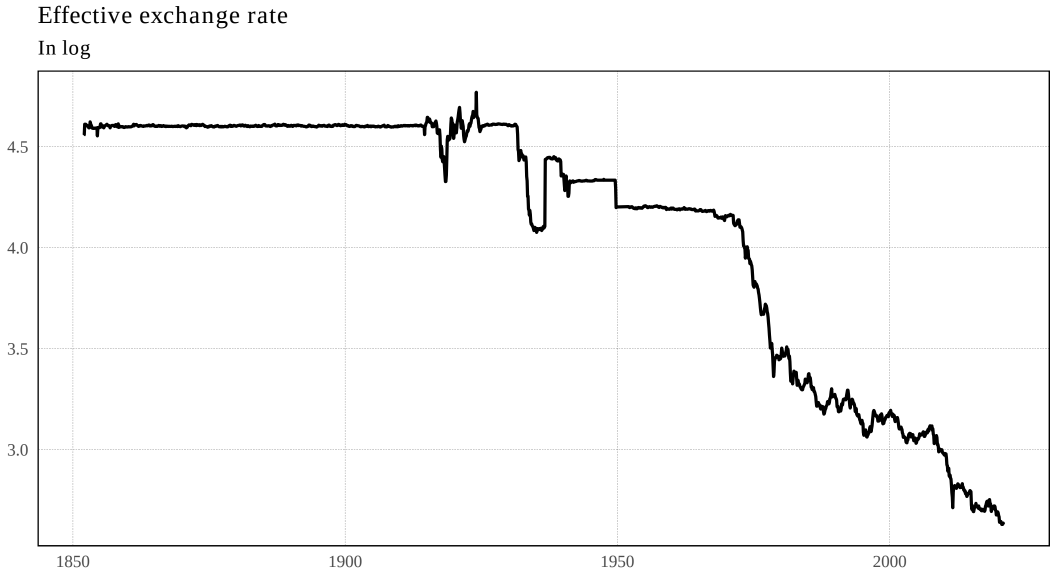
Long−term bond yields (1874−1914)

In %



Notes: The figure shows monthly long-term bond yields (in %).

Fig. A.3: Monthly effective exchange rate



Notes: CHF/GBP until 1914, equally weighted CHF/GBP and CHF/USD until 1963, trade-weighted exchange rate thereafter.

A.1.3 Computing bond yields

When calculating bond yields, we resort to widely used formulas to calculate the yield-to-maturity. In what follows, we discuss the formulas we use and provide a simulation exercise to highlight potential biases.

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:

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

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, $C = r \times F$.

If the maturity date is unknown we have to resort to an approximation. In this case, we assume that the bond is of very long maturity, which we can verify for many of the bonds. If m tends to infinity, the yield-to-maturity equals the current yield, which is the solution i to the bond pricing equation:

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

Note that, despite their long term to maturity, many 19th century bonds were callable and some are subject to a (random) repayment plan. A callable bond can be repaid in part or in full after a notification period of usually around 6 months. This implies that, each period, there is an (unknown) probability that the issuer calls the bond. In addition, once a bond is called, the time to maturity declines immediately to the notification period. A (random) repayment plan specifies that a certain number of bonds are repaid. Which bonds are repaid was often determined randomly. This implies that, in each period, there is a (known) probability that the bond an individual is holding is repaid. Although this probability is in principle known, we do not have accurate data or it was prohibitively costly to collect this information for all bonds. A further complication arises because the probability of a bond being drawn increases at shorter time to maturity because fewer bonds are outstanding.

We chose to ignore the repayment probabilities in our calculations. In principle, however, we can examine how the bond pricing equation has to be modified for a callable bond and a bond subject to a repayment plan. Suppose a bond has a constant annual repayment probability of p. This may occur because a fraction p of all bonds is randomly repaid each year. Or, this may be because each period the government may randomly choose to call the bond.[2] Then, in the first year, the bond is repaid in full with a probability p, whereas only the coupon is paid with a probability $1-p$. In the second year, we have to multiply the income stream with the probability that the bond has not been repaid in the previous year $(1-p)$. Following this logic for all future periods, and taking into account that the bond is repaid with certainty in the last period, the bond pricing equation reads:

$$P = p\frac{C+F}{1+i}+(1-p)\frac{C}{1+i}+p(1-p)\frac{C+F}{(1+i)^2}+(1-p)^2\frac{C}{(1+i)^2}+\ldots+(1-p)^{m-1}\frac{C+F}{(1+i)^m}\ . \quad \text{(A.3)}$$

