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# Understanding Swiss real interest rates in a financially globalized world

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## Abstract

This paper proposes long-run estimates of ex ante real interest rates in Switzerland and other developed economies, and it describes their relative evolution. Our results highlight the decline in—and convergence of—global real interest rates that has unfolded over the last three decades for all maturities. While Swiss yields stand out as being particularly low and stable from a historical perspective, we find that Swiss interest rates have fallen less than in many other countries during the last decade. We then examine whether the reduction in the interest differential is related to a lower attractiveness of the Swiss franc. Focusing on the difference of Swiss minus German real government bonds yields, we find a significant increase in expected real depreciation of the Swiss franc and a somewhat lower convenience yield for Swiss bonds—the convenience yield reflecting the non-pecuniary value that investors impute to the liquidity of a given bond. In contrast, the safety premium in favor of the Swiss franc increased and therefore cannot explain the smaller decline in real interest rates in Switzerland. The last part of the paper analyzes the negative convenience yield on Swiss government bonds and its recent decline. We show that both the purchase of government bonds by foreign central banks and foreign exchange interventions by the Swiss National Bank may have contributed to this decline by reducing the relative supply of foreign versus domestic government bonds.

**Keywords:** Real interest rate, Switzerland, Safe haven, Convenience yield

## 1 Introduction

The objective of this paper is to understand the evolution of real interest rates in Switzerland from a global perspective. The secular decline in global real interest rates is a well-documented fact. This phenomenon alone puts a downward pressure on Swiss real interest rates. In addition, the Swiss franc is considered as a safe-haven currency, which may also depress the Swiss interest rate. The first part of the paper estimates carefully ex ante real interest rates in Switzerland and in other developed economies and describes their relative evolution over the last 50 years. Surprisingly, we find that in the recent decade real interest rates in Switzerland have fallen less than in many other countries while, at the same time, the Swiss

franc has fully played its role as safe haven with a substantial real appreciation. The second part of the paper examines these issues in detail and attempts to provide explanations.

In the first part of our analysis, we compute real interest rates on government bonds at different maturities for 17 countries from 1970 to 2020. To obtain nominal yields, we employ filtering procedures to interpolate nominal yields coming from different sources, including the macro-history database of Jordà et al. (2015). Inflation expectations are inferred from an approach combining econometric specifications posited for the inflation process and survey-based forecasts (as in Grishchenko et al., 2019; Aruoba, 2020). Our results highlight the decline in global real interest rates that has unfolded over the last three decades, for all maturities. We also document the convergence of national interest rates: over the last few decades the explanatory power of a single global component has dramatically increased. The growing integration

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in international financial markets, and the related emergence of a “global cycle” may have contributed to this convergence (Miranda-Agrippino & Rey, 2015; Gerko & Rey, 2017). An implication of this phenomenon is the reduced importance of national factors to account for real interest rate movements.

Among the yields associated with the 17 countries of our sample, Swiss ones stand out as being particularly low and stable. On average over the last fifty years, nominal and real Swiss yields have been several percentage points below global averages, which confirms previous analyses (e.g., see Baltensperger & Kugler, 2017). Moreover, the volatility of Swiss yields, as measured by their standard deviations, is substantially lower than for other countries. These characteristics of Swiss bonds (low-yield/low-risk) are consistent with the status of safe haven of these assets (e.g., Rinaldo & Söderlind, 2010; Leutert, 2018).

Under the combined effects of the fall in world rates and the convergence of national rates, very low long-term interest rates have become less specific to Switzerland over the last decade. More precisely, while it is still the case that nominal yields are among the lowest in our sample, it is now less the case for real rates. This comes from the relative low levels of inflation expectations in Switzerland. For instance, although nominal Swiss yields have been slightly lower than German ones, the position of associated real rates has been inverted over the last five years because of lower Swiss inflation expectations over this period.<sup>1</sup>

The econometric analysis does not enable us to identify robust factors explaining the recent evolution of Swiss real rates compared to global rates. On the other hand, if we take an international arbitrage perspective, we can draw interesting lessons. The real interest rate differential is made of three elements: (i) a safety premium for the Swiss franc, which reflects the intrinsic insurance value of an asset denominated in Swiss franc (as this currency tends to appreciate during crises), (ii) the expected real depreciation of the Swiss franc and (iii) the relative convenience yield on Swiss vs foreign government bonds. The latter can be measured as the difference in government yields after hedging exchange rate risk (through the forward market). It captures the non-pecuniary value that investors impute to Swiss

government bonds relative to foreign ones (Jiang et al., 2018). Focusing on the difference of Swiss minus German real government bonds yields, we see that this difference turned from negative to positive in the last decade. We show that this change in sign comes from an increased expected depreciation of the Swiss franc and a lower convenience yield for Swiss bonds. In contrast, the safety premium in favor of the Swiss franc actually increased and cannot account for the smaller decline in real interest rates in Switzerland.

The last part of the paper focuses on the convenience yield. The analogy with the US dollar would suggest that an appreciating currency should be associated with an increase in the convenience yield, but this is not the case for the Swiss franc, as its appreciation came with a decrease in the convenience yield. We therefore examine the contemporaneous relationship between the convenience yield and the exchange rate in the Swiss context, using regressions as in Engel and Wu (2022). We find that, controlling for other factors, the Swiss convenience yield is positively related on average to an appreciation of the Swiss franc, which is consistent with what the literature has found for the dollar. However, this mechanism accounts for a limited share of exchange rate fluctuations and is dominated by other factors that have led to an appreciation in the most recent period.

We then propose some explanations for the negative convenience yield on Swiss government bonds and for its recent decline. We examine the hypothesis that the convenience yield of the Swiss franc vis-à-vis foreign currencies results from the relative supply of and the relative demand for Swiss and foreign government bonds. We show that both the purchase of government bonds by foreign central banks and foreign exchange interventions by the Swiss National Bank (SNB) may have contributed to this decline by reducing the relative supply of foreign versus domestic government bonds. Indeed, this makes Swiss bonds relatively less scarce, which decreases the convenience yield as it pushes the relative return of Swiss bonds up. Interestingly, we also find that a *lagged* exchange rate appreciation leads to a decline in the convenience yield, which contrasts with the previous evidence. This can be explained by the fact that an exchange rate appreciation increases the foreign currency value of Swiss government bonds, which also reduces the convenience yield by making Swiss bonds less scarce. So the coexistence of an appreciating currency and a declining convenience yield could be explained by a causal link going from the exchange rate to the convenience yield, at least in the Swiss context.

The rest of the paper is organized as follows: After having explained their computation, Sect. 2 analyzes the

<sup>1</sup> Interestingly, this relative position of German and Swiss real yields is consistent with the view offered by another interest rate decomposition that we conduct in the working paper version of the present paper Bacchetta et al. (2021). Using the approach originally proposed by (Laubach & Williams, 2003), we compute measures of monetary-policy stances, defined as the difference between effective real rates and estimates of so-called natural rate of interest (NRI). Although imprecisely estimated, these measures suggest that the monetary-policy stance is slightly more accommodating in Germany than in Switzerland.

evolution of the global and Swiss real interest rates. In Sect. 3, we analyze the international dimension of real interest rate differentials, and in Sect. 4, we focus on the convenience yield. Section 5 concludes.

## 2 The evolution of global and Swiss real interest rates

In this section, we examine the evolution of real interest rates over the last fifty years.<sup>2</sup> Section 2.1 describes the calculation of the real interest rates. Section 2.2 discusses the evolution of global rates, and Sect. 2.3 focuses on the Swiss case.

### 2.1 Measuring real rates of interest

There is no unique measure of the real interest rate. First, there are *ex post* and *ex ante* real interest rates. Second, on each date, there is a term structure of real interest rates: short-term real rates may differ from long-term ones. For example, denoting by  $i_{t,h}$  the yield-to-maturity associated with a nominal bond of maturity  $h$ , the *ex ante* real interest rate of maturity  $h$  is approximately given by:

$$r_{t,h} = i_{t,h} - \mathbb{E}_t(\pi_{t+h}), \quad (1)$$

where  $\pi_{t+h}$  is the annualized inflation between dates  $t$  and  $t+h$ . Naturally, one can also define the *ex post* real interest rate  $r_{t,h}^{expost}$ . However, since the date- $t$  *ex post* rate of maturity  $h$  can be computed only on date  $t+h$ , the measurement of *ex post* long-term real rates comes with a substantial lag. Hence, economic decisions taken by agents on date  $t$  depend on *ex ante* and not on *ex post* real rates. Third, the real interest rate depends on the price index underlying the inflation  $\pi_t$ . Inflation can be based on consumer/producer price indexes or on the GDP deflator; it can also exclude volatile food and energy prices (core inflation). Differences among these different inflation rates usually tend to vanish when it comes to compute their medium- to long-term expectations. In the remainder of this study, we focus on inflation rates based on consumer price indices, as this is the most widely used concept of inflation.

For countries where governments issue inflation-indexed bonds (e.g., Treasury Inflation-Protected Securities, or TIPS, in the USA), real rates of different maturities ( $r_{t,h}$ ) are readily observable on secondary sovereign-bond markets. However, inflation-indexed bonds have not been issued by many governments and not for very long. In the absence of inflation-linked bonds, one has to rely on Eq. (1) to compute real rates. Nominal government yields are relatively easily available, for any maturity and at any frequency—at least for the last three

to four decades. By contrast, measures of inflation expectations are more difficult to obtain. Surveys provide such expectations, but are not available for long time periods.

We develop and apply a methodology to compute long-historical samples of real interest rates, for any maturity and seventeen countries. This approach is based on filtering methods that allow to handle missing data. The general idea is the following: for both (i) the term structure of nominal interest rates and (ii) the term structure of inflation expectations, we consider a factor model and posit a dynamics for the factors driving these term structures. Then, we feed the (state-space) models with observations of available nominal yields (for i) and inflation realizations as well as survey-based inflation forecasts (for ii). The Kalman filter is then used to estimate the model. Once this is done, we can compute nominal yields and inflation expectation at any horizon. We refer to Appendix A and Additional file 1: I and II for estimation details.

