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by Claudio Borio, Piti Disyatat, Mikael Juselius and Phurichai Rungcharoenkitkul

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# Why so low for so long?
# A long-term view of real interest rates*

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## Abstract

Prevailing explanations of the decline in real interest rates since the early 1980s are premised on the notion that real interest rates are driven by variations in desired saving and investment. But based on data stretching back to 1870 for 19 countries, our systematic analysis casts doubt on this view. The link between real interest rates and saving-investment determinants appears tenuous. While it is possible to find some relationships consistent with the theory in some periods, particularly over the last 30 years, they do not survive over the extended sample. This holds both at the national and global level. By contrast, we find evidence that persistent shifts in real interest rates coincide with changes in monetary regimes. Moreover, external influences on countries' real interest rates appear to reflect idiosyncratic variations in interest rates of countries that dominate global monetary and financial conditions rather than common movements in global saving and investment. All this points to an underrated role of monetary policy in determining real interest rates over long horizons.

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# Introduction

Global real (inflation-adjusted) interest rates, short and long, have been on a downward trend throughout much of the past 30 years and have remained exceptionally low since the Great Financial Crisis (GFC). This has triggered a debate about the reasons for the decline. Invariably, the presumption is that the evolution of real interest rates reflects changes in underlying saving-investment determinants. These are seen to govern variations in some notional "equilibrium" or natural real rate, defined as the real interest rate that would prevail when actual output equals potential output, towards which market rates gravitate.

The presumption that real interest rates are so anchored is evident in two broad analytical strands.

The first focuses on *observed* real interest rates and relates them directly to the evolution of the factors that underpin the economy's saving-investment balance (eg IMF (2014), Bean et al (2015), Council of Economic Advisers (2015)). One prominent variant is the hypothesis that persistently weak demand for capital, a rising propensity to save and lower trend growth have brought about an era of "secular stagnation" (Summers (2014, 2015)). Another variant argues that a higher propensity to save in emerging market economies (EMEs), coupled with investors' growing preference for safe assets, has boosted the supply of saving worldwide (Bernanke (2005), Broadbent (2014), Caballero et al (2008)). Most recently, demographic changes have been singled out (Carvalho et al (2016), Gagnon et al (2016), Rachel and Smith (2017)). This strand typically does not consider inflation explicitly and links real interest rates directly to the posited real-sector determinants. In effect, it assumes that over the relevant horizon the observed (market) rate and the unobserved natural rate coincide.

The second strand focuses on the *equilibrium* or *natural* real rate, estimated as an unobserved variable in a filtering system (eg Laubach and Williams (2015), Justiniano and Primiceri (2010)). Typically, the natural rate is anchored to theory-prescribed variables, such as potential growth and household preferences, which are themselves unobserved, and inflation plays a critical role in pinning down the natural rate alongside the other latent system variables. In Laubach and Williams (2003), for example, rising inflation indicates that output is above potential and, correspondingly, that the actual interest rate is below the natural rate; falling inflation indicates the reverse. These reflect the well known Phillips-curve and aggregate-demand (IS) relationships that lie at the core of standard macroeconomic models.

Both strands share a couple of limitations. The bulk of the analysis examines the period since the mid-1980s, when real interest rates have been declining. And neither tests directly the hypotheses that the postulated saving-investment framework and/or the postulated inflation determination process adequately characterise the data. These are regarded as *maintained* hypotheses, be it in the underlying narrative and calibration of structural models or in the filtering systems. There is little by way of direct estimation that tests the link between *observable* variables, such as demographics, and real interest rates. Notable exceptions are Hamilton et al (2015) and Lunsford and West (2017), who consider some such variables over longer periods.

We aim to fill this gap by systematically examining the empirical link between real interest rates and the posited determinants, not just since the 1980s but also back in history. Based on data starting in the 19th century for 19 economies, we find only a tenuous link between real interest rates and observable proxies for the main saving-investment determinants. Some variables, notably demographics, do exhibit the expected relationship with real interest rates in *some* subsamples, especially in the more recent one. But there is little evidence of a stable relationship across subsamples. This applies to both domestic and global variables.

Going beyond the standard factors, we investigate whether monetary policy has persistent effects on real interest rates. In our long sample, monetary policy regimes, such as the gold standard, Bretton Woods and inflation targeting, go hand-in-hand with significant shifts in real interest rates. At a global level, we find that the influence of external factors on countries' real interest rates reflects the importance of the financially dominant countries' role as global monetary anchors rather than common variations in global saving-investment determinants. This suggests that co-movements in real interest rates across countries are more closely related to the monetary policy of global anchor countries than to factors such as a global saving glut.

Overall, our results raise questions about the prevailing paradigm of real interest rate determination. The saving-investment framework may not serve as a reliable guide for understanding real interest rate developments. And inflation may not be a sufficiently reliable signal of where real interest rates are relative to some unobserved natural level. Monetary policy, and financial factors more generally, may have an important bearing on persistent movements in real interest rates.

The rest of the paper is organised as follows. Section 1 provides an overview of existing approaches to explaining real interest rates, highlighting their limitations. Section 2 analyses the relationship between real interest rates and a standard set of real-sector determinants for a cross section of countries over a long time span. Section 3 explores the possible role of monetary factors. The final section concludes. The Annexes provide detailed information about the data and robustness tests.

## 1. Real interest rate determination: an overview of approaches

Prevailing approaches to explaining real interest rates are premised on the notion that the desired (ex ante) supply of saving and the desired (ex ante) demand for investment determine some notional equilibrium real interest rate consistent with full employment or output at potential, also known as the "natural rate". This notion takes root in the "loanable funds" framework, where saving-investment determinants drive the demand for, and supply of, funds that pin down the market-clearing interest rate (in equilibrium at the marginal product of capital).[1] The framework therefore focuses on the determinants of saving and investment.

On the saving side, the standard building block is grounded on households' optimising intertemporal consumption decisions, as captured by the Euler equation. The derived saving function depends positively on unobserved intertemporal preferences and expected consumption growth (or output growth in equilibrium). With household heterogeneity, demographic variables and income distribution also come into play. A higher life expectancy influences life-cycle decisions, raising desired saving and lowering the equilibrium real interest rate. A higher dependency ratio lowers saving and raises the real interest rate as the working-age population saves more than younger and older cohorts. Population growth influences

1 See Wicksell (1898) and Woodford (2003). As discussed in detail in Borio and Disyatat (2011, 2015), despite the term, this market for funds is in fact a market for goods and bears no relationship to the flow of financing that actually underpins economic activity. In fact, in contrast to current usage (eg Mankiw (2013)), even in the original literature, "loanable funds" was not used as synonymous with "saving", as credit also played a key role (eg Robertson (1934) and Ohlin (1937)).

both the demographic dynamics and the capital-labour ratio, resulting in offsetting effects on interest rates (Carvalho et el (2016)).[2] Higher income inequality increases saving, as richer households have a higher marginal propensity to save.

On the investment side, firm profit maximisation and the resulting demand function for capital point to the relevance of factors such as the relative supply of labour and capital, population growth, investment profitability, productivity growth and the relative price of capital to that of output. Cheaper physical capital, eg from technological advances, means that less investment is needed to maintain the same level of production. Provided this income effect always dominates, as typically assumed, the relative price of capital should go hand-in-hand with higher desired investment, and hence higher real interest rates.