The bond pricing equations we use to calculate bond yields introduce two types of biases. First, we use the current yield when we do not know the time to maturity. Because most bonds had a finite term to maturity, the formula is incorrect, which biases the bond yield. Second, by ignoring the fact that bonds were callable or subject to random repayment plans, we assume that the probability of being repaid prematurely is $p = 0$

To assess the severity and nature of these biases, we conduct a simulation exercise. First, we compare the difference of the bond yield calculated using the current yield (Eq. A.2) and yield-to-maturity (Eq. A.1) formulas, respectively (see Figure A.4). 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 figures then show 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 becomes slightly less severe if the coupon interest rate increases. The intuition is that the current yield ignores the face value repayment. This repayment matters less, however, if the coupon interest payment is more important. However, 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

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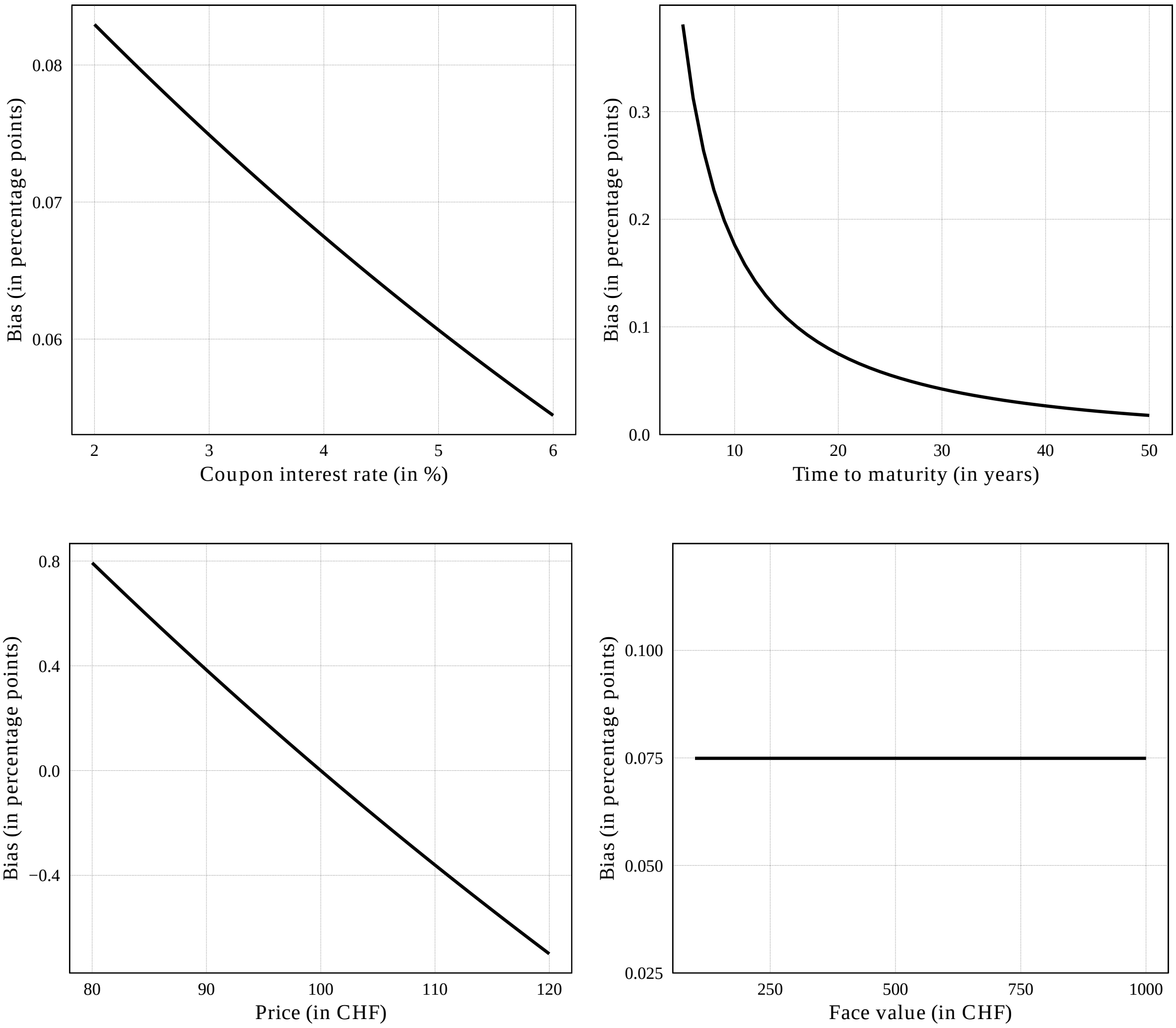
[2] In reality, this probability has hardly been constant. Indeed, governments were more likely to call the bond when the situation on bond markets were such that their interest rate payments where lower when issuing a new bond.