Our dataset covers 17 countries: Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, the UK, Italy, Japan, Netherlands, Norway, Portugal, Sweden and the USA.<sup>3</sup>

### 2.2 Evolution of global rates

Global rates are defined as the averages of the rates associated with the 17 countries of our dataset.<sup>4</sup> The top panel of Fig. 1 shows the evolution of long-term global nominal and real interest rates since 1970.<sup>5</sup> The global long-term real rate was fluctuating around 2–3% in the 70s. It then rose to reach 5% in the 1980s, in a context of rising inflation, and has essentially decreased since the mid-1990s.

The lower panel of Fig. 1 illustrates the interest rate convergence that has characterized the last decades. Conducting a principal component analysis on a 30-year rolling window, we find that the share of real rates variances accounted for by the first principal component—that can be interpreted as a global factor—increased from levels of about 50% over 1960–1990 to 85% over 1990–2020. Over the same period, the variance of the country-specific components of the yields has been divided by 5.

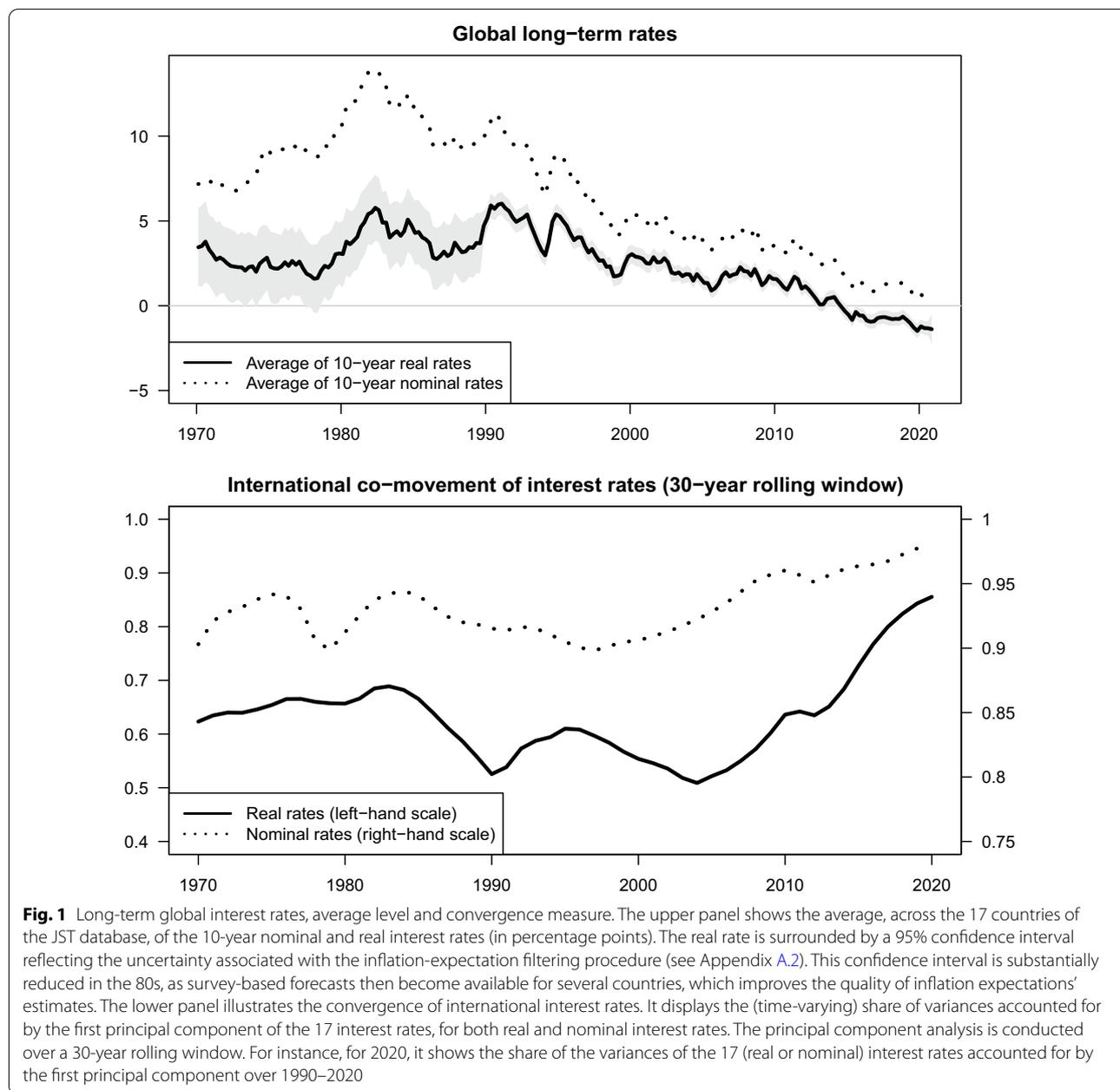
The real rate convergence reduces the scope for national determinants to account for recent changes in national real rates. Consistently with this idea, Rachel and Summers (2019) take the advanced economies as

<sup>3</sup> These 17 countries are those considered by Jordà et al. (2015).

<sup>4</sup> Alternative computations of the global rate would provide close results. In particular, the fluctuations of this simple average of the long-term yields are very close to those of the first principal component of the set of yields.

<sup>5</sup> The real rate is surrounded by a 95% confidence interval reflecting the uncertainty associated with the inflation-expectation filtering procedure (see Appendix A.2). This confidence interval is substantially reduced in the 80s, as survey-based forecasts then become available for several countries, which improves the quality of inflation expectations' estimates.

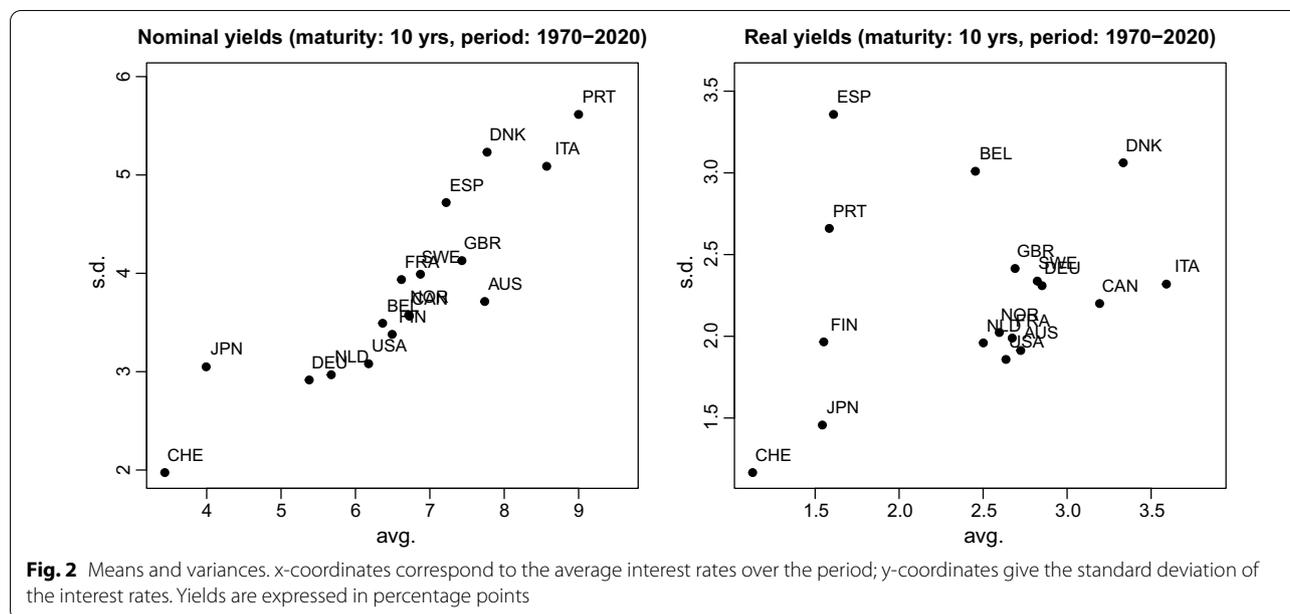
<sup>2</sup> In Bacchetta et al. (2021) we estimate real rates since 1870.



a bloc to explain the decreasing trend in real rates over the last forty years. According to Del Negro et al. (2019), the convergence of interest rates may reflect the growing integration in international financial markets. They also note that this finding is in line with the literature emphasizing the emergence of a “global cycle” explaining a large share of the variance in returns of risky assets around the world (e.g., Miranda-Agrippino & Rey, 2015; Gerko & Rey, 2017). According to the empirical evidence provided by Hofmann and Takáts (2015), the substantial correlation across interest rates partly reflects international

monetary spillovers, i.e., a direct impact of changes in policy rates in core advanced economies on rates elsewhere, above and beyond what might be expected from other economic linkages.

The fact that policy rates of most advanced economies have hit, or approached, the Effective Lower Bound (ELB) for nominal rates has accentuated the yields compression since the global financial crisis. Indeed, the volatility of long-term nominal interest rate tends to be diminished when short-term rates are constrained by the ELB (see, e.g., Swanson & Williams, 2014). This reduced volatility



of long-term nominal rates combined with relatively low and stable inflation expectations has contributed to the clustering of long-term real rates around zero.

There is an expanding literature that discusses the determinants of real interest rates and that provides explanations for the decline in the global rate.<sup>6</sup> These well-known explanations point to an increase in global saving, e.g., due to demographic or precautionary saving reasons, and a decline in global investment, e.g., due to lower productivity or higher uncertainty. There may also be an increase in the demand for safe assets putting downward pressure on government yields (see Caballero et al., 2016; Glick, 2020). Note, however, that it is difficult to identify factors that can significantly explain real interest rates over long horizon. For example, estimated coefficients are not robust in panel regression analyses (see Borio et al., 2019, for a discussion).

### 2.3 The relative evolution of Swiss yields

Over the last fifty years, Swiss yields have been particularly low, and less volatile than in the other countries of the sample. This is notably illustrated by Fig. 2, which plots yields standard deviations against averages for the 17 countries of our dataset. Switzerland appears in the lower-left corner of the plots (as it features the lowest average and lowest standard deviation).