If economies are financially integrated, the equivalent global variables matter as well. For example, the saving glut hypothesis (Bernanke (2005)) posits that desired saving in emerging markets has put downward pressure on real rates globally. Similarly, a greater demand for safe assets (Caballero et al (2008, 2016)) may help explain declining risk-free rates. More generally, a higher risk premium may lower desired investment and raise desired saving.[3]

The corresponding explanations for declining and persistently low real interest rates follow essentially two approaches. The first, which focuses on *observed* real interest rates and relates them directly to the evolution of the factors that underpin the economy's saving-investment balance, comes in two variants. One is largely narrative: it tells plausible stories relating real interest rates to its determinants, typically based on informal inspection of the behaviour of the relevant variables (eg IMF (2014), Bean et al (2014), Eichengreen (2015) and Council of Economic Advisers (2015)). The other is calibration: this systematically uses theory to identify factors behind shifts in real interest rate trends, and data to calibrate the corresponding structural models (eg Gagnon et al (2016), Carvalho et al (2016), Eggertsson et al (2017), Rachel and Smith (2017), Thwaites (2015), Vlieghe (2017)). In this variant of the first approach, theory dictates the relationships and the data are only used to gauge their quantitative importance conditional on the theory being true. The second approach is filtering: this recovers equilibrium real interest rates statistically by anchoring them to some economic relationships, notably the link between economic slack and inflation – the Phillips curve (eg Laubach and Williams (2003, 2015), Holston et al (2016), Justiniano and Primiceri (2010), Del Negro et al (2017) and Johannsen and Mertens (2016)). Table 1 provides a summary of selected studies.

How far does the resulting empirical evidence support the hypothesis that saving-investment imbalances have driven real interest rates to such low levels? Existing studies, in our view, have provided estimates of the extent to which saving-investment determinants can explain real interest rate movements *conditional* on the theory, but not convincing evidence supporting the underlying theory itself. Too much of the theory has been embedded in maintained hypotheses and thus its validity has not been subject to a test.

This conclusion is most obvious for the narrative variant of the first approach, which never quite tests the saving-investment framework. Rather, it uses it to see what factors appear to be more consistent with the downward trend in rates. And since it largely relies on informal inspection of bilateral relationships graphically, it is not that hard to find some that appear to

[2] Lower population growth raises the old-age dependency ratio, increasing the equilibrium real interest rates. But it also raises the capital-to-labour ratio and lowers the marginal product of capital. The net effect on the equilibrium real interest rate is a priori ambiguous.

[3] The risk premium is defined as the difference between the cost of capital and the risk-free rate. Risk premium shifts may originate from a repricing of risks (eg due to demand for safe assets, as in Gourinchas and Rey (2016) and Del Negro et al (2017)) or changes in underlying risks (eg productivity growth uncertainty, as in Marx et al (2017) or Vlieghe (2017)).

hold for at least part of the time. This type of analysis is best interpreted as a first look at the data and as a basis for a more in-depth evaluation. Nor, in all fairness, does it pretend to be more than that.

Calibration based on structural models – the second variant of the first approach – takes the narrative approach much further. It quantifies the effect that specific saving and investment factors would have within a fully specified theoretical model that is calibrated to fit the data as closely as possible. Hence, it provides information about the relative importance of the different factors in a general equilibrium setting, while at the same time addressing the challenges raised by regime changes and expectations. Nevertheless, just as with the informal approach, the validity of the underlying theory is not tested. Moreover, the models typically include parameters that are poorly identified and have no clear benchmark values. The resulting large number of degrees of freedom complicate the evaluation of the final results: there is a risk that the importance of particular factors may be overstated or specific periods "overfitted".[4]

The filtering approach faces similar challenges. Here, the role of a priori restrictions on the data is critical. In particular, one typical key maintained hypothesis is that inflation provides the right signal to identify cyclical deviations of the market rate from the natural rate. All else equal, if, say, inflation increases, it is inferred that output is above potential (Phillips curve), which in turn implies that the market rate is below the natural rate (IS curve). And yet, the link between economic slack and inflation has proved rather weak and elusive over the years, making any firm inferences suspect (ie Forbes et al (2017), Stock and Watson (2007), Borio (2017a)). Indeed, recent work has found that financial cycle proxies capture cyclical output variations better than inflation (Borio et al (2017), Kiley (2015)), yielding natural interest rate estimates that are somewhat higher and decline by less (Juselius et al (2017)). Moreover, filtering approaches typically relate the unobserved natural rate to other unobservable variables in the system, such as potential growth and preferences, giving rise to many degrees of freedom when fitting the story. Thus, the maintained hypothesis ends up having a decisive influence on the end-result (see Lubik and Matthes (2015) for a similar critique). And as with calibration, the risk of "overfitting" in any given sample is material.

4 To be more precise, in calibration, the researcher choses values for both the structural parameters and unobserved shock processes to mimic some key features of the data. These commonly include steady-state ratios between variables, second moments of selected variables and so on. Yet the key features typically only constitute a small subset of the model's full implications for the data and there is less discipline in the remaining directions. This gives the investigator considerable degrees of freedom when fitting the features of interest at the expense of general model fit. Equally problematic is the high reliance on persistent shock processes or unobserved stochastic trends. With sufficiently many such processes, the model can generate a perfect fit without an increase in predictive power – a case of "overfitting".

A summary of selected studies on real interest rate determination

Table 1

| Study | Methodology | Coverage | Key factors: Growth & productivity | Demographics | Relative price of capital | Inequality | Global saving glut | Demand for safe assets | Risk premium | Others |
|---|---|---|---|---|---|---|---|---|---|---|
| IMF (2014) | Narrative | Global | X | | X | | X | X | | |
| Bean et al (2015) | Narrative | Global | | X | X | X | X | X | | |
| Eichengreen (2015) | Narrative | US | X | X | X | | X | | | |
| CEA (2015) | Narrative | Global | X | X | | | X | X | X | |
| Goodhart and Pradhan (2017) | Narrative | Global | | X | | | | | | |
| Gagnon et al (2016) | Calibration | US | | X | | | | | | |
| Carvalho et al (2016) | Calibration | Global | | X | | | | | | |
| Rachel and Smith (2017) | Calibration | Global | X | X | X | X | X | | X | |
| Thwaites (2015) | Calibration | Global | | | X | | | | | |
| Vlieghe (2017) | Calibration | UK | X | | | | | | X | |
| Marx et al (2017) | Calibration | Global | X | X | | | | | X | |
| Eggertsson et al (2017) | Calibration | US | X | X | X | X | | | | |
| Del Negro et al (2017) | Filtering | US | X | | | | | | X | |
| Laubach and Williams (2003) | Filtering | US | X | | | | | | | |
| Holston et al (2016) | Filtering | Four advanced | X | | | | | | | |
| Justiniano and Primiceri (2010) | Filtering | US | X | | | | | | | |
| Clarida (2017) | Filtering | Four advanced | X | | | | | | | |
| Gourinchas and Rey (2016) | Predictive regression | Four advanced | | | | | | | | Consumption -to-wealth |
| Hamilton et al (2015) | Long-run correlation | Global | X | | | | | | | |
| Lunsford and West (2017) | Long-run correlation | US | X | X | X | X | X | | X | Money growth |

All this highlights the importance of confronting the hypothesis more directly with the data, examining systematically the relationship between real interest rates and *observable* variables. And yet, there are very few studies that do this. Much of this work examines an earlier period – the surge of real interest rates in the early 1980s (Blanchard and Summers (1984), Barro and Sala-i-Martin (1990), Orr et al (1995)). Hardly any have covered the more recent phase of declining rates. An exception is Lunsford and West (2017), who focus on the United States for the period 1890-2015 and evaluate the bivariate correlation between real interest rates and a number of factors. The authors find weak evidence overall, particularly for variables representing aggregate growth (GDP, consumption, total factor productivity (TFP)), though they do find some support for demographic variables (for the weak explanatory power of output growth, see also Hamilton et al (2015)). Our paper complements this work by considering a wider set of countries, conducting joint-specification analysis to allow for interactions between explanatory variables, and exploring the role of monetary policy.

Indeed, a common premise of all the traditional approaches is that real interest rates over long horizons are determined *exclusively* by real factors. Monetary policy exerts only a transitory influence, which can be entirely ignored (narrative and calibration analysis) or filtered out (filtering analysis). The maintained assumption is that monetary policy is neutral in the long run. For example, Del Negro et al (2017, p 1) describe the natural rate as "... the counterfactual rate that would be observed 'in the absence' of monetary policy". Still, in our view, the notion that in a complex monetary economy it is possible to cleanly delineate a "monetary veil" from the underlying real drivers is an exceedingly strong presumption. This presumption has not been sufficiently scrutinised. In Section 3 we explore its validity and usefulness in the current context.