Fig. A.4: 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.

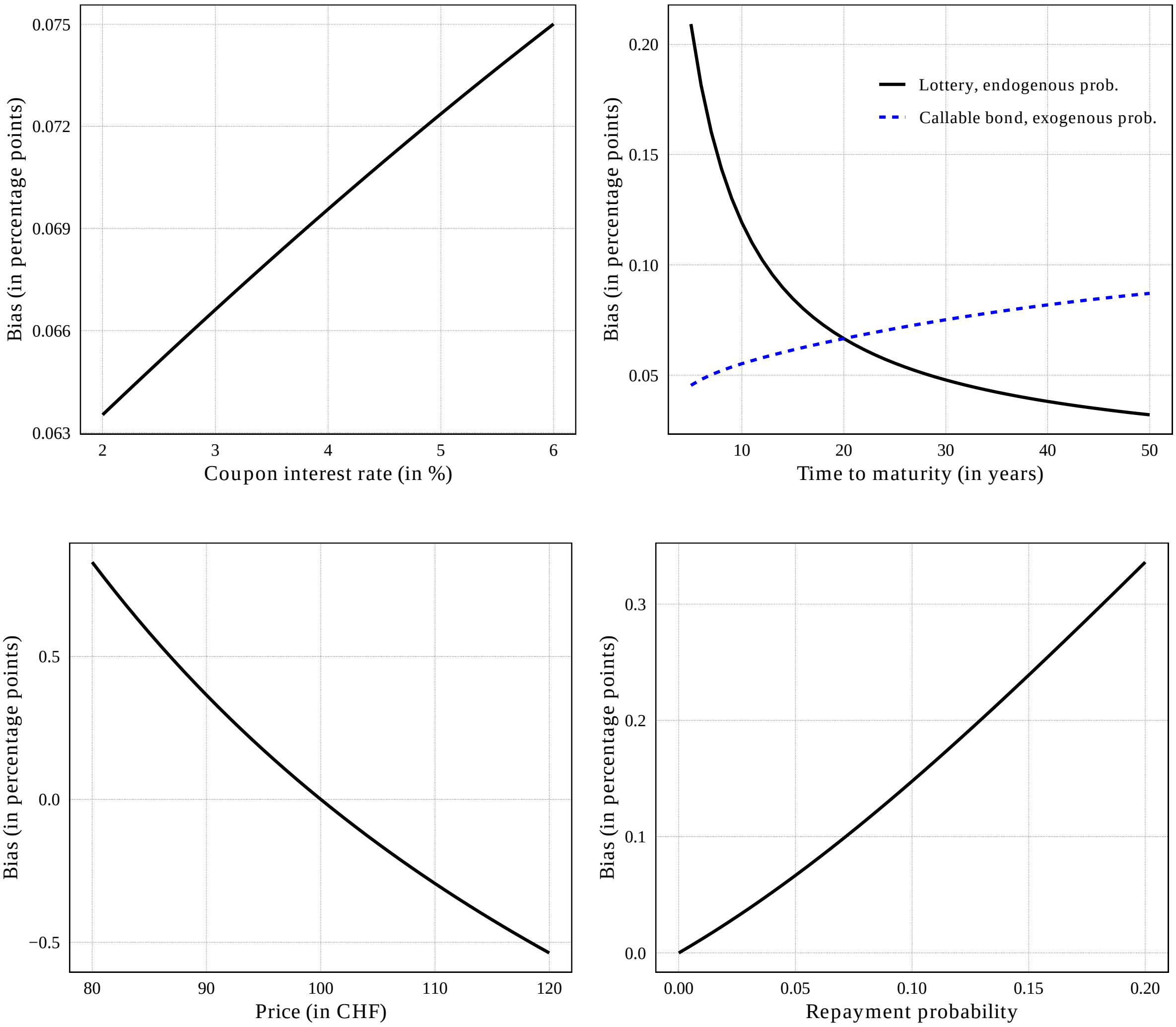
bias is less severe. Importantly, the bias is below 0.1 percentage points for time to maturities of 15 years and longer. More worryingly, the bias switches sign when varying the price of the bond. For a low price, the bias is positive (we underestimate the bond yield) while for a high price the bias is negative (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, the bond yield series will be too smooth for those bonds where we do not know the time to maturity. Finally, varying the face value of the bond has no impact because it changes proportionally with the coupon interest payments.