Figure 3 allows to assess the relative position of Swiss yields through time, considering the breakdown of nominal yields into their real yield component and inflation expectations. The different plots of this figure compare the Swiss 10-year yields and expectations (black solid lines) to Germany (blue), Japan (dashed red) and the 14 other countries of our dataset (grey circles). It appears, in particular, that while nominal German yields were at least 100 bp above Swiss ones between 1980 and 2010, this spread has almost vanished. Moreover, because German inflation expectations are now substantially higher than Swiss ones,<sup>7</sup> German real rates have been evolving slightly below Swiss ones for more than five years now.<sup>8</sup>

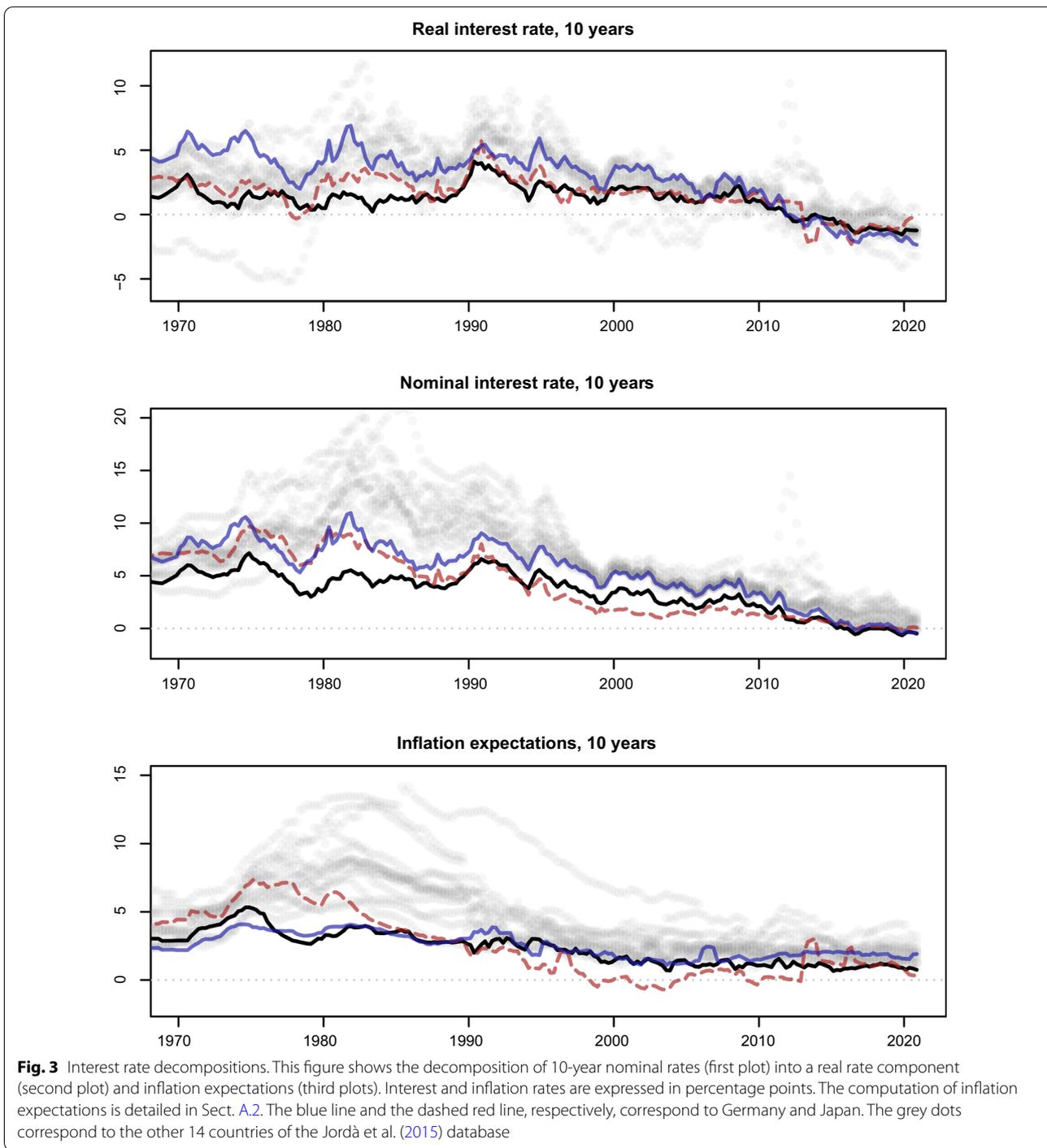
An important question is whether we can identify factors specific to Switzerland that can explain the recent decline in real yields. To examine this question, we applied a standard regression analysis, either in a panel for the 17 countries in our sample or for Switzerland only. Following the literature, we included a set of variables affecting saving and investment.<sup>9</sup> The results of such an analysis are basically inconclusive. First, and similarly to the analyses of the global interest rate, the variables

<sup>6</sup> E.g., see Rachel and Smith (2015), Hördahl et al. (2016), Demary and Voigtländer (2018), Rachel and Summers (2019). Lunsford and West (2019) focus on the US real rate.

<sup>7</sup> In 2020Q4, the 5-year inflation expectations for Switzerland and the euro area were, respectively, of 0.84% and 1.66%, according to the KOF consensus forecast and the ECB survey of professional forecasters.

<sup>8</sup> Fig. III.1 in Online Appendix III shows similar patterns for two- and five-year maturities, but Swiss real rates have been lower than German ones for almost ten years.

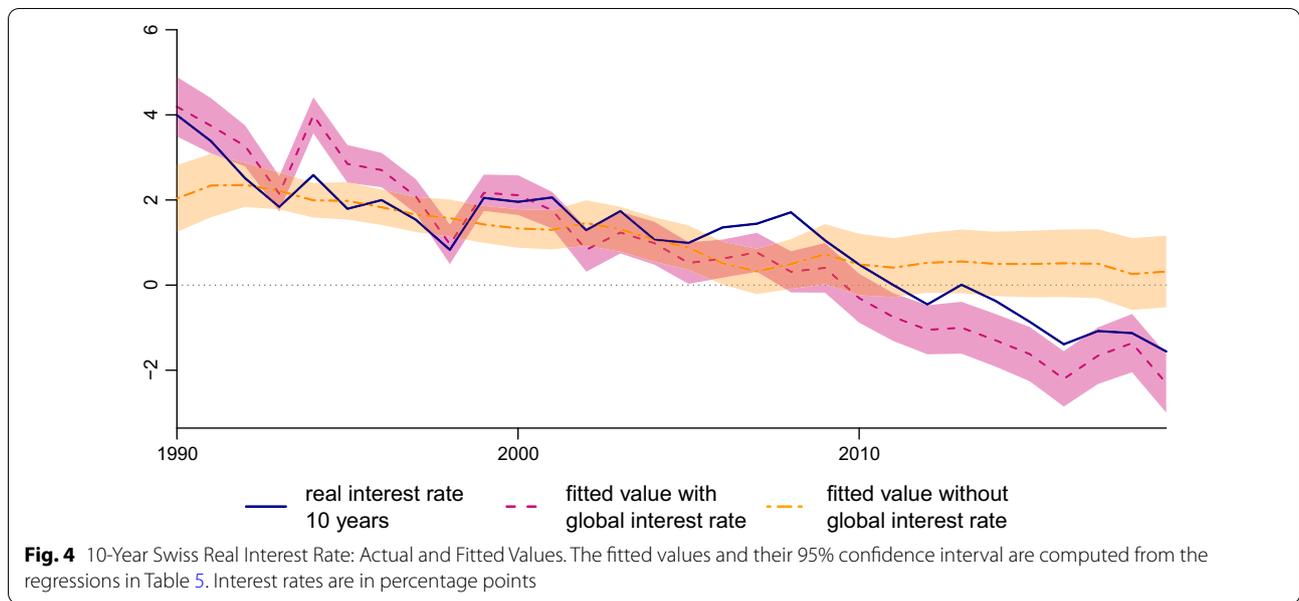
<sup>9</sup> The variables considered include life expectancy, the dependence ratio, the share of the top ten percent income, GDP growth, the investment rate, government consumption, inflation or government debt.



are often insignificant and the regression results are not robust to changes in sample length and specifications. Second, even in the specifications with significant variables, the decline in real interest rates cannot be explained by country-specific variables (see Kiley, 2019, for similar results).

The variable that is most significantly associated with the recent decline in the Swiss real rate is the global real rate.<sup>10</sup> This is illustrated in Fig. 4. It shows the evolution

<sup>10</sup> Kiley (2019) also shows that global variables are predominant in a panel regression.



of the Swiss 10-year real interest rate, as well as the fitted values derived from two panel regressions with a 95% confidence interval. The first regression only includes country-specific variables, while the second regression also includes the global (GDP-weighted) real interest rate. These regressions are presented in Table 5 in Appendix. The fitted value of the regression including the global interest rate is closely in line with the actual interest rate, even showing a larger decline. In contrast, the fitted value without the global rate is unable to capture the recent decline. This result is consistent with the previous analysis that shows the growing co-movement in real interest rate (Sect. 2.2) and confirms that movements in the Swiss real rate are dominated by the global rate.

### 3 Real interest rates and international arbitrage

The previous section has shown that Swiss real interest rates have decreased less than in many other countries and are even currently higher than German rates (see Fig. 3). Does this mean that Swiss franc bonds have become less attractive so that Swiss bonds have to offer higher yields than German bonds? To answer this question, we need to examine the relevant arbitrage conditions and take into account the fact that interest rates are measured in different currencies. We also make explicit the difference between government yields and risk-free yields. This will give a finer analysis of interest rate differentials, especially in the shorter run. On the other hand, we need to restrict the analysis to a shorter sample starting in 1999, due to data availability.

For notational convenience, we focus on the differential between two countries, Home and Foreign. Denote  $r_{t,h}$  and  $r_{t,h}^*$  the Home and Foreign country real yields on government bonds. All Foreign country variables have a \* superscript. We also consider risk-free yields (guaranteed by collateral) for Home and Foreign  $i_{t,h}^s$  and  $i_{t,h}^{s,*}$ . Moreover, let define the nominal depreciation rate of the Home currency versus the Foreign currency as  $\Delta s_{t+h} = s_{t+h} - s_t$ , where  $s_t$  is the log nominal exchange rate, and the real depreciation rate as  $\Delta q_{t+h} = q_{t+h} - q_t$ , where  $q_t$  is the log real exchange rate. Notice that  $\Delta q_{t+h} = \Delta s_{t+h} + \pi_{t+h}^* - \pi_{t+h}$ . It is also useful to define the excess return in foreign currency, or the risk premium, as:  $xs_{t+h} = \Delta s_{t+h} + i_{t,h}^{s,*} - i_{t,h}^s$ .