## 2. Real interest rate determination: the role of real factors

We next exploit long historical data and cross-country variation to test for long-term relationships between real interest rates and the saving-investment determinants suggested by theory. We impose no prior restrictions on these relationships and allow the data to speak about their nature and stability. Before turning to the data and estimation, we outline the essential elements of our empirical approach.

### 2.1 Essential elements of the empirical strategy

As noted, the standard saving-investment framework relies on the assumption that money is neutral "in the long run", so that only real factors drive real interest rates. Of course, strictly speaking, the "long run" is an analytical concept. It is the result of a thought experiment: it refers to a situation in which all the variables in the system, most notably prices, have been allowed to adjust (a steady state). For the empirical analysis, that concept has to be translated into calendar time.

Concretely, this can be done as follows:

$$r_t = r^*(X_t;\ \beta) + r_t^{MP} \tag{1}$$

where $r_t$ is the real interest rate, $r^*$ is the equilibrium real interest rate, which is a function of saving-investment factors, $X_t$, with parameters $\beta$, and $r_t^{MP}$ captures movements in the real rates due to monetary policy. We assume that the $r^*(\cdot)$ function is approximately linear, so that $r^*(X_t;\ \beta) = X_t\beta'$. The more important assumption is that monetary policy does not have lasting real effects on the real rate, which can be written formally as $r_t^{MP} \sim I(0)$. We relax this assumption in Section 3.

Given that monetary policy does not have lasting effects, Equation (1) implies that any low-frequency movements or permanent changes in the real rate reflect solely saving-investment factors.[5] For instance, both the real interest rate and the saving-investment factors display dynamics which are statistically hard to distinguish from a unit-root process over the full sample. If (1) is true, this should in and of itself yield a lot of statistical power to estimate $\beta$. But if (1) is not true, it could also generate "spuriously" strong correlation between the real interest rate and the saving-investment factors in specific subsamples.[6] To the extent that such

[5] Note that (1) is not a reduced form. The reduced form of $r_t$, given (1) and the above assumptions, is a stationary autoregressive representation around $r_t^*$ with steady-state $r_t = r^*(X_t;\ \beta)$.

[6] Under the unit-root assumption, estimates of $\beta$ would be super-consistent, ie they would converge at the rate of $T$. However, in this case, spurious correlation can also arise. Of course, unit-roots are best seen as convenient

correlations do not reflect a true structural relationship like (1), they are likely to be unstable and strongly subsample-dependent.

We use several different approaches to correctly identify the parameters, $\beta$.

The main part of the analysis is done based on *long-term* real interest rates, which should be less influenced by cyclical factors and less contaminated by monetary policy. Here, we use static panel regressions as well as dynamic ones, which identify explicitly the empirical steady state.[7] For robustness, we also estimate the correlations from five-year or 10-year non-overlapping averages of all variables.[8] We also employ different modelling strategies for inflation expectations, as these are especially hard to measure over a 10-year horizon.[9] Specifically, we use an autoregressive model in the baseline and an alternative one that imposes a rational expectations assumption as robustness check – a model that is arguably more consistent with the assumption of money neutrality.

We also carry out the analysis based on *short-term* rates. Here, it is more important to tease out cyclical fluctuations and the influence of monetary policy. We do so by estimating explicitly a short-term natural rate following a standard filter (Holston et al (2016)) on US and UK data. For robustness, we also use raw short-term rates for a broader set of countries.

We rely on two statistical criteria to evaluate the results. First, we require the effects of saving-investment factors to be statistically different from zero and have signs that accord with theory. Moreover, the size of the effects should ideally also explain the bulk of the decline in real rates. Second, we require the effects of the saving-investment factors, $\beta$, to be reasonably stable over different subsamples.[10] Parameter instability would undermine the framework's predictive ability and be indicative of spurious correlation, possibly due to coincidentally matching trends in specific subsamples or omitted persistent factors. This possibility may be of particular concern given that the real interest rate and the saving-investment factors display low-frequency trends that tend to co-move across countries and are difficult to distinguish from unit-roots.[11] For the purpose of checking parameter stability, we split our sample into several subsamples. As additional robustness checks, we also run rolling regressions with windows of 20, 30 and 40 years and examine backward- and forward-expanding samples recursively. We exclude the two world wars throughout the analysis.

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approximations to non-stationarity behaviour in $r_t$ and $X_t$, but similar properties apply in general. For instance, spurious correlation and structural breaks are notoriously difficult to tell apart. See Perron (2006) for an in-depth discussion.

7 Again, under the unit-root assumption, estimates of $\beta$ can be obtained from a static specification due to super consistency. Indeed, this was the idea behind the original Engle-Granger two-step procedure. Co-breaking has similar properties.

8 Assuming that the business cycle does not exceed 10 years and that at least two full cycles are needed to identify the relationship between the real rate and the saving-investment factors, we need at least 20 years of data for any given sample.

9 For the measurement of the saving-investment factors themselves, we sidestep the thorny issue of measuring expectations and simply use actual values.

10 More formally, we adopt the relatively weak requirement that 95% confidence intervals, $I_{\hat{\beta}}$, of $\hat{\beta}_T$ and $\hat{\beta}_{T'}$, where $T$ and $T'$ index different subsamples, overlap, ie $I_{\hat{\beta},T} \cap I_{\hat{\beta},T'} \neq 0$

11 In Annex B.1, we carry out a rudimentary assessment of the presence of spurious correlation due to global trends by including linear time trends. If the parameters are sensitive to adding such a trend, either the results are spurious or inference is fragile, as it is solely based on matching unidirectional trends. That is, any persistently growing or declining series would yield significant results. We do indeed find that the estimates are sensitive to the inclusion of time trends, casting further doubt on the existence of true underlying relationships.

One reasonable objection to our requirement of parameter stability is that true structural breaks may have occurred as a result of fundamental changes in the economy. While this may be so, it is not immediately apparent to us what observable drivers of such structural breaks could be. We thus leave this possibility for further work, noting that if the supposed factors are left unspecified or are intrinsically unobservable, the theory becomes untestable.

## 2.2 Data and definition of variables

The data are annual and cover 19 (currently) advanced economies over the period 1870-2016.[12] Table 2 summarises the key independent variables used, the predicted sign of their influence on real rates, and our choice of proxies. Annex A provides details about data sources and coverage.

The dependent variable is the ex ante real interest rate – a nominal rate minus expected inflation, based on a CPI index. For the baseline, we use 10-year government bond yields (or their closest proxies). We proxy expected inflation by recursively projecting an autoregressive (AR) model, and compute its average over the relevant horizons. As in Hamilton et al (2015) and Lunsford and West (2017), we use an AR(1) process estimated over a rolling 20-year window to allow for time variation in inflation persistence.[13] In Annex A2, we plot the time series of interest rates and expected inflation.

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[12] Countries covered include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

[13] This procedure is a parsimonious way to allow for potential breaks in inflation dynamics. For an earlier discussion of inflation process from historical perspective, see Friedman and Schwartz (1982). The 20-year estimation window is shorter than the 30 years in Hamilton et al (2015) but the same as in Lunsford and West (2017). This choice does not appear materially to affect the results. We measure expected inflation with at least 10 years of input data, though the vast majority of countries have real interest rate series that start from 1870 (Annex A). We remove inflation rates in excess of 25 per cent in absolute value from the estimation (an assumption that extreme inflation rates are not useful for inferences about inflation dynamics). The autoregressive coefficient is capped at 0.9, to limit the impact of extreme inflation (eg during the wars or hyperinflation episodes) on the long-term forecast. With this assumption, the half-life for deviations between actual and expected inflation is at most 6.5 years. When the cap is binding, the constant term is re-estimated.