Second, we compare the difference of the bond yield accounting for a random repayment (Eq. A.3) and ignoring the repayment probability (Eq. A.1), respectively (see Figure A.5). In the baseline, we use the same parameter values as before and set $p = 1/20$, which implies an unconditional repayment probability of 5% for a callable bond or that a constant fraction of outstanding bonds is repaid at random. When varying the time to maturity, the difference between a callable bond and a bond subject to a repayment plan is that the probability of being repaid likely increases for shorter terms to maturity as fewer bonds are outstanding. We account for this fact by setting $p = 1/$Time to maturity. Meanwhile, for a callable bond it is more sensible to assume that the repayment probability does not depend on the time to maturity so that we set $p = 1/20$ even when varying the time to maturity.

Again, we underestimate the bond yield because we ignore repayment plans and callable bonds. A higher coupon interest rate increases the bias slightly. However, for reasonable values of the coupon interest rate the bias is very small. A higher repayment probability of course increases the bias. As long as this probability is not too high, however, the bias is again small. Again, a more serious issue is that ignoring the repayment probability leads to a switch in the sign of the bias for low and high bond prices. This will also lead to excess smoothness of our bond yields for callable bonds and bonds subject to random repayment plans. An interesting difference arises between repayment plans and callable bonds when we vary the time to maturity. For repayment plan bonds, a longer time to maturity lowers the bias. Meanwhile, for short time to maturity, the bias can be quite severe because this implies that the (endogenous) repayment probability is quite high. Meanwhile, for callable bonds increasing the term to maturity increases the bias. For a repayment probability of 5%, however, the bias appears to be quite small.

In sum, the simulation exercises suggests that we likely underestimate the level of the bond yields, although this bias is probably quite small (smaller than 0.1 percentage points) as long as

Fig. A.5: Bias when ignoring repayment plans or callable bonds



Notes: The figure shows the bias when ignoring that a bond is subject to a random repayment plan, where each period a share of $p = 1/$Time to maturity of outstanding bonds is randomly repaid. Alternatively, we can interpret the results as being for a bond where the probability of being repaid each period equals p. We assume that the true bond has an (unconditional) annual repayment probability of 5%, 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.

we focus on bonds with a long time to maturity. In our application, we ensure this by selecting bonds that are available over long sample periods when the maturity information is missing. In addition, the inverse relationship with the price of the bond suggests that for the historical period, our bond yield series will be smoother than modern series that are not subject to these biases.

A.1.4 Interpolating demographic data

In our analysis we use the attrition rates in the data from 1860 to 1869 and apply these to the data to work backwards and obtain dependency ratios for the period prior to 1860. Here we outline an alternative method to calculate these dependency ratios and some checks we carried out to select our preferred methodology (see Figure A.6).

Data on live births are available since 1803. Our alternative method is therefore to work forwards from births. One issue that arises is that the data on live births do not correspond closely to the number of children aged 0 in the census data in the period after 1860. Therefore, the average percentage of live births that appear as children aged 0 in the census over the period 1860 to 1869 is calculated and applied to the live births data. The attrition rates, described already, can then be applied (forwards) to these data. Since live births are available from 1803, the oldest cohort for which we can make an estimate in 1840 is of age 37. Therefore, even when this method is applied, we still have to use the backwards method described in the main part of the report to calculate the number of people in older age groups.

Overall, the first, backwards method is preferred for two reasons. First, comparing with the total population in the 1850 census, we find that the first method is more accurate (an error of just over 15,500 compared to almost 79,000 when using births). Second, we carry out a replication exercise for the 1860s, where the attrition rates applied are calculated from the period 1870-1879 (see Figure A.6). We calculate the young and old dependency ratios and compare them with the actual data. We find that the first method more closely matches the actual data in absolute levels for the young dependency ratio (mean absolute error of 0.006 per cent compared to 0.025 per cent) while the method using births is marginally better for the old dependency ratio (mean absolute error of 0.0072 per cent compared to 0.0078 per cent) and that the correlation coefficients for the two methods with the actual data are similar.