The Home country convenience yield can be measured by the differential in yields between the risk-free asset and government bonds:  $i_{t,h}^s - i_{t,h}$ . The relative convenience yield between Home and Foreign is therefore defined as:

$$\lambda_{t,h} = (i_{t,h}^s - i_{t,h}) - (i_{t,h}^{s,*} - i_{t,h}^*).$$
(2)

The real interest rate differential can then be written as:

$$\begin{aligned} r_{t,h}^* - r_{t,h} &= (i_{t,h} - \mathbb{E}_t(\pi_{t+h})) - (i_{t,h}^* - \mathbb{E}_t(\pi_{t+h}^*)) \\ &= \mathbb{E}_t(xs_{t+h}) + \lambda_{t,h} - \mathbb{E}_t(\Delta q_{t+h}). \end{aligned}$$
(3)

The previous expression shows that three factors influence the differential in real bond yields. First, the real yield differential is higher with a positive nominal expected excess return, or risk premium. Second, the

**Table 1** Decomposition of the real yield differential euro-Swiss franc with one-year horizon, in percent

Mean Variable	1999Q1–2009Q4	2010Q1–2020Q4	Difference
Real Differential: $r^* - r$	0.79	-1.08	-1.87
Expected excess return	1.34	2.49	1.15
Convenience Yield: $\lambda$	-0.21	-0.44	-0.23
-Expected real depreciation	-0.34	-3.09	-2.75
Ex post excess return	0.28	-2.06	-2.34
-Ex post real depreciation	0.38	0.83	0.45

This decomposition is based on Eq. (3), according to which: real yield differential = expected excess return + convenience yield - expected real depreciation. The data come from Datastream and Consensus Economics. All figures are expressed in percentage points

Home real government bond yield is higher if it has a lower convenience yield.<sup>11</sup> Third, the differential is higher with a lower expected real depreciation.

Table 1 shows the components of the decomposition in Eq. (3) over the two subperiods before and after 2010 for the euro-Swiss franc differentials.<sup>12</sup> Exchange rate expectations are measured by survey expectations from Consensus Economics. Inflation expectations are computed in Sect. 2. In the last two lines of the table, we also show *ex post* excess return and real depreciation, using actual exchange rates and inflation rates.

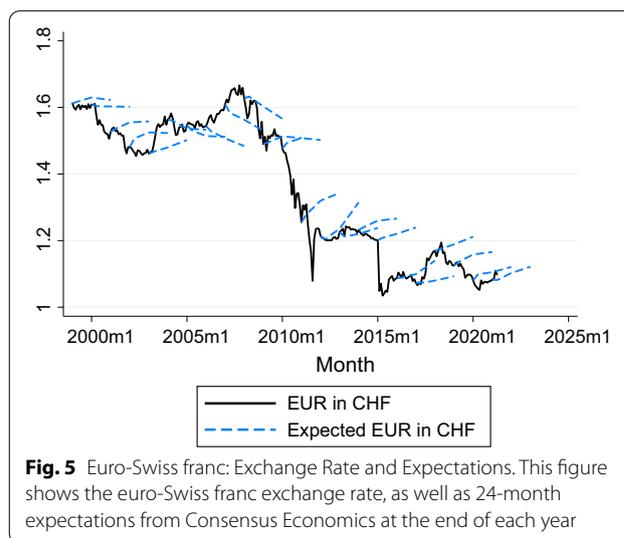
Table 1 first shows that the real yield differential decreased by almost 2 percentage points over the two subperiods, which is substantial. This decrease can be accounted for by a more negative convenience yield and by an increase in expected real depreciation. In contrast, the increase in the expected excess return limits the decrease in the differential. We examine below these three elements.

### 3.1 Expected excess returns

The previous literature has shown that returns in Swiss francs are expected to be systematically lower than returns in foreign currency, especially the euro or previously the Deutsche mark. This implies that deviations from Uncovered Interest-rate Parity (UIP) are positive, i.e., the expected appreciation of the Swiss franc was smaller than the interest rate differential. Kugler and Weder di Mauro (2005) conjectured that this evidence can be explained by a reverse peso problem for the Swiss franc, i.e., a small probability of a large appreciation. More generally, the Swiss franc is often seen as a safe-haven currency (e.g., see Hoffmann & Suter, 2010; Rinaldo & Söderlind, 2010; Leutert, 2018).

<sup>11</sup> A recent literature points to the role of the convenience yields for government bonds in explaining the attractiveness of the US dollar (e.g., Jiang et al., 2021; Engel & Wu, 2022; Valchev, 2020; Jiang et al., 2018).

<sup>12</sup> For the whole period the real interest rate differential is about zero, so this decomposition is less interesting.



**Fig. 5** Euro-Swiss franc: Exchange Rate and Expectations. This figure shows the euro-Swiss franc exchange rate, as well as 24-month expectations from Consensus Economics at the end of each year

However, returns in Swiss francs increased significantly after 2008 as the Swiss franc appreciated. This led, for example, Kugler and Weder di Mauro (2009) to wonder whether the expected return differential disappeared. If we look at *ex post* excess returns in Table 1, we see a significant decrease, implying a larger return in Swiss francs.<sup>13</sup> However, the evolution of *ex post* excess returns contrasts with the one of *expected* excess returns that increase. The difference comes from the fact that the Swiss franc appreciation in the last decade seems to have been unexpected. This is illustrated in Fig. 5, which shows the evolution of the euro-Swiss franc exchange rate compared to 2-year forecasts (from Consensus Economics) shown at the end of each year. The Swiss franc has been expected to depreciate since 2010, while in most cases it appreciated.

Therefore, the use of *ex post* data gives an incorrect picture of expected returns. Using exchange rate expectations instead of actual exchange rate changes, we see that

<sup>13</sup> This decrease is even more significant if we split the sample in 2008.

expected excess returns have even increased, i.e., returns in Swiss francs are still expected to be lower. This would mean that, after a decade of turbulent times, the safety premium on the Swiss franc has increased. Moreover, the real appreciation of the Swiss franc is likely to reinforce this expected excess return as “overvalued” currencies are expected to depreciate. Consequently, expected excess returns or risk premia cannot explain the change in real interest rate differential.

### 3.2 Expected real depreciation

When UIP holds and abstracting from convenience yields (i.e.,  $\lambda_t = 0$  and  $\mathbb{E}_t(x_{s_{t+h}}) = 0$  in Eq. 3), the real interest rate parity is:  $r_{t,h} = r_{t,h}^* + \mathbb{E}_t(\Delta q_{t+h})$ . This means that if Home interest rates are higher, this is compensated by an expected depreciation. Table 1 shows a substantial increase in the expected real depreciation. This increase more than compensates for the increase in expected excess returns. An expected real depreciation of 3.09 percent per year appears large, but the Swiss franc has appreciated sharply in the last decade. The empirical evidence shows that large real appreciations (or deviations from Purchasing Power Parity, PPP) are corrected over time. The expectations of nominal depreciation shown in Fig. 5 are complemented by lower inflation expectations in Switzerland.

## 4 Convenience yields

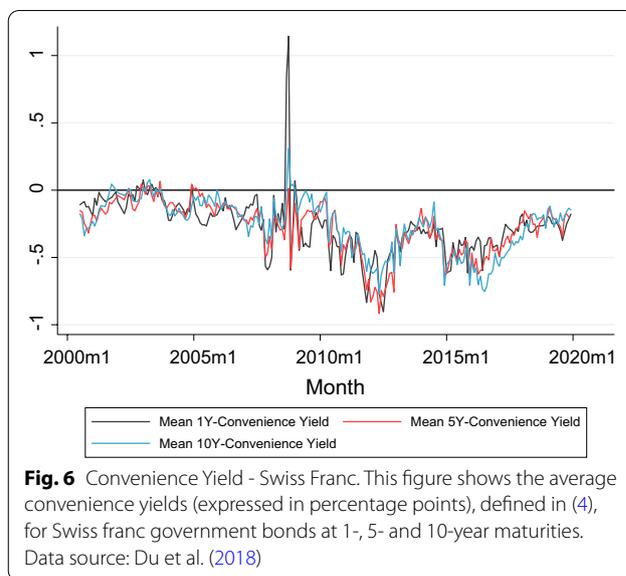
In this section, we focus on the convenience yield. It is of interest to examine whether the recent analyses of convenient yields, applied to the US dollar, also apply to the Swiss franc (see Footnote 11). We start by showing the recent evolution of convenience yields for Switzerland. Then, we revisit the literature on the link between the convenience yield and the exchange rate. Finally, we conduct an econometric study on the determinants of the convenience yield in Switzerland.

### 4.1 Evidence on convenience yields

In practice, it is difficult to get data on risk-free yields for all maturities to compute  $\lambda_{t,h}$ , and researchers may use the forward discount instead to compute convenience yields. More precisely, define the forward discount  $fd_{t,h} = f_{t,h} - s_t$ , where  $f_{t,h}$  is the log forward rate. Researchers sometimes assume covered interest rate parity (CIP) and replace  $i_{t,h}^s - i_{t,h}^{s,*}$  by  $fd_{t,h}$ . The alternative measure of the convenience yield is then:

$$\eta_{t,h} = i_{t,h}^* - i_{t,h} + fd_{t,h}. \tag{4}$$

Using the monthly data from Du et al. (2018), which is available from 1999 to 2019, Fig. 6 shows the convenience yield  $\eta_{t,h}$  at maturities of one, five, and ten years with



respect to an average of ten countries.<sup>14</sup> We see that there is a clear decline in the convenience yield after 2009 at all maturities and that it stayed negative until recently.