Saving-investment determinants: definition and theoretical predictions

Table 2

| Factor | Expected relationship | Variable definition |
|---|---|---|
| Marginal product of capital | + | Labour productivity (the ratio of GDP to hours worked) divided by capital intensity (the ratio of the total capital stock to total hours worked) times a constant capital share |
| Output growth | + | Annual real GDP growth |
| Productivity growth[1] | + | Annual total factor productivity (TFP) growth |
| Dependency ratio[2] | + | Size of the dependent population (aged 65 or above and 19 or under), divided by the size of the working-age population |
| Life expectancy[3] | – | Life expectancy at birth |
| Population growth | +/- | Annual population growth |
| Relative price of capital | + | The capital price index divided by the consumption price index, and since 1929, the gross private domestic investment deflator divided by the personal consumption expenditures deflator |
| Inequality | – | Income share of the top 1% of the population |
| Risk premium[4] | – | (i) Higher moments of annual GDP growth and inflation, as measures of fundamental risks,[5] (ii) US equity risk premium |

[1] Considered in robustness exercises. TFP growth is largely subsumed by GDP growth in the baseline analysis.

[2] In robustness exercises (Annex B.6-B.7), we also consider the old-age dependency ratio (the size of population aged above 65 over its working-age counterpart) and an alternative savers' ratio (where the dependency ratio is redefined using 40-64 as the working-age bracket)

[3] We use life expectancy at birth for its more complete coverage. Life expectancy at a higher age, say 20 years, shares a very similar trend over our sample (eg the correlation between the two series is close to 90% even for the first 40 years of the sample, suggesting that child mortality was not the dominant driver of the upward trend). In robustness exercises, we also control for time variation in the retirement age (itself negatively related to interest rates), using the labour force participation above age 65 as a proxy for it.

[4] Considered in robustness exercises (Annex B.9). Note that some risk premium measures have not trended up over the last 30 years, hence are not congruent with the decline in real interest rates. For instance, Cochrane (2016) has observed that the S&P 500 price-earnings ratio is higher today than in 1980s. Gourinchas and Rey (2016) also find that the equity risk premium cannot explain secular movements in the consumption-wealth ratio, which is their predictor of future real rates.

[5] Skewness, measured as the third standardised moment, should have a positive relationship with real rates, as greater downside tailed risk raises the risk premium.

Note that we capture any cross-border effects (à la global saving glut) to the extent that the shifts in saving and investment can be traced back to the set of explanatory variables and countries considered. We will investigate more specifically the role of *global* aggregates of saving-investment factors in explaining individual countries' real interest rates further below. We do not attempt to account for the importance of the safe-asset-shortage channel or (modern-day) emerging markets, however, owing to a lack of measures suitable for our long-horizon analysis.[14]

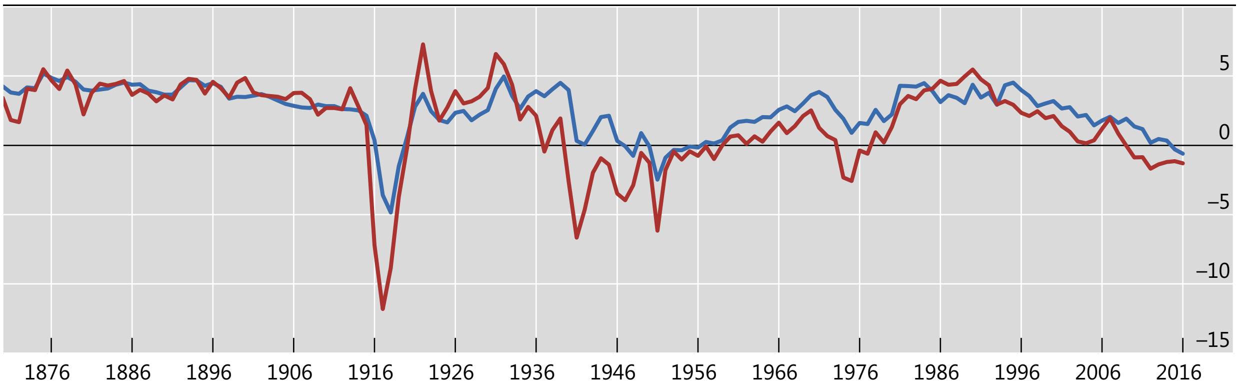
[14] Data on external positions for the United States and Germany are available only from 1950. Growing global imbalances of net safe asset positions, with the United States and the euro area accounting for much of the net asset supply, have been identified as a symptom of a safe-asset shortage, though not without controversy (eg Cochrane (2016)).

## 2.3 A first look at the data

Real interest rates

In per cent

Graph 1




Sources: Authors' calculations.

Graph 1 shows the time series of global real interest rates, captured by the cross-country median. We see that real rates of both long and short maturities tend to co-move closely, although short-term rates are naturally more volatile. Excluding the World Wars, when real rates drop, sometimes deeply into negative territory, one can discern four distinct phases. Up to World War I – mostly the classical gold standard – real rates were comparatively high and stable. In the interwar years, after recovering quickly from World War I, they started to fall markedly in the wake of the Great Depression. Real rates then rose much more gradually starting in the early 1950s and, after a new big dip during the Great Inflation, peaked in the early to mid-1980s, reaching levels broadly similar to those seen in the early part of the sample. Finally, real rates have been declining since then, to historically low levels, wars excepted. Annex Graphs A.2 provide plots of real interest rates for individual countries.

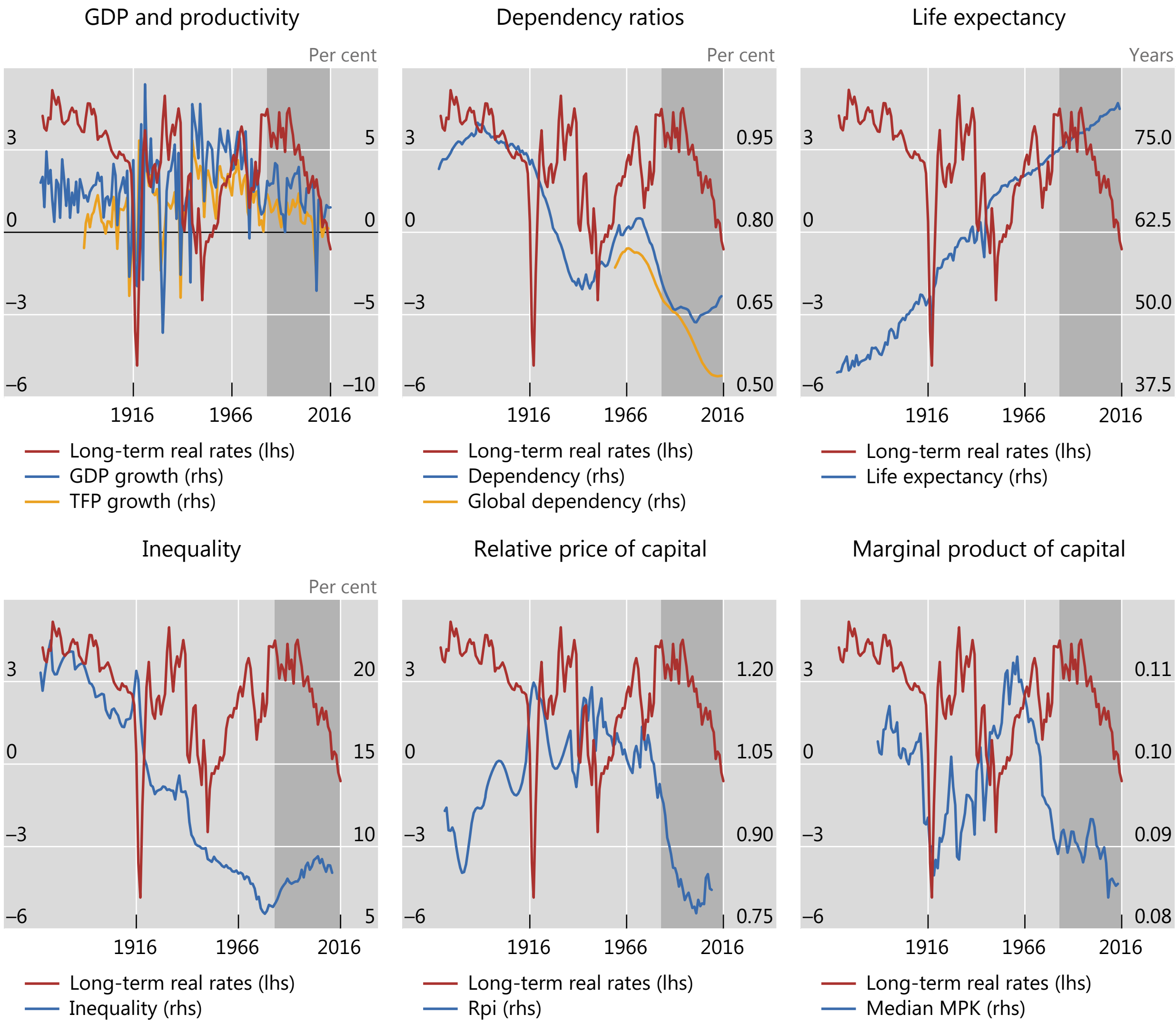
Graph 2 plots the long-term real interest rates against the standard factors singled out as potential drivers, all in terms of cross-country medians. Two observations stand out.