Fig. A.6: Interpolating demographic data

Estimates of old dependency ratio (1852−1873)

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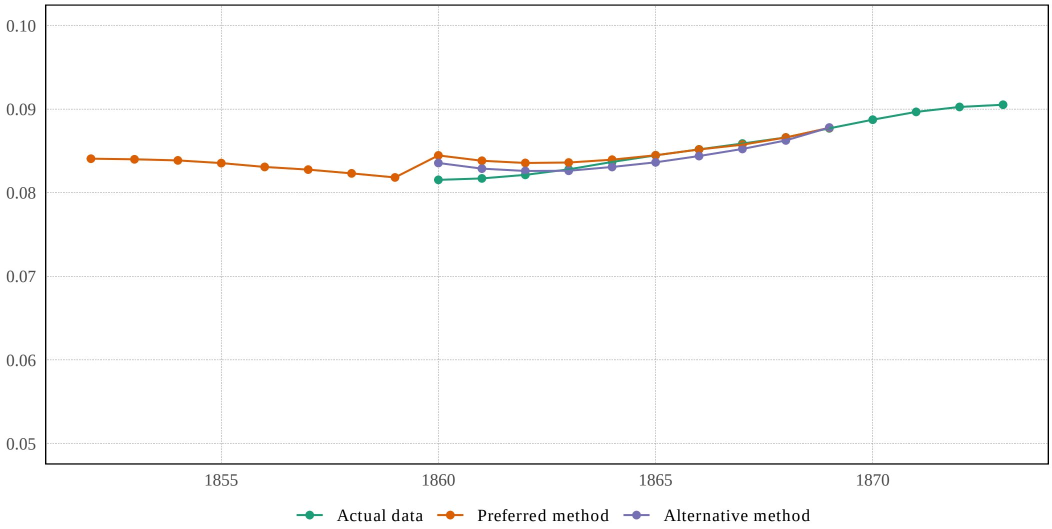

Estimates of young dependency ratio (1852−1873)

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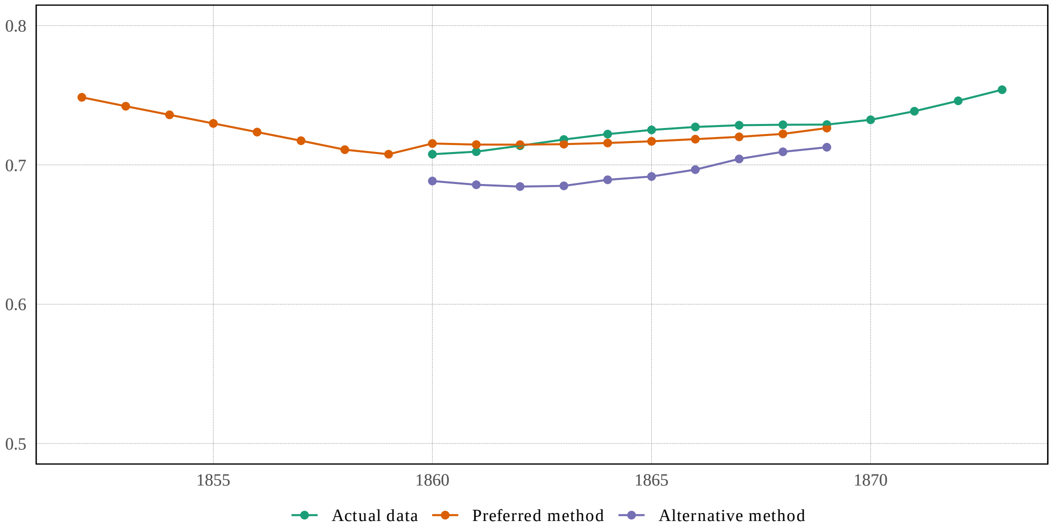
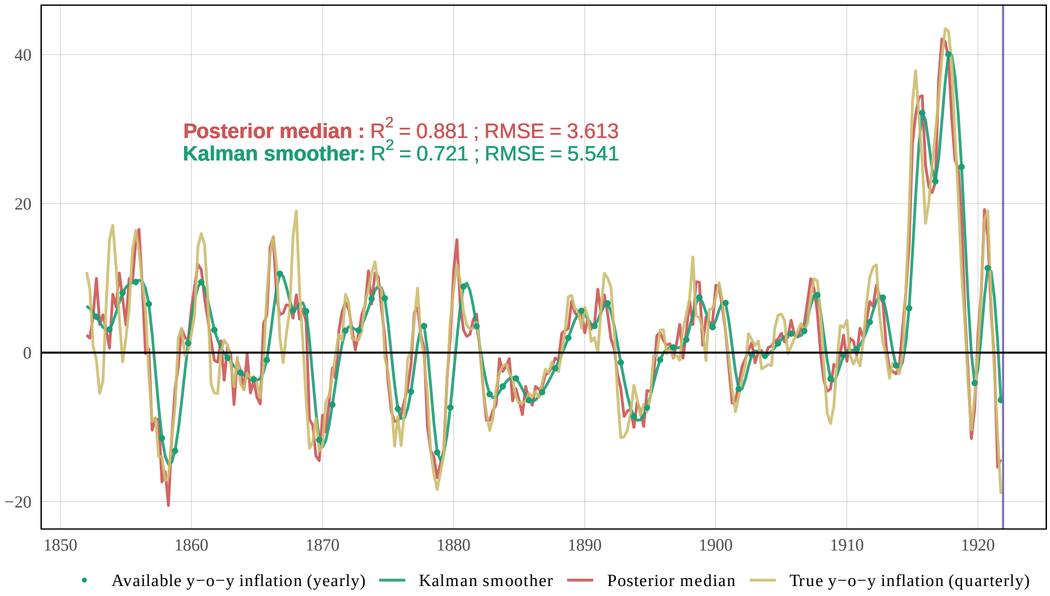