This measure differs from  $\lambda_{t,h}$  to the extent that there are deviations from CIP, given by

$$\tau_{t,h} = i_{t,h}^{s,*} - i_{t,h}^s + fd_{t,h}. \tag{5}$$

We have:<sup>15</sup>

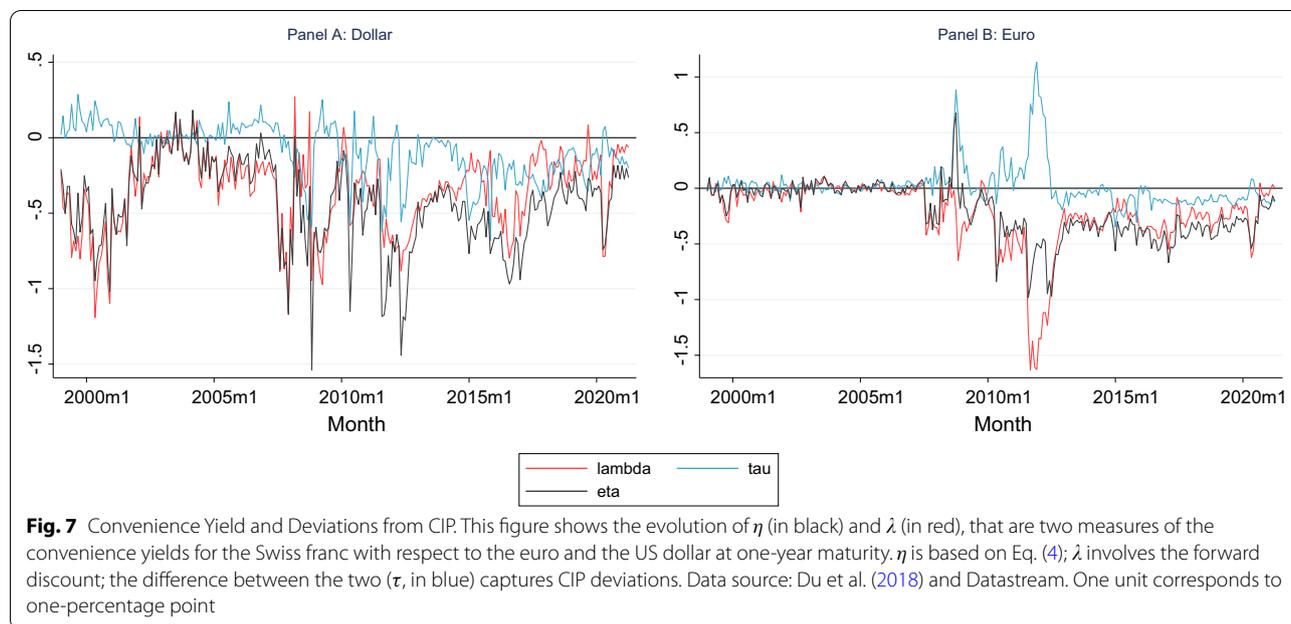
$$\eta_{t,h} = \lambda_{t,h} + \tau_{t,h}. \tag{6}$$

Considering the one-year maturity, we can easily compute  $\eta_{t,h}$ ,  $\tau_{t,h}$  and  $\lambda_{t,h}$ , using Libor rates as risk-free rates. Figure 7 shows the evolution of  $\eta_{t,h}$ ,  $\tau_{t,h}$  and  $\lambda_{t,h}$  for one-year bonds with respect to the US dollar and the euro. Except for a few periods,  $\tau_{t,h}$  is small and fluctuations in  $\eta_{t,h}$  and  $\lambda_{t,h}$  are very similar.

The negative convenience yield for Swiss government bonds is surprising. For example, in our comparison with the euro, we consider German bonds. This means that, after hedging for exchange rate risk, the Swiss government bond yield has been higher than the German one in the last decade. Below we analyze the potential determinants of the convenience yield, in particular public debt and monetary policy. A declining convenience yield is surprising because the last decade coincides with a period of strong pressure on the Swiss franc. The analogy

<sup>14</sup> The ten countries are Australia, Canada, Denmark, Germany, Japan, New Zealand, Norway, Sweden, UK and USA. We will use the same set of ten countries throughout this section.

<sup>15</sup> There might also be a credit default component, but we focus on countries where this element has been negligible.



with the US dollar would tell us that an increase in the convenience yield should be associated with an appreciating currency, but this is not the case for the Swiss franc. However, it is interesting to examine the relationship between the convenience yield and the value of the Swiss franc, which we do in the next subsection.

#### 4.2 Convenience yield and the exchange rate

Jiang et al. (2021) and Engel and Wu (2022) relate the value of the convenience yield to the nominal exchange rate, focusing on one-year government yields. To analyze this relationship more precisely, Engel and Wu (2022) consider the following panel regression for the home country versus country  $j$ :

$$\Delta s_{j,t+h} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 (\Delta \eta_{j,h,t}) + \beta_3 (\Delta i_{j,h,t}^R) + \beta_4 \eta_{j,h,t-1} + \beta_5 i_{j,h,t-1}^R + u_{j,h,t} \quad (7)$$

where  $q_{j,t-1}$  is the log real bilateral exchange rate and  $i_{j,h,t}^R = i_{t,h} - i_{j,h,t}$ . They focus on one-year government yields and find that both the interest differential and the convenience yield are strongly significant. They also examine the differentiated impact of  $\tau_t$  and  $\lambda_t$  (their Table 2A). Table 2 presents evidence on Eq. (7) for the Swiss franc, using the same methodology as in Engel and Wu (2022), for one-year yields and with monthly data.<sup>16</sup>

Our results are quite similar to those of Engel and Wu (2022). Column (1) indicates strong significance for both the interest differential and the convenience yield (as in their Table 1A). Column (2) shows significance of the convenience yield without the interest differential, but with a lower  $R^2$ . Column (3) shows significance for the interest differential only. The last column shows that both  $\tau_t$  and  $\lambda_t$  are significant. We see that the coefficient on  $\lambda$  is somewhat lower than the coefficient on  $\eta$  in column

**Table 2** The Effect of Convenience Yields on Bilateral Exchange Rates

	(1)	(2)	(3)	(4)
$q_{j,t-1}$	-2.208*** (0.340)	-2.284*** (0.369)	-2.074*** (0.323)	-2.563*** (0.400)
$\Delta \eta_{j,h,t}$	-1.289*** (0.289)	-0.395 (0.278)		
$\Delta i_{j,h,t}^R$	-1.485*** (0.274)		-1.023** (0.326)	-1.282*** (0.263)
$\Delta \lambda_{j,h,t}$				-0.987** (0.354)
$\Delta \tau_{j,h,t}$				-1.391*** (0.322)
Observations	2666	2666	2666	2666
Within R-squared	0.0224	0.0119	0.0158	0.0348

The table reports the OLS estimates of Eq. (7) with country-fixed effects. It uses the Swiss franc as the home currency and the other 10 currencies as foreign currency  $j$ . Standard errors clustered by country in parentheses. \* $p < .1$ , \*\* $p < .05$ , \*\*\* $p < .01$

<sup>16</sup> We consider the Swiss franc with respect to 10 other currencies and use OLS with country dummies. The coefficients on lagged variables are included in the regression, but are not shown.

(1), which implies that deviations from CIP play a (small) role.

There are some econometric issues with regression (7), but we will not discuss them here. What we can conclude from Table 2 is that there is a significant negative relationship between the convenience yield and the nominal exchange rate. This means that an increase in the convenience yield is associated with an appreciation of the Swiss franc, which is what we would expect. However, this mechanism does account for a limited share of exchange rate fluctuations: with a decline in the convenience yield of about 0.5 percentage points (as seen in Fig. 6) and a coefficient  $\beta_2$  of about  $-1$ , the order of magnitude of the associated change in the exchange rate is of half a percentage point.

### 4.3 What drives convenience yields?

In this section, we examine the role of potential drivers of the convenience yield. We perform a panel analysis of the Swiss bilateral convenience yield using quarterly data from January 2004 to March 2020 for the ten currencies listed in Sect. 4.1 (Footnote 14).<sup>17</sup> One of the purposes of this section is to propose some explanations to the recent decline in the convenience yield. We show that both the purchase of government bonds by foreign central banks and the appreciation of the Swiss franc may have contributed to this decline.

In this empirical exercise, we examine the assumption that the convenience yield reflects the equilibrium price of Swiss government bonds, relative to foreign government bonds. A consequence of this assumption is that this relative price reflects the relative demand for Swiss government bonds, but also their relative supply. Namely, if some factors increase the demand for Swiss bonds relative to the demand for foreign bonds, then we expect the Swiss convenience yield to increase. Similarly, if some factors increase the supply of Swiss bonds relative to foreign bonds, we expect the Swiss convenience yield to decrease.

We use as demand drivers the VIX (CBOE Volatility Index), which is commonly used as a measure of global uncertainty. Under the assumption that Swiss government bonds are considered relatively safe, an increase in the VIX should lead to an increase in their demand and hence to an increase in the Swiss convenience yield. We

also use the ratio of the Swiss real GDP to the foreign real GDP. Assuming that investors have a home bias in bond holding, we may expect that an increase in this ratio increases the Swiss convenience yield vis-à-vis the foreign country. Indeed, a higher GDP in Switzerland relative to the foreign country increases the relative demand for Swiss government bonds and must therefore increase the Swiss convenience yield. This variable may also capture capital flights from countries that go through a recession.

We also examine the role of the supply of public debt. Public debt has a potentially significant role for interest rates and especially the convenience yield (Rachel & Summers, 2019; Krishnamurthy & Vissing-Jorgensen, 2012; Du et al., 2018). One of the main purposes of this section is to estimate the elasticity of the government convenience yield to exogenous changes in the supply of government bonds. We expect this elasticity to be negative. Indeed, for the market to absorb an excess supply of public debt, the relative return on public debt must increase, which means that the convenience yield must decrease. Du et al. (2018) find that the US supply of bonds reduces the US convenience yield, while the foreign supply of bonds increases it. Our approach builds on theirs, but we focus on Switzerland. We also emphasize that what matters for the convenience yield is not gross public debt *per se* but public debt *net* of central bank holdings, i.e., the amount of public debt that is available to the private sector. This implies that central bank purchases of government bonds matter as well. We will therefore also examine separately the role of these central bank purchases.

Finally, we will also examine the assumption that the exchange rate contributes to the convenience yield by affecting the supply of Swiss public bonds evaluated in foreign currency. If the exchange rate appreciates, then the supply of Swiss public bonds evaluated in foreign currency increases mechanically, which should depress its relative price. We thus expect an appreciation of the Swiss franc to decrease the Swiss convenience yield.

#### 4.3.1 Panel data analysis

We estimate the effect of the supply of government bond debt on the convenience yield, measured by  $\eta$  as defined in Eq. (4), by estimating the following panel regression:

$$\eta_{t,h,j} = \beta_1 \Delta \left( \frac{\text{Debt net of CB}}{\text{GDP}} \right)_{CH,t} + \beta_2 \Delta \left( \frac{\text{Debt net of CB}}{\text{GDP}} \right)_{j,t} + \beta_3 (i_{CH,t} - i_{j,t}) + \beta_4 \log(VIX_t) + \beta_6 \log \left( \frac{\text{Real GDP}_{CH,t}}{\text{Real GDP}_{j,t}} \right) + \beta_7 t + \beta_8 t^2 + \alpha_j + \epsilon_{it} \tag{8}$$

where  $\Delta(\text{Debt net of CB}/\text{GDP})_{CH,t}$  is the change in the Swiss ratio of federal government debt (net of the

<sup>17</sup> The analysis starts in 2004 because of data availability.