First, over the latest phase starting in the early 1980s, most of the standard factors are correlated with the decline in real interest rates with signs that accord with the saving-investment framework. This is confirmed in Table 3, which summarises the correlation between median real interest rate and the median of each factor (correctly signed correlations are in green). The median dependency ratio is the only exception – although a correct correlation resurfaces if one takes into account the demographic dividends of large EMEs in recent decades and looks at the dependency ratio based on a larger set of countries, including the likes of China and India (broad dependency ratio).

Second, once we extend the sample to cover preceding periods, almost all of the correctly-signed correlations disappear. Only life expectancy is consistently correlated with real interest rates and with the right sign. Even then, Graph 2 suggests that this may reflect strong correlations over certain subsamples, since life expectancy trends up throughout. Even the marginal product of capital, which according to theory should be a summary statistic of the net saving-investment balance, is hardly correlated with the real interest rate over the full sample.

Cross-country median of saving-investment determinants

Graph 2




Shaded area indicates the last 30 years.

Sources: Bergeuad et al (2016); Costa (1998); Eichengreen (2015); Roine and Waldenström (2015); Chartbook of Economic Inequality; International Historical Statistics; World Wealth & Income Database; OECD; United Nations, Human Mortality Database; national data; authors' calculations.

Correlation between median real interest rates and saving-investment factors[1]

Table 3

| Factor | Expected relationship | 1985-2017 | 1870-2017 |
|---|---|---|---|
| Marginal product of capital | + | 0.65 | –0.20 |
| GDP growth | + | 0.37 | –0.28 |
| TFP growth | + | 0.49 | –0.29 |
| Dependency ratio | + | –0.02 | 0.42 |
| Broad dependency[2] | + | 0.87 | NA |
| Life expectancy | – | –0.87 | –0.48 |
| Relative price of capital | + | 0.36 | –0.43 |
| Inequality | – | –0.62 | 0.49 |

[1] Correlation with signs consistent with saving-investment theory is shown in green, otherwise in red. War years are excluded.

[2] Broad dependency ratio covers EMEs' demographic information. Since the series is only available from 1960 onwards, only the correlation over the recent sample is reported.

Sources: Authors' calculations.

## 2.4 Tests and main results

To test more formally the relationship between real rates and their posited determinants, we now estimate panel regressions to exploit also any cross-country heterogeneity for identification. We start by estimating a *bivariate* fixed-effect panel specification

$$r_{i,t} = \beta_0 + \beta_{0,i} + \beta_1 X_{f,i,t} + \varepsilon_{i,t}$$

where $r_{i,t}$ is the 10-year real interest rate, and $X_{f,i,t}$ is the $f^{th}$ saving-investment factor.[15]

In addition to considering the full sample, we also test the relationship in various subsamples identified on the basis of the previous visual data inspection. These correspond to the metallic standards (mostly the classical gold standard),[16] interwar and postwar phases. We further subdivide the postwar subsample into the pre- and post-Volcker-tightening eras. The latter subsample has been extensively used in studies of the secular decline in interest rates.

The results confirm the indications of the simple correlation exercise (Table 4). For the last 30-year period (post-Volcker), the relationships appear to be more in line with the saving-investment framework: most variables are significantly and correctly signed, except for the marginal product of capital and the dependency ratio. For the full sample, however, only life expectancy is significantly associated with real interest rates with the correct sign. And across subsamples, there is clear parameter instability in *all* the variables, in both size and sign.

[15] Unless otherwise stated, we apply the standard fixed-effects estimator here and below. While this estimator is biased in dynamic specifications, the bias is likely to be small in samples with a large time dimension. All our results are similar to those obtained by applying the Arellano and Bond (1991) estimator. Our results are also similar if we treat some of the saving-investment factors as endogenous and use GMM instead. For instance, the estimates where inflation expectations and GDP growth are endogenous are shown in Annex B5.

[16] In what follows, we often use the shorthand "gold standard" or "classical gold standard" to refer to the metallic standards more generally. This is because the classical gold standard covers most of the period and, in the estimation, we do not distinguish the two types of regime. See Table 9 for details.

Bivariate panel regressions

Table 4

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| Marginal product of capital (+) | 0.05 | 0.32*** | –0.25 | –0.33*** | –0.57** | 0.32 |
| GDP growth (+) | –0.09** | 0.01 | –0.08** | –0.05 | 0.02 | 0.09* |
| TFP growth (+) | –0.08 | –0.01 | –0.04 | –0.04 | 0.11 | 0.24*** |
| Population growth (+/-) | –0.12 | 0.10 | 0.10** | –1.25*** | –0.64*** | –1.30** |
| Dependency ratio (+) | 0.03*** | –0.01 | –0.12** | –0.04** | 0.13** | 0.03 |
| Life expectancy (-) | –0.04*** | –0.11*** | 0.43*** | 0.15*** | 0.33* | –0.35*** |
| Relative price of capital (+) | 0.00 | 0.05 | –0.12 | –0.02** | –0.07* | 0.07*** |
| Inequality (-) | 0.03 | –0.00 | –0.46** | –0.28** | –0.61*** | –0.33*** |

Robust standard errors in parentheses based on country clusters; ***/**/* denote results significant at the 1/5/10% level. Significant coefficients with signs consistent with saving-investment theory are highlighted in green. Other significant coefficients are highlighted in red.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations

Thus, while the results in the most recent period may appear consistent with the standard narrative, they clearly fail to survive once the sample is extended. This raises questions about drawing strong inferences from the standard theoretical framework.

Moving to a multivariate framework confirms this conclusion. Complex interactions among determining factors could introduce offsetting effects over time, making any bilateral association (or lack thereof) between real rates and these factors unreliable. We thus estimate a joint specification

$$r_{i,t} = \beta_0 + \beta_{0,i} + \beta_1 X_{i,t} + \varepsilon_{i,t}$$

where $X_{i,t}$ now includes GDP growth, population growth, the dependency ratio, life expectancy, the relative price of capital and income inequality. For parsimony, we leave out TFP and the marginal product of capital, which should be redundant after the inclusion of GDP growth and other saving-investment determinants (we will reconsider TFP and other independent variables in robustness tests). Given that the different variables have different coverage, the sample drops to 11 countries starting in 1870 at the earliest. This serves as our baseline specification.

The results indicate even weaker evidence for the theory than the bivariate tests (Table 5). Not only is there little support in the full sample, but even for the most recent 30-year window the only variable that significantly retains the expected sign is life expectancy. Again there is substantial coefficient instability across subsamples in terms of both sign and size.