Notes: This figure presents actual and interpolated dependency ratios according to two methods (preferred, alternative).

A.1.5 Testing the disaggregation method using Norwegian data

We collect data for Norway to use it as a laboratory to test how well our disaggregation method for the annual Swiss price index works. The monthly wholesale price index starts in 1777 and stems from Klovland (2013). We then link this wholesale price index with a CPI from Statistics Norway in 1920. The monthly NOK/GBP exchange rate stems from Eitrheim et al. (2004) and starts in 1819. We then link this with a NOK/GBP exchange rate from the Norges Bank (2021).

Fig. A.7: Quarterly estimate of Norwegian inflation



Notes: The figure shows actual annual, quarterly, and estimated quarterly year-on-year inflation (in %). Point estimate of quarterly Norwegian inflation (in red), with actual quarterly inflation (in yellow), annual inflation (green dots) and a Kalman smoother estimate (in green).

We then aggregate the CPI for the 19th and early 20th century to annual data and disaggregate it with the same approach as for Switzerland.[3] Figure A.7 compares the estimates (in red) with the actual data (yellow) and a univariate model (in green). Our approach works better than the univariate model. The R^2, a measure of how well the estimate fits the actual quarterly series, is higher with the multivariate model. In addition, the root-mean-squared error (RMSE), a measure of how much the estimate deviates from the actual observation, is considerably smaller. This suggests that the disaggregation works quite well, and in particular, better than simpler approaches.

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[3] More precisely, the information set for Norway is smaller because we were not able to obtain long- and short-term interest rates. This is left for future research.

A.2 Technical Appendix

In this technical appendix we briefly outline the methods and models used in the paper. The next sub-section discusses the mixed frequency model used to interpolate inflation data prior to 1922 while Sub-sections A.2.2 and A.2.3 discuss the multivariate TVP regression and how we obtain trend and gap measures from this model, respectively.

A.2.1 Mixed frequency VARs for interpolating inflation data

Let $\boldsymbol{y}_t$ denote a M-dimensional vector measured at the quarterly frequency which includes data on inflation, short- and long-run interest rates, the quarterly growth rate of the exchange rate for Switzerland as well as inflation and short- and long-term interest rates for the rest of the world. Notice that prior to 1922, the inflation data in Switzerland was available only at the yearly frequency, implying that some elements in $\boldsymbol{y}_t$ prior to 1922 are not observed.