**Table 3** Drivers of the Convenience Yield

	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
$\Delta(\text{Debt net of CB/GDP})_{CH}$	-28*** (3.1)	-14*** (2.8)	-11*** (2.6)	-12*** (2.2)
$\Delta(\text{Debt net of CB/GDP})_j$	2.1** (.94)	1.8* (.91)	1.9*** (.63)	2.1*** (.59)
$i_{CH} - i_j$	.14*** (.0098)	.16*** (.0082)	.044*** (.013)	.066*** (.012)
$\log(VIX)$	.011 (.041)	.12*** (.041)	.14*** (.034)	.094*** (.033)
$\log\left(\frac{\text{Real GDP}_{CH}}{\text{Real GDP}_j}\right)$				2.9*** (.25)
Observations	602	602	602	602
R-squared	0.30	0.43	0.71	0.75
Kleibergen-Paap F-stat				
Hansen J-stat p-val				
Quad. trend	No	Yes	Yes	Yes
Country FE	No	No	Yes	Yes

Quarterly data. The dependent variable is the convenience yield of Swiss government debt vis-à-vis country *i*'s government debt in basis points, at a 10-year maturity,  $\eta_{t,10year,j}$ . Government debt is the change in the ratio of government debt net of central bank holdings to GDP, in percentage points. The log of relative GDP is multiplied by 100, so that the coefficients read as the effect of a 1-percent increase in relative GDP

Standard errors in parentheses

\* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

Swiss National Bank holdings) to GDP in percentage points,  $\Delta(\text{Debt net of CB/GDP})_{j,t}$  is the change in country *j*'s ratio of central government debt (net of country *j*'s central bank holdings) to GDP in percentage points,  $i_{CH,t} - i_{j,t}$  is the policy interest rate differential in basis points,  $\text{Real GDP}_{CH,t}/\text{Real GDP}_{j,t}$  is the ratio of real GDPs,  $t$  and  $t^2$  capture a quadratic trend and  $\alpha_j$  are country-fixed effects. The short-term interest differential is important because it is an element of the convenience yield measurement. While in theory the convenience yield is supposed to be independent from it, it could still be correlated with it if the government bond yield differential is sluggish.  $\eta_{t,h,j}$  is the average convenience yield of Swiss government debt vis-à-vis country *j*'s government debt at maturity *h* in quarter *t*, in basis points.<sup>18</sup> Our

<sup>18</sup> The countries in our panel are the same as in Table 2. We use quarterly government debt data from the IMF to measure the supply of government bonds, net of central bank holdings. Convenience yields come from Du et al. (2018). Swiss Treasury zero-coupon yields at maturities ranging from 1 to 10 years come from the Swiss National Bank. Monetary policy rates for the central banks of the countries in the panel come from Refinitiv Datastream, as well as the exchange rates of the Swiss Franc with respect to the other currencies. Data on the VIX comes from FRED. We use nominal GDP from the IMF to compute debt ratios and the real GDP from the OECD to compute the relative GDP. In our baseline regression, we focus on a maturity of 10 years.

specification is close to Du et al. (2018), but we consider more controls than they do and regress the convenience yield in level on the change of government debt, instead of regressing it on the level of government debt as they do.<sup>19</sup>

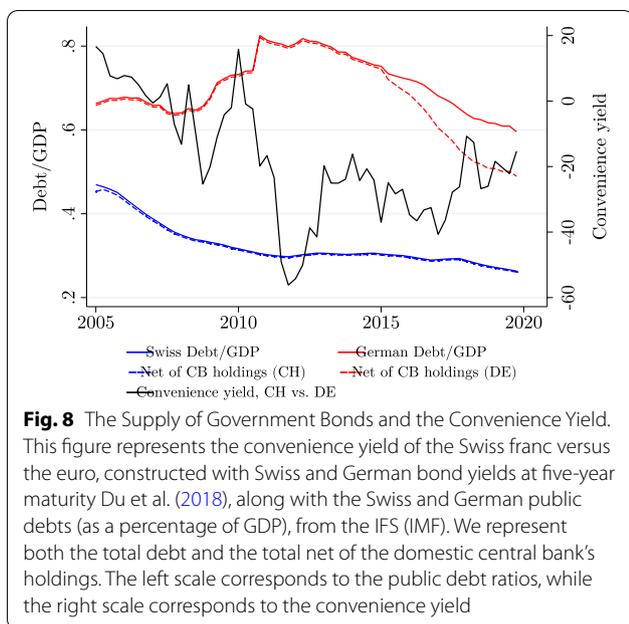
Column (4) of Table 3 shows the results of our regression. Columns (1) and (2) do not include the country-fixed effects in order to determine how far we can explain the convenience yield without them. In a similar spirit, column (1) shows the results without the quadratic trend. Relative GDP is included only after we have introduced fixed effects, because the unit is arbitrary (real GDPs are normalized to 100 in 2000). Note that it is important to include the quadratic trend, not only because it is significant and increases the fit of the regression from 30% to 43%, but also because it changes the magnitude of some coefficients (see columns 1 and 2). When we include the country-fixed effects, the fit increases as well, to reach 71% (see columns (2) and (3)). Finally, in column (4), we add relative GDP. The fit of column (4) is 75%, which is rather large.

Focusing on column (4), we see that the demand drivers have the expected signs. An increase in the VIX generates a statistically significant increase in the 10-year Swiss convenience yield. This positive coefficient may reflect the safe-haven nature of Swiss government debt. However, as we will see, this result is not very robust. The coefficient of the relative GDPs is also statistically significant, with a positive sign. This is consistent with home bias in asset holdings. An increase in domestic GDP relative to the foreign GDP increases the demand for home assets relative to foreign assets, which has a positive effect on the Swiss convenience yield. The coefficient means that a 1% increase in relative GDP leads to an increase of the Swiss convenience yield by 3 basis points.

The coefficients of the supply of Swiss and foreign public debt are also significant and have the expected signs: An increase in Swiss government debt and a decline in the foreign government debt both decrease the Swiss convenience yield as they both make the Swiss debt relatively less scarce. Economically, the coefficients imply that an increase in the supply of Swiss government bonds equivalent to 1% of GDP decreases the Swiss convenience yield by 12 basis points. Similarly, an increase in the supply of government bonds in country *j* equivalent to 1% of its GDP increases the Swiss convenience yield vis-à-vis country *j* by 2 basis points.

Figure 8 illustrates how the relative supply of public debt could contribute to explaining the evolution of convenience yields in recent years. It represents the

<sup>19</sup> Table III.1 (in Online Appendix III) provides the results using the level of debt.



convenience yield of the Swiss franc versus the euro, constructed with Swiss and German bond yields at five-year maturity, along with the Swiss and German public debts (as a percentage of GDP). We represent both the total debt and the total net of the domestic central bank's holdings. In 2010, the German debt stops increasing, while the Swiss debt stops decreasing. This is the time where the Swiss franc-euro convenience yield turns persistently negative, which could result from a relative scarcity of German bonds. Later, in 2014, the convenience yield starts decreasing again. This coincides with an acceleration of the decline in the net supply of German bonds. Again, this potentially reflects the relative scarcity of German bonds. It appears from the figure that there is a role played by the supply of public debt, but also by central banks' interventions. We next examine more specifically the role of central bank interventions.

Note though that most of the drivers that we have identified so far contribute positively to the convenience yield after 2010, which seems to contradict the findings in Table 1. Looking at the euro case documented in Additional file 1: Fig. III.2 (Online Appendix), we see indeed that the Swiss real GDP has been increasing relative to the German GDP. We also see in Fig. 8 that the Swiss government bonds have been declining as a share of GDP. However, in what follows, we identify other drivers that may have contributed negatively to the convenience yield after 2010.

### 4.3.2 The role of central banks' sovereign debt purchases

In this section, we examine the role of central banks' purchases of public bonds. As illustrated in Fig. 8, these purchases have been important in driving the convenience yield. To test this assumption, we estimate an equation similar to Eq. (8), where we add  $\Delta \log(CB/GDP)_j$ , which is the growth rate of the central banks holdings of domestic government debt to GDP ratio in country  $j$ , using IMF data.<sup>20</sup> We expect the effect of this variable on the Swiss convenience yield to be negative, as central bank purchases of foreign public bonds make foreign bonds relatively scarcer as compared to Swiss government debt. In order to isolate the effect of the central bank purchases of domestic public bonds from the effect of public bonds, we replace government bonds net of central bank purchases by gross domestic debt in the regressions. Therefore,  $\Delta(\text{Debt net of CB}/GDP)_{CH}$  and  $\Delta(\text{Debt net of CB}/GDP)_j$  are replaced, respectively, by  $\Delta(\text{Debt}/GDP)_{CH}$  and  $\Delta(\text{Debt}/GDP)_j$ .

We would also like to examine the more specific role of the ECB's quantitative easing (QE) policy. The ECB's QE consisted in buying government bonds but also in supporting the private sector through the Long-Term Refinancing Operations for instance, which benefited commercial banks, the Asset-backed Securities Purchasing Program or the Corporate Sector Purchase Program. Through QE the ECB could potentially reduce the perceived riskiness of the euro area and make European government bonds more attractive. We expect this policy to have an effect on the convenience yield beyond the mere ECB's government purchases. We thus also add  $\Delta \log(EB\text{ assets}/GDP_{EA12})\#(j = EURO)$ , which is the growth rate of the ECB's assets to Euro-12 GDP ratio, multiplied by a dummy equal to one when  $j = EURO$ , and zero otherwise. The data comes from the ECB. We expect the effect of this variable on the Swiss convenience yield to be negative, because it makes European bonds relatively more attractive by reducing the risk associated to the euro area. Later, when we consider the role of the exchange rate, we will examine the policy of the SNB as well.