## Baseline specification

Table 5

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.09** | –0.00 | –0.07 | 0.08 | 0.07 | 0.03 |
| | (0.04) | (0.02) | (0.05) | (0.07) | (0.07) | (0.05) |
| Population growth (+/–) | –0.83* | –0.50 | 0.25 | –0.77** | –0.00 | –0.68 |
| | (0.39) | (0.50) | (0.36) | (0.28) | (0.28) | (0.71) |
| Dependency ratio (+) | 0.02 | –0.03 | –0.04 | 0.03 | 0.14*** | –0.03 |
| | (0.02) | (0.02) | (0.09) | (0.02) | (0.02) | (0.07) |
| Life expectancy (–) | 0.04 | –0.20*** | 0.41 | 0.23** | 0.47*** | –0.32*** |
| | (0.03) | (0.05) | (0.24) | (0.09) | (0.13) | (0.09) |
| Relative price of capital (+) | 0.01 | 0.11** | –0.06 | –0.00 | –0.06* | 0.01 |
| | (0.02) | (0.03) | (0.05) | (0.01) | (0.03) | (0.03) |
| Income inequality (–) | 0.10* | –0.01 | 0.00 | –0.26*** | –0.10 | –0.10 |
| | (0.05) | (0.05) | (0.30) | (0.05) | (0.21) | (0.15) |
| Constant | –1.97 | 15.33*** | –17.90 | –14.27* | –42.48*** | 31.18*** |
| | (2.97) | (2.61) | (21.61) | (7.79) | (11.80) | (7.95) |
| Adjusted R-squared | 0.07 | 0.51 | 0.22 | 0.21 | 0.34 | 0.26 |
| Number of observations | 1102 | 202 | 205 | 643 | 303 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

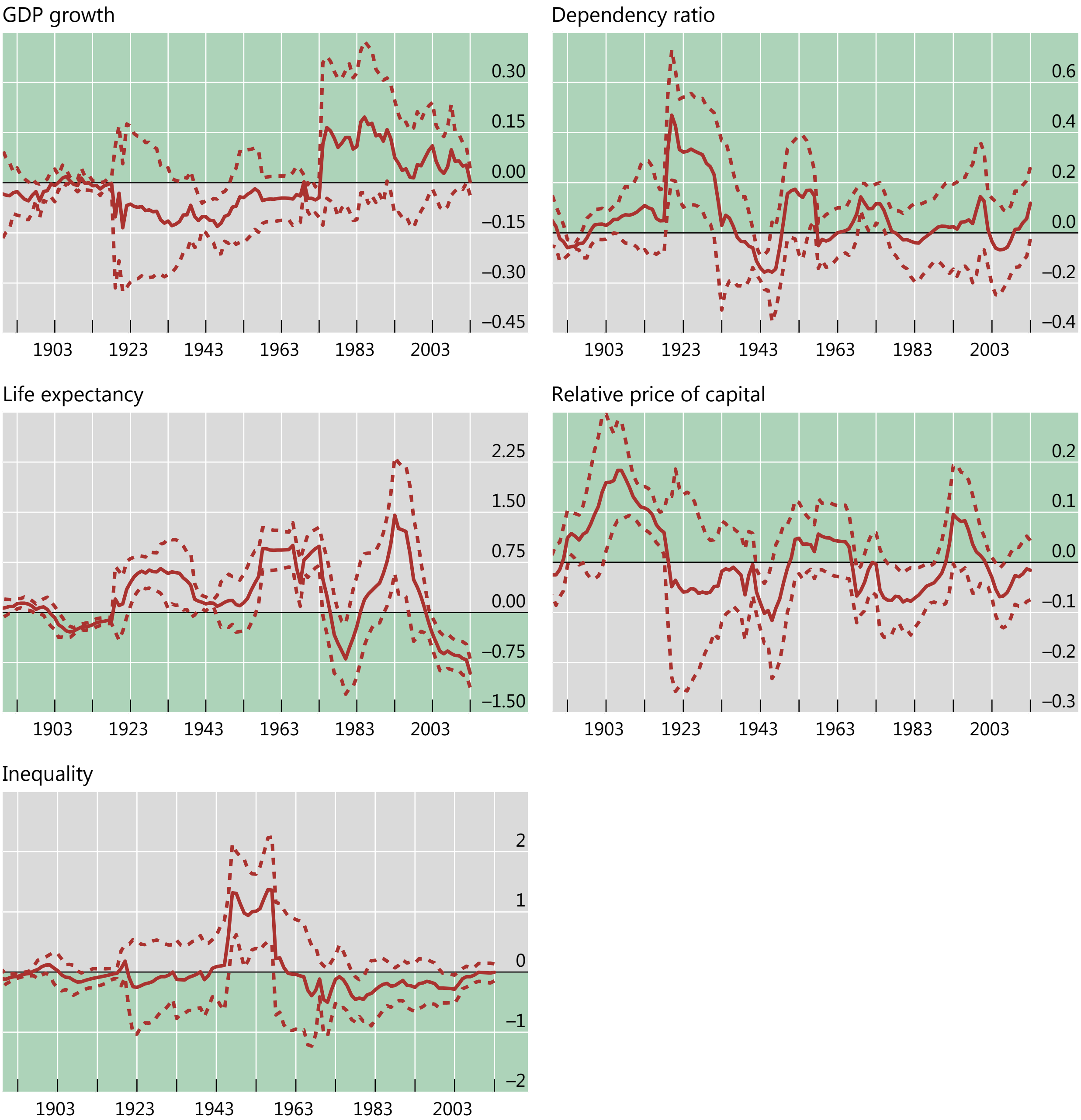
Full sample, 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations

One likely reason for these results is that the strong subsample trends in the real interest rate occasionally coincide with similar trends in the saving-investment factors, leading to "spurious" subsample correlation. For instance, the steady decline in real interest rates in the post-Volcker period is picked up by the steady increase in life expectancy over the *entire* sample. In fact, any variable that trends over the same subsample will pick up the decline in the real interest rate. In Table 4 above, the trends between any given pair generate significant results. To test whether unidirectional trends within specific subsamples are the culprit, we add a linear time trend in the bivariate specifications and check if the correlations survive. Indeed, in this case, the factors typically lose significance or flip signs (see Annex B.1).

Another simple test of coefficient stability is to run a rolling regression. Graph 3 depicts the time-varying estimates of the coefficients from a 20-year rolling window for the baseline specification. In all cases, the estimates are very unstable.

Time-varying coefficients of the baseline regression Graph 3




Dashed lines indicate two-standard error bands and the shaded area in green the correct coefficient sign. Data during the two wars are dropped from the estimation samples. Smaller subsamples around war periods are partly responsible for an increase in standard errors.

Source: Author's calculations.

Given that movements in real interest rates are quite persistent, it is worth distinguishing more formally between higher- and lower-frequency correlation. The static specification we have used so far mixes up correlation at all frequencies, even though low-frequency correlation tends to dominate asymptotically. To capture the low-frequency relationship between the variables, we estimate a dynamic fixed-effects panel specification

$$\Delta r_{i,t} = \beta_0 + \beta_{0,i} + \sum_{s=1}^{2} \rho_s \Delta r_{i,t-s} + \sum_{0=1}^{2} \gamma_s \Delta X_{i,t-s} - \alpha\left(r_{i,t-1} - \beta_1 X_{i,t-1}\right) + \varepsilon_{it}$$

where $X_{i,t-s}$ again consists of the same variables as before. The term in brackets captures any long-run relationship between the real interest rate and these variables. Thus, the $\beta_1$ coefficients are the dynamic-specification equivalents to $\beta_1$ in the static model. The short-run adjustment parameter, $\alpha$, captures the speed with which changes in the real interest rate correct deviations between the real interest rate and its determining factors in steady state. Obtaining a short-run adjustment statistically different from zero requires that the steady-state deviation in the parenthesis is approximately stationary: by construction, the change in the real interest rate on the left-hand side is a stationary variable.