We will assume that $\boldsymbol{y}_t$ evolves according to a VAR model:

$$\boldsymbol{y}_t = \boldsymbol{A}_1 \boldsymbol{y}_{t-1} + \dots + \boldsymbol{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\boldsymbol{0}_M, \boldsymbol{\Sigma}_M), \tag{A.4}$$

with $\boldsymbol{A}_j$ $(j = 1, \dots, p)$ denoting a $M \times M$ coefficient matrix associated with lag j of $\boldsymbol{y}_t$ and $\boldsymbol{\Sigma}_M$ denotes the variance-covariance matrix of the system.[4] Since $\boldsymbol{y}_t$ is partially latent before 1922 we cannot estimate the VAR using standard techniques. In principle, one could simply interpolate missing values using, e.g., splines or other techniques. These, however, fail to take into account that prices are highly persistent, might co-move with other elements in $\boldsymbol{y}_t$ which are observed on a quarterly basis, and that we are able to infer the relations between the elements in $\boldsymbol{y}_t$ at the quarterly frequency from 1922 onward.

As a solution, we will treat the missing values in $\boldsymbol{y}_t$ as additional latent quantities that are estimated alongside the remaining model parameters. This is achieved by specifying a so-called inter-temporal aggregation scheme. More precisely, we assume that observed CPI inflation, labeled π_t^o, is related to the quarterly, latent, inflation series, π_t^* as follows:

$$\pi_t^o = \begin{cases} \frac{1}{4}\left(\pi_t^* + \pi_{t-1}^* + \pi_{t-2}^* + \pi_{t-3}^*\right) + \eta_t^0 & \text{if } t \leq 1921\text{:Q4 and } t \text{ refers to the } 4^{th} \text{ quarter of a year} \\ \emptyset & \text{if } t \leq 1921\text{:Q4 and does not refer to the } 4^{th} \text{ quarter} \end{cases}. \tag{A.5}$$

This equation states that year-on-year CPI inflation is the average of the latent measures of

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[4] In all our empirical work we set $p = 4$.

year-on-year CPI inflation plus a Gaussian measurement error η_t^j $(j = 0, 1)$. This measurement error is centered on zero and features a variance $\vartheta_{\eta t}^0$. In case that t refers to a quarter of a year other than the fourth quarter (and is before 1922:Q1), there is no information available and the corresponding measurement error will be infinite. From 1922:Q1 onward, CPI inflation is observed with measurement error η_t^1. This measurement error has variance $\vartheta_{\eta t}^1$ with $\vartheta_{\eta t}^0 > \vartheta_{\eta t}^1$, implying that measurement errors have been much larger prior to the first quarter of 1922.

Equation A.5 can be viewed as the observation equation of the model while (A.4) denotes the state equation. Hence, estimating the latent quarterly inflation measures boils down to exploiting the linear Gaussian structure of the model and employ filtering-based techniques. In this paper, we adopt the Bayesian approach outlined in Schorfheide and Song (2015) and estimate the model using Markov chain Monte Carlo techniques. These methods yield a distribution over the latent values of π_t^* which we view as the true year-on-year inflation rate. In the next step, we will use the mean estimate of this time series to extract the permanent (non-stationary) factors.

A.2.2 A threshold time-varying parameter VAR

Since our sample covers several economic crises, wars, and structural shifts in the underlying macroeconomic relations (such as the end of the Bretton-Woods system), we need an econometric model which is capable of controlling for this. We capture these breaks by resorting to a time-varying parameter (TVP) VAR model. Since standard TVP-VARs typically assume smoothly evolving coefficients, we use a so-called mixture innovation model which allows for rapid jumps in the coefficients (Huber et al., 2019). Assuming that $\boldsymbol{y}_t$ now includes the interpolated and measurement-error free Swiss CPI inflation series, we use a TVP-VAR:

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

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

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

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

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

$$\kappa_{jt} = \begin{cases} \kappa_j & \text{with probability } p_j \\ 0 & \text{with probability } 1 - p_j \end{cases} \tag{A.6}$$

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

The idea of this model is that in periods of stable structural relationships, coefficients tend towards being constant, while in periods of structural upheavals, coefficients are allowed to change in an almost unrestricted manner.

A.2.3 Extracting long-run trends

After estimating the reduced-form coefficients, we recast the VAR(p) model in its companion form:

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

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

The companion form allows us to perform structural analysis in an easy manner. In the following, we are interested in two measures for the long-run relationships between macroeconomic variables. 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-specific) unconditional mean of the model:

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

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