The results are shown in columns (1) and (2) of Table 4. The coefficients have the expected signs and are significant. Consider first central bank holdings. If the ratio of central bank holdings of public debt to GDP increases by 1% in country  $j$ , then the Swiss convenience yield vis-à-vis country  $j$  decreases by 0.07 basis points. This might seem small but the standard deviation of this variable is equal to 23% in our sample. This corresponds to close to

<sup>20</sup> In order to deal with zero values, we compute the log as  $\log(CB/GDP + 0.01)$ .

**Table 4** The Role of Central Banks' Sovereign Debt Purchases and the Exchange Rate

	(1) OLS	(2) OLS	(3) OLS	(4) OLS
$\Delta(\text{Debt}/\text{GDP})_{CH}$	-16*** (2.5)	-16*** (2.4)	-16*** (2.6)	-12*** (2.7)
$\Delta(\text{Debt}/\text{GDP})_j$	2.6*** (.6)	2.8*** (.62)	2.7*** (.75)	2.3*** (.72)
$i_{CH} - i_j$	.069*** (.012)	.066*** (.012)	.092*** (.013)	.11*** (.014)
$\log(VIX)$	.092*** (.033)	.095*** (.033)	.035 (.037)	.055 (.039)
$\log\left(\frac{\text{Real GDP}_{CH}}{\text{Real GDP}_j}\right)$	2.8*** (.24)	2.7*** (.25)	3.7*** (.28)	4.1*** (.31)
$\Delta \log(\text{CB}/\text{GDP})_j$		-.07*** (.016)	-.07*** (.017)	-.059*** (.019)
$\Delta \log\left(\frac{\text{ECB assets}}{\text{GDP}_{EA12}}\right) \#(j = \text{EURO})$		-.58** (.25)	-.67** (.26)	-.51** (.25)
$\tau_t$			.12* (.061)	.089 (.062)
$s_{t-1j}$				.44*** (.14)
$\Delta(\text{FX}/\text{GDP})_{CH}$				-.55* (.32)
Observations	602	602	507	507
R-squared	0.76	0.76	0.78	0.79
Quad. trend	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

See the note of Table 3. The logs of the ratio of CB holdings to GDP and of the ratio of ECB assets to GDP are multiplied by 100, so that the coefficients read as the effect of a 1-percent increase in these ratios.  $\tau$  is the deviation from CIP defined in Eq. (5). An increase in the log exchange rate  $s_{t-1j}$  means that the Swiss franc depreciates vis-à-vis the other currency. The log exchange rate is multiplied by 100, so that the coefficient reads as the effect of a 1-percent depreciation in the Swiss franc. The ratio of foreign exchange (FX) reserves to GDP is also multiplied by 100, so that the coefficient reads as the effect of an increase in FX reserves equivalent to 1% of GDP

Standard errors in parentheses

\* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

1.5 basis points. In the case of the euro and Germany, this ratio has been multiplied by 10 between 2015 and 2020, as shown in Additional file 1: Fig. III.2 in Online Appendix. Alone, these purchases would have contributed to a decline in the convenience yield of 70 basis points. So, quantitatively, these purchases can have a potentially large effect. However, since they are correlated with other factors, we must consider these numbers with great caution.

Consider now the role of ECB's asset purchases. If the ECB's assets to GDP ratio increases by 1%, then the Swiss convenience yield vis-à-vis the euro decreases by 0.58

basis points. The standard deviation of this variable is equal to 7% in our sample. This corresponds to about 4 basis points. The assets of the ECB have tripled between 2009 and 2019, as shown in Additional file 1: Fig. III.2 (Online Appendix), which amounts to more than a 100 basis points decline in the Swiss convenience yield vis-à-vis the euro. Again, we can, with caution, assume that they played a significant role.

In Additional file 1: Table III.2 of the Online Appendix, we show the results for other maturities. Central banks' sovereign debt purchases and ECB's QE policy have larger and more significant effects for longer maturities. Indeed, these policies usually target the yield curve and a reduction in the maturity premium.

### 4.3.3 The role of the exchange rate

We next examine the role of the exchange rate. As explained earlier, we conjecture that the exchange rate affects the convenience yield through a valuation effect: An appreciation of the Swiss franc inflates the foreign-currency value of Swiss government bonds, which may have a negative effect on the convenience yield. To test these valuation effects, we introduce the log of the bilateral exchange rate  $s_{t,j}$ , which is the price in CHF of currency  $j$ . We use the first lag in order to limit endogeneity issues. We expect the coefficient of the exchange rate to have a positive sign (an appreciation of the Swiss franc generates a decrease in the convenience yield).

The exchange rate may have another role, but this time due to measurement. Indeed, we measure the convenience yield by  $\eta$ , using the data of Du et al. (2018), which is constructed under the assumption that covered interest parity holds. However, as documented by Du et al. (2018), and as illustrated in Fig. 7, there are deviations from CIP. Neglecting these deviations may bias our results. We therefore take this into account by introducing  $\tau_{t,h} = i_{t,h}^{s,*} - i_{t,h}^s + f_{t,h}^d$ , the deviation from CIP, in the regression. Unfortunately, only the CIP deviation at the one-year maturity  $\tau_{t,1year,j}$  is available.

Finally, note that the periods of strong exchange rate appreciation (2009–2011, 2015) correspond to periods where monetary policy became constrained by the Zero or Effective Lower Bounds on the interest rate. Indeed, in 2009, the policy rate dropped below 50 basis points (but remained positive). In 2015, it dropped below zero as the SNB abandoned the floor on the euro-Swiss franc exchange rate. These periods were characterized not only by a limited ability of the SNB to fight the appreciation of the exchange rate through the policy rate, but also through massive foreign exchange interventions. The interventions may have also contributed to lower the convenience yield, as the demand for foreign bonds by

the SNB increases. We therefore introduce changes in the ratio of the SNB official reserve assets and other foreign currency assets to GDP,  $\Delta(FX/GDP)_{t,CH}$ , for their own sake, but also to check the robustness of our results.

The results are shown in columns (3) and (4) of Table 4. As shown in column (3), the CIP deviation's coefficient is positive and significant. One basis point increase in the CIP deviation increases the convenience yield by 0.12 basis point. This positive coefficient is reflecting the fact that  $\tau$  introduces a measurement error in  $\eta$ . The coefficient is not 1 as in Eq. (6), because  $\tau$  is correlated to the other regressors, and because of the maturity mismatch between  $\eta_{t,10year,j}$  and  $\tau_{t,1year,j}$ .<sup>21</sup> Importantly, when the CIP deviations are introduced, the coefficients change a little but the results remain robust. Only the VIX coefficient becomes insignificant. Cerutti et al. (2019) find indeed that the VIX is an important determinant of CIP deviations. These results thus suggest that the VIX may be affecting the convenience yield only because it is correlated to the measurement error in  $\eta$ . We conclude that the effect of the VIX is not robust.

Column (4) shows the results when we introduce the lagged exchange rate and changes in SNB foreign reserves. The coefficient of the exchange rate is significantly positive and economically large. As shown in Additional file 1: Fig. III.2 (Online Appendix), the Swiss franc appreciated by 25% in 2009–2011, which per se would have generated a decline in the convenience yield by 11 basis points. In 2015, it appreciated by 15%, which could have accounted for a 7 basis point decline. Up to 16 basis points out of the 23 basis point decline documented in Table 1 could be explained by the exchange rate.

The coefficient of foreign exchange interventions is negative and significant, as expected, and the coefficient of the exchange rate remains unchanged. In quantitative terms, this coefficient means that an increase in foreign reserves equivalent to 1% of GDP decreases the convenience yield by 0.55 basis points. This is extremely high. Between 2009 and 2020, the SNB bought the equivalent of the entire Swiss GDP in foreign reserves, as Additional file 1: Fig. III.2 shows. This, taken independently from the other explanatory variables, generates a 55 basis point decrease in the convenience yield. Again, these numbers should be considered cautiously. Indeed, the estimated coefficient must be interpreted as the effect of the exogenous foreign exchange interventions, that is, the part that is unrelated to the other explanatory variables in the regression. Since changes in foreign exchange reserves are highly correlated with the exchange rate, the nominal interest rate differential, the ECB interventions

and real GDP (and probably also all the other variables), and are thus not exogenous, we must not expect that the totality of the change in foreign reserves observed during the period have affected the convenience yield with that magnitude. The same argument holds for the other coefficients.<sup>22</sup>

All in all, we find evidence that foreign central bank policies, foreign exchange interventions by the SNB and the exchange rate may have contributed to the fall in the Swiss convenience yield since 2010. Our methodology does not allow us to quantitatively decompose the fall in the convenience yield into the contribution of these different drivers nor to estimate their joint total effect, but our results suggest that their potential contribution may have an order of magnitude similar to the observed evolution of the convenience yield.

## 5 Conclusion

The decline in real interest rates in recent decades is a global phenomenon and is not specific to Switzerland. One of the initial objectives of our study was to identify econometrically the determinants of Swiss real interest rates. However, we have found that Swiss real yields have followed closely global yields in recent decades. This means that Swiss real rates are determined mainly by global, rather than domestic, factors. This is true both for our measures of ex ante real rates and for estimates of equilibrium or trends in real rates.<sup>23</sup> The remaining cross-country differences cannot be explained by standard real rates determinants. This also means that we no longer have a “Swiss Interest Rate Island” (Baltensperger & Kugler, 2017).

Critics sometimes point to the policy of the Swiss National Bank as responsible for low interest rates. Our analysis illustrates why it is not the case. The decline in real interest rates is not only a global phenomenon but has been somewhat smaller in Switzerland than in some other countries, in particular Germany. If anything, Swiss monetary policy has limited the decline in Swiss real rates compared to Germany. Foreign exchange interventions, which have increased by the same magnitude as the Swiss GDP, have contributed to the decline in the Swiss convenience yield and have therefore put upward pressure on the Swiss real rate. Moreover, it is the inability to decrease short-term interest rate that could explain

<sup>21</sup> In the regression of  $\eta_{t,1year,j}$ , the coefficient of  $\tau_{t,1year,j}$  jumps to 0.36.

<sup>22</sup> Going further would require identifying all the independent shocks that affect the previous set of variables. This task, that would require various additional (and debatable) assumptions, is outside the scope of this study.

<sup>23</sup> In Bacchetta et al. (2021), we consider two different measures of equilibrium interest rates. More precisely, we estimate natural rates of interest using the approach of Laubach and Williams (2003), and we compute low-frequency components of interest rates as in Del Negro et al. (2019).