## Dynamic fixed-effects panel specification

Table 6

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| Long-run coefficients | | | | | | |
| GDP growth (+) | –0.19*** | 0.04 | –0.15** | –0.09 | 0.09 | –0.25* |
| | (0.07) | (0.33) | (0.08) | (0.19) | (0.14) | (0.15) |
| Population growth (+/–) | –0.67 | –1.60*** | –0.54 | 0.30 | 0.24 | –0.53 |
| | (0.48) | (0.58) | (0.81) | (0.73) | (0.59) | (0.95) |
| Dependency ratio (+) | 0.03 | –0.05 | –0.13** | 0.05* | 0.24*** | –0.06 |
| | (0.02) | (0.04) | (0.06) | (0.03) | (0.04) | (0.10) |
| Life expectancy (–) | –0.05** | –0.27** | 0.06 | 0.20** | 0.54*** | –0.38** |
| | (0.02) | (0.11) | (0.08) | (0.10) | (0.20) | (0.18) |
| Relative price of capital (+) | –0.01 | 0.14*** | –0.06* | –0.01 | –0.08** | 0.04 |
| | (0.01) | (0.02) | (0.03) | (0.02) | (0.03) | (0.02) |
| Income inequality (–) | –0.08** | 0.20*** | 0.14 | –0.22** | 0.27 | –0.05 |
| | (0.04) | (0.07) | (0.15) | (0.10) | (0.22) | (0.21) |
| Short-run coefficients | | | | | | |
| Adjustment parameter | –0.32*** | –0.28*** | –0.69*** | –0.31*** | –0.54*** | –0.42*** |
| | (0.04) | (0.08) | (0.14) | (0.05) | (0.08) | (0.04) |
| Constant | 1.66 | 4.53 | 7.48 | –4.44 | –31.81*** | 16.28*** |
| | (1.01) | (3.19) | (5.38) | (2.88) | (10.62) | (6.04) |
| Adjusted R-squared | 0.30 | 0.17 | 0.59 | 0.21 | 0.36 | 0.24 |
| Number of observations | 997 | 177 | 177 | 633 | 293 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |
| Differences | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Differences: lagged differences from t to t-2 of all variables included in the regressions.

Source: Authors' calculations.

Estimates from the dynamic specification again fail to establish robust relationships between real rates and saving-investment determinants (Table 6). For the full sample, life expectancy and income inequality now have the correct sign and are statistically significant. But these relationships, as well as those for the other variables, are not robust across subsamples. For the post-Volcker period, again only life expectancy – the variable that trends up throughout the sample – has a significant and correct sign.

Another, albeit crude, way of capturing the low-frequency correlation between the variables is to use averages of the data in the regressions. In Annex B.2 we explore this method with averages over non-overlapping samples for the baseline and bivariate regressions.[17] Similar results obtain.

Next, given the high co-movement of interest rates across countries, many studies have emphasised the role of global factors. This is most evident in the global saving glut and global safe asset-shortage narratives, but can also arise if saving-investment factors have a common component (eg Clarida (2017)). We explore this by constructing global counterparts to the posited determinants and estimate their impact alongside the respective country-specific variables, defined in terms of deviations from the global trend. The specification is the following

$$r_{i,t} = \beta_0 + \beta_{0,i} + \beta_1^G X_t^G + \beta_1^C (X_{i,t} - X_t^G) + \varepsilon_{i,t}$$

where $X_t^G$ is a measure of the global components in the determinants.[18] We measure the global components as the averages of each variable based on real GDP at purchasing power parity. The main difference between this specification and the previous ones is that we allow for the common global components to have different effects on real interest rates from the country-specific ones.

For the most part, the global variables represent some improvement relative to the domestic ones, but the instability generally persists (Table 7). The dependency ratio is significant and correctly signed in subsamples prior to the most recent one, but is not significant over the full sample. Inequality performs well over the full sample and the postwar subsamples. However, in all other cases, the co-movements between the common trends in real interest rates and the saving-investment variables are highly unstable. The coefficients on the global components fluctuate over the different subsamples, sometimes changing signs or losing statistical significance. This suggests that these relationships may be coincidental.

It might be argued that the global saving-investment factors exert uneven influence over time, being stronger in periods of higher financial integration. We can readily use the subsample estimates to test this proposition. Economic historians typically judge the gold standard and the last 30 years or so as the two episodes of heightened financial globalisation (eg Obstfeld and Taylor (2003), BIS (2017)). One should then expect the global saving-investment determinants to be significant in both of these periods, and weaker otherwise. But as Table 7 shows, this pattern hardly emerges.

[17] The procedure is very closely related to that proposed by Lunsford and West (2017).

[18] This parametrisation allows us to directly compare the size of $\beta_1^G$ and $\beta_1^C$. For instance, if $\beta_1^G = \beta_1^C$, the global and country-specific components have the same effect on the real interest rate. The connection between the coefficients from this parametrisation and an alternative parametrisation given by $r_{i,t} = \beta_0 + \beta_{0,i} + \acute{\beta}_1^G X_t^G + \acute{\beta}_1^C X_{i,t} + \varepsilon_{i,t}$ is $\acute{\beta}_1^G = \beta_1^G - \beta_1^C$ and $\acute{\beta}_1^C = \beta_1^C$. Hence, in the alternative parametrisation, $\acute{\beta}_1^G$ reflects the difference in the real interest rate response to changes in the global saving-investment components and those in their idiosyncratic counterparts. If, for instance, the global and country-specific components have the same effect on the real interest rate, then $\acute{\beta}_1^G = 0$.

## Global versus country-specific determinants

Table 7

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre–Volcker | (6) Post–Volcker |
|---|---|---|---|---|---|---|
| Global component: | | | | | | |
| GDP growth (+) | 0.01 | –0.03 | –0.13* | 0.14*** | 0.21*** | 0.14* |
| | (0.03) | (0.02) | (0.06) | (0.04) | (0.06) | (0.07) |
| Population growth (+/–) | –1.43*** | –0.44 | –2.45 | 0.56** | 1.25*** | 17.65** |
| | (0.36) | (1.14) | (1.57) | (0.18) | (0.24) | (7.60) |
| Dependency ratio (+) | 0.05 | 0.40*** | 0.83*** | 0.08*** | 0.24*** | –0.06 |
| | (0.03) | (0.09) | (0.22) | (0.02) | (0.06) | (0.16) |
| Life expectancy (–) | –0.08 | 0.13 | 2.18*** | 0.30** | –0.50* | 0.63 |
| | (0.05) | (0.09) | (0.58) | (0.13) | (0.25) | (0.36) |
| Relative price of capital (+) | –0.09*** | 0.01 | 0.62** | –0.14*** | –0.08 | 0.03 |
| | (0.03) | (0.02) | (0.13) | (0.04) | (0.07) | (0.07) |
| Income inequality (–) | –0.15* | –0.07 | 1.56** | –1.02*** | –2.96*** | –0.95*** |
| | (0.08) | (0.12) | (0.66) | (0.08) | (0.54) | (0.25) |
| Country specific component: | | | | | | |
| GDP growth (+) | –0.08* | –0.00 | –0.11 | 0.02 | 0.01 | –0.02 |
| | (0.04) | (0.02) | (0.07) | (0.05) | (0.05) | (0.06) |
| Population growth (+/–) | 0.02 | –0.15 | 0.33 | –0.18 | –0.13 | –0.20 |
| | (0.41) | (0.14) | (0.34) | (0.22) | (0.29) | (0.64) |
| Dependency ratio (+) | –0.00 | –0.06*** | 0.10 | 0.02 | –0.01 | 0.04 |
| | (0.02) | (0.02) | (0.15) | (0.02) | (0.04) | (0.07) |
| Life expectancy (–) | 0.05 | 0.07 | 0.21 | 0.01 | –0.50** | 0.58 |
| | (0.07) | (0.05) | (0.12) | (0.11) | (0.19) | (0.40) |
| Relative price of capital (+) | 0.02 | 0.09*** | –0.05 | 0.01 | –0.04* | 0.02 |
| | (0.01) | (0.02) | (0.03) | (0.01) | (0.02) | (0.02) |
| Income inequality (–) | 0.04 | –0.04* | –0.12 | 0.05 | –0.10 | 0.13 |
| | (0.07) | (0.02) | (0.24) | (0.08) | (0.11) | (0.13) |
| Constant | 7.44 | –38.44** | –210.70*** | –17.26* | 41.77* | –42.76 |
| | (6.09) | (13.06) | (59.31) | (9.43) | (21.87) | (29.43) |
| Adjusted R-squared | 0.17 | 0.75 | 0.30 | 0.45 | 0.53 | 0.39 |
| Number of observations | 1102 | 202 | 205 | 643 | 303 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016. Global components calculated as the averages of each variable based on real GDP at purchasing power parity.

Source: Authors' calculations.

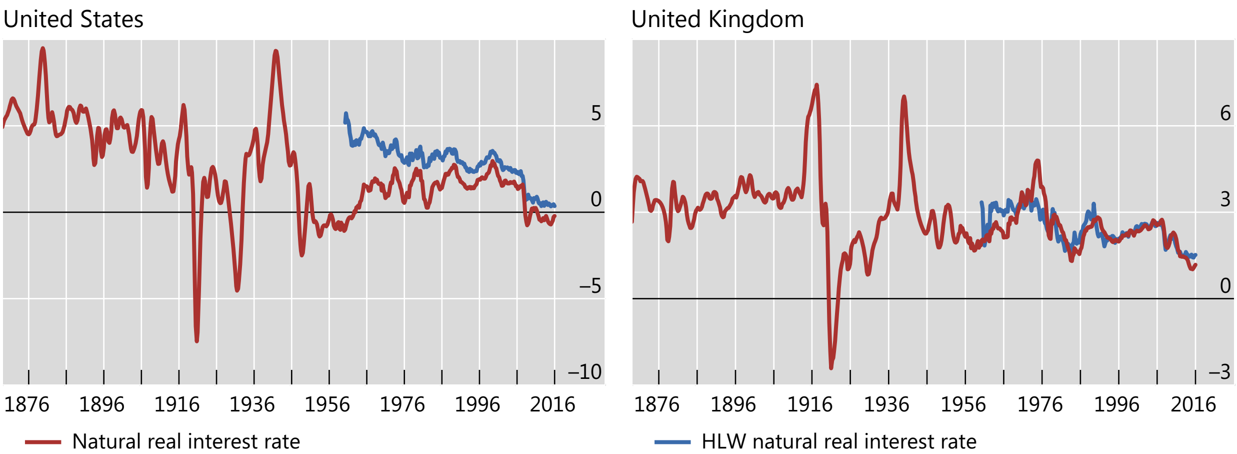
Lastly, we check whether the relationships remain as elusive if we use Holston-Laubach-Williams filtered short-term natural rates in place of actual rates. This helps remove the variation at business cycle frequencies. Recall that the methodology posits that the natural interest rate $r_t^*$ consists of two components

$$r_t^* = g_t + z_t$$

where $g_t$ is the potential growth rate of the economy, and $z_t$ is the latent variable that captures other unobserved determinants of the natural rate. We use the estimated models in Holston et al (2016) to filter the natural rates and their components but start the exercise in 1861.[19] Graph 4 shows these natural rate estimates for the United States and the United Kingdom. As a preliminary observation, we note the interesting behaviour of the natural rate during the gold (metallic) standard period (1870-1913). With inflation and nominal rates relatively stable, the actual and estimated natural real rates are also relatively stable and track each other closely. This contrasts with the substantial variation in underlying saving-investment determinants during this period (Annex Graph A.3). We return to this point later.

Filtered natural interest rates based on Holston-Laubach-Williams model

In per cent Graph 4




Sources: Holston et al (2016) and authors' calculations.

The formal test of the relevance of saving-investment balances does not provide strong support for the standard view once the role of maintained hypotheses is taken into account. In Table 8, we report the estimated long-run relationships between $r_t^*$ (as well as its latent component, $z_t$) and the set of saving-investment determinants from individual country versions of the dynamic specification for the United States and the United Kingdom. True, over the full sample, GDP growth now appears to be a significant determinant for both countries. But this is so *by construction:* in this method, potential growth $g_t$ is *assumed* to be a major determinant of the natural rate and GDP is an observed variable used to estimate it. Other significant and correctly signed variables are life expectancy for the United States and the

[19] We use their model as well as their estimated parameters. Thus, any differences between our natural rate estimates and Holston et al (2016) stem essentially from different initial conditions for the latent variable, $z_t$. Starting in 1961, Holston et al (2016) set the initial value of $z_t$ at zero. In our case, we filter the model from 1861, so our $z_t$ as of 1961 is filtered using the historical data rather than assumed to be zero. As it turns out, the UK natural rate estimates are very similar for the overlapping sample (Graph 4). For the United States, our natural rate estimate fell significantly in the late 1940s (due to the decline in $z_t$), and subsequently remained persistently lower than Holston et al (2016) estimates. We use policy interest rates where available, and replace them with short-term rates as needed. In earlier samples for which only annual data are available, we interpolate all the series to generate a quarterly time series before filtering. The filtered series are then aggregated up to the annual frequency again for the dynamic fixed-effects regression.

relative price of capital for the United Kingdom. But if we consider only the component of the natural rate that is unrelated to potential growth, ie the latent variable, $z_t$, then *none* of the determinants has significant explanatory power. This suggests that it is hard to find much support for saving-investment factors without hard-wiring the link a priori.

Filtered short-term natural rates and saving-investment determinants — Table 8

| | United States | | United Kingdom | |
|---|---|---|---|---|
| | r* | z | r* | z |
| Long-run coefficients | | | | |
| GDP growth (+) | 0.39*** | | 0.32*** | |
| | (0.05) | | (0.12) | |
| Population growth (+/–) | –1.28*** | –2.07*** | –0.13 | 0.01 |
| | (0.41) | (0.71) | (0.29) | (0.17) |
| Dependency ratio (+) | –0.08** | –0.05 | –0.00 | –0.02* |
| | (0.03) | (0.05) | (0.02) | (0.01) |
| Life expectancy (–) | –0.09* | –0.07 | 0.04 | –0.02 |
| | (0.05) | (0.08) | (0.06) | (0.04) |
| Relative price of capital (+) | –2.12 | 3.96 | 4.76* | 2.02 |
| | (3.90) | (6.48) | (2.70) | (1.62) |
| Income inequality (–) | –0.09 | 0.21 | 0.08 | 0.06 |
| | (0.14) | (0.24) | (0.08) | (0.05) |
| Short-run coefficients | | | | |
| Adjustment parameter | –0.48*** | –0.32*** | –0.28*** | –0.44*** |
| | (0.06) | (0.06) | (0.04) | (0.06) |
| Constant | 8.09 | 1.20 | –1.89 | 0.15 |
| | (5.13) | (5.16) | (2.11) | (1.99) |
| Adjusted R-squared | 0.92 | 0.86 | 0.86 | 0.86 |
| Number of observations | 96 | 96 | 137 | 137 |
| Differences | yes | yes | yes | yes |

The specification is equivalent to the dynamic fixed-effects panel specification in 2.4, but without the country fixed-effects term and the country index suppressed; ***/**/* denotes results significant at the 1/5/10% level.

Full sample, 1870-2016.

Differences: lagged differences from t to t-2 of all variables included in the regressions.

Source: Authors' calculations.

In addition to these specifications, we have conducted a wide range of robustness tests (Annex B). These include: a replication of all key results using short-term interest rates; an alternative treatment of inflation expectations; alternative independent variables and samples, such as the exclusion of immediate postwar years; and the inclusion of risk premium proxies. The broad conclusion remains the same. Moreover, it is also unlikely that an attenuation bias due to possible measurement errors drives the results: this would just lead to statistically insignificant results. Instead, most of the coefficients flip sign, for example from significantly positive to significantly negative over different subsamples. Similarly, collinearity between the saving-investment factors is probably not the culprit either, as the same conclusion emerges from the bivariate specifications.

Overall, the results point in the same direction: no single real factor, or combination of such factors, can consistently explain the long-term evolution of real interest rates. This holds at both the domestic and global levels. It suggests that the observed correlation between the saving-investment factors and the real interest rate in the latest sample is largely coincidental, mostly driven by temporary but unrelated trends in the variables.

## 3. Real interest rate determination: the role of monetary factors

In light of the weak empirical support for saving-investment proxies in explaining real interest rate movements, is it possible to find a tighter relationship with other factors? Note that the nominal long-term yields are currently at their unprecedented lows for most countries (Graph 5). Annex A.2.4 shows that the same is true for short-term nominal rates. Monetary policy responses in the aftermath of the GFC clearly play an important role in driving down nominal and, given relatively stable inflation, real interest rates. Could monetary policy play a more important role than typically believed?

### 3.1 Analytical considerations