**Table 5** Determinant of Real Interest Rates: Panel Regressions

	<i>Dependent variable: <math>r_t</math></i>	
Debt/GDP	−0.010*** (0.004)	−0.001 (0.002)
Government consumption/GDP	0.135*** (0.012)	0.042*** (0.010)
Investment/GDP	0.065* (0.036)	−0.043 (0.027)
Life expectancy	−0.298*** (0.037)	−0.109*** (0.028)
Real GDP growth	−0.052** (0.025)	−0.021 (0.022)
Global interest rate, $r_t^w$		0.907*** (0.053)
Observations	1,178	1,178
$R^2$	0.227	0.515

\* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ 

Robust standard errors

the recent evolution. Since Swiss franc interest rates have traditionally been lower, nominal interest rates in other countries have had more space to decline. At the same time, inflation expectations remained lower in Switzerland, which explains the smaller decline in real rates.

## Appendix

### Computation of real rates

This appendix outlines the calculation of nominal and inflation expectations we use to compute ex ante real rates (Eq. 1). Additional details are given in Online Appendices I and II, which cover nominal yields and inflation expectations, respectively.

### Nominal yields

For the 17 countries of our dataset, we extract nominal yields (with maturities from 3 months to 10 years) from Thomson Reuters Refinitiv. For several countries—including Switzerland—yields of maturities between 1 and 10 years are only observed since the 1990s. Hence, we complete the Refinitiv data with historical series for the 3-month and the 10-year government yields taken from the database built by Jordà et al. (2015). For the early part of the sample, we then observe nominal yields for only two maturities: 3 months and 10 years. In order to obtain estimates of missing yields (for intermediate maturities), we build a state-space model relying on a

parsimonious factor representation of each yield curve, as in Diebold and Li (2006), and make use of the Kalman filter. Technical details are provided in Additional file 1.

### Inflation expectations

In order to compute ex-ante real interest rates, we need estimates of inflation forecasts that could have been formed as of all quarters in our sample (1970Q1 to 2020Q4), for all countries and all maturities (up to 10 years). Introducing a subscript  $j$  to refer to a particular country, these forecasts are the  $\mathbb{E}_t(\pi_{j,t+h})$  in Eq. (1). These forecasts—and their estimates that we will compute—have to be based only on information that is available at date  $t$  (i.e., “real-time” information). This information includes, in particular, the values of inflation preceding date  $t$ . But this information set—including only  $\{\pi_t, \pi_{t-1}, \dots\}$ —is arguably too narrow compared to the date- $t$  information that is effectively used by agents to form forecasts. As a result, an approach producing estimates of (past) inflation expectations using only realized inflation data may sometimes lead to poor estimates of the forecasts agents are effectively producing. To try and address this issue, we make use of surveys of professional forecasters (SPF), when available. Intuitively, a SPF that is released on date  $t$  concentrates information that is (i) available as of date  $t$  and (ii) useful to form inflation predictions. As a result, SPF data are particularly relevant to inform our estimation of real-time inflation forecasts.<sup>24</sup>

Moreover, because we allow for correlations between the inflation components of the different countries, the information conveyed by the survey-based forecast of some countries is exploited for all countries. More details regarding the estimation are provided in Additional file 1.

### Panel regression of real interest rates

This Appendix presents the regressions used to produce Fig. 4. The annual panel includes the 17 countries considered in the paper for the period 1950–2019. The dependent variable is the 10-year real yield computed in Sect. 2. Each regression includes a country fixed effect. Most of the data comes from the JST data base and has been updated with OECD (government expenditure and debt) or IMF (investment and real GDP growth) Economic Outlook data. Life expectancy comes from ourworldindata.org. Comparing columns 1 and 2, we see that adding the global interest rates decreases the absolute value of all coefficients and makes some of them insignificant. This also makes the  $R^2$  much higher.

<sup>24</sup> Grishchenko et al. (2019) and Aruoba (2020) also exploit SPF data to recover real-time inflation expectations. The former jointly consider the euro-area and the US term structures of inflation expectations; the latter focuses on the US inflation expectations and uses model outputs to derive the term structure of real interest rates.

## Abbreviations

CIP: Covered interest rate parity; ELB: Effective lower bound; FX: Foreign exchange; JST: Jordà, Schularick, and Taylor (2015); NRI: Natural interest rate; SNB: Swiss National Bank; PPP: Purchasing power parity; QE: Quantitative easing; TIPS: Treasury Inflation-Protected Securities; UIP: Uncovered interest rate parity.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s41937-022-00095-3>.

**Additional file 1.** Online Appendix.

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## Author contributions

The three authors contributed fully to the paper. All authors read and approved the final manuscript.

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## Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Competing interests

The authors declare that they have no competing interests.

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## References

- Aruoba, S. B. (2020). Term structures of inflation expectations and real interest rates. *Journal of Business & Economic Statistics*, 38, 542–553.
- Bacchetta, P., Benhima, K., & Renne, J.-P. (2021). Understanding swiss real interest rates in a financially globalized world. *Grundlagen für die Wirtschaftspolitik* 25, Staatssekretariat für Wirtschaft SECO.
- Baltensperger, E., & Kugler, P. (2017). *Swiss Monetary History since the Early 19th Century*. Studies in macroeconomic history. Cambridge University Press.
- Borio, C., Disyatat, P., & Rungcharoenkitkul, P. (2019). What Anchors for the Natural Rate of Interest? BIS Working Papers 777, Bank for International Settlements.
- Caballero, R. J., Farhi, E., & Gourinchas, P.-O. (2016). Safe asset scarcity and aggregate demand. *American Economic Review*, 106(5), 513–518.
- Cerutti, E. M., Obstfeld, M., & Zhou, H. (2019). Covered interest parity deviations: Macrofinancial determinants. IMF Working Papers 19/14.
- Del Negro, M., Giannone, D., Giannoni, M. P., & Tambalotti, A. (2019). Global trends in interest rates. *Journal of International Economics*, 118(C), 248–262.
- Demary, M., & Voigtländer, M. (2018). Reasons for the declining real interest rates. IW-Report 47/2018, Institut der deutschen Wirtschaft (IW), Köln.
- Diebold, F. X., & Li, C. (2006). Forecasting the term structure of government bond yields. *Journal of Econometrics*, 130(2), 337–364.
- Du, W., Im, J., & Schreger, J. (2018). The U.S. Treasury premium. *Journal of International Economics*, 112(C), 167–181.
- Du, W., Tepper, A., & Verdelhan, A. (2018). Deviations from covered interest rate parity. *Journal of Finance*, 73(3), 915–957.
- Engel, C., & Wu, S. P. Y. (2022). Liquidity and exchange rates: An empirical investigation. *Review of Economic Studies*, forthcoming.
- Gerko, E., & Rey, H. (2017). Monetary policy in the capitals of capital. *Journal of the European Economic Association*, 15(4), 721–745.
- Glick, R. (2020).  $r^*$  and the global economy. *Journal of International Money and Finance*, 102, 1–19.
- Grishchenko, O., Mouabbi, S., & Renne, J. (2019). Measuring inflation anchoring and uncertainty: A U.S. and Euro area comparison. *Journal of Money, Credit and Banking*, 51(5), 1053–1096.
- Hoffmann, M., & Suter, R. (2010). The Swiss Franc exchange rate and deviations from uncovered interest parity: Global vs domestic factors. *Swiss Journal of Economics and Statistics (SJES)*, 146(I), 349–371.
- Hofmann, B., & Takáts, E. (2015). International Monetary Spillovers. *BIS Quarterly Review*.
- Hördahl, P., Sbrun, J., & Turner, P. (2016). Low long-term interest rates as a global phenomenon. BIS Working Papers 574, Bank for International Settlements.
- Jiang, Z., Krishnamurthy, A., & Lustig, H. (2018). Foreign safe asset demand for US treasuries and the dollar. *AEA Papers and Proceedings*, 108, 537–41.
- Jiang, Z., Krishnamurthy, A., & Lustig, H. (2021). Foreign safe asset demand and the dollar exchange rate. *The Journal of Finance*, 76(3), 1049–1089.
- Jordà, O., Schularick, M., & Taylor, A. M. (2015). Leveraged bubbles. *Journal of Monetary Economics*, 76(S), 1–20.
- Kiley, M. T. (2019). The global equilibrium real interest rate: Concepts, estimates, and challenges. Finance and Economics Discussion Series 2019-076, Washington: Board of Governors of the Federal Reserve System.
- Krishnamurthy, A., & Vissing-Jorgensen, A. (2012). The aggregate demand for treasury debt. *Journal of Political Economy*, 120(2), 233–267.
- Kugler, P., & Weder di Mauro, B. (2005). Why are returns on swiss franc assets so low? Rare events may solve the puzzle. CEPR Discussion Papers 5181, C.E.P.R. Discussion Papers.
- Kugler, P., & Weder di Mauro, B. (2009). The Demise of the Swiss interest rate puzzle. WWZ Working Paper 04/09, WWZ Basel.
- Laubach, T., & Williams, J. C. (2003). Measuring the natural rate of interest. *The Review of Economics and Statistics*, 85(4), 1063–1070.
- Leutert, J. (2018). The Swiss Franc safety premium. *Swiss Journal of Economics and Statistics*, 154(1), 1–21.
- Lunsford, K. G., & West, K. D. (2019). Some evidence on secular drivers of us safe real rates. *American Economic Journal: Macroeconomics*, 11(4), 113–39.
- Miranda-Agrippino, S., & Rey, H. (2015). World asset markets and the global financial cycle. CEPR discussion papers 10936, C.E.P.R. Discussion Papers.
- Rachel, L., & Smith, T. (2015). Secular drivers of the global real interest rate. Bank of England working papers 571, Bank of England.
- Rachel, L., & Summers, L. H. (2019). On secular stagnation in the industrialized world. NBER working papers 26198, National Bureau of Economic Research, Inc.
- Ranaldo, A., & Söderlind, P. (2010). Safe haven currencies. *Review of Finance*, 14(3), 385–407.
- Swanson, E. T., & Williams, J. C. (2014). Measuring the effect of the zero lower bound on medium- and longer-term interest rates. *American Economic Review*, 104(10), 3154–85.
- Valchev, R. (2020). Bond convenience yields and exchange rate dynamics. *American Economic Journal: Macroeconomics*, 12(2), 124–66.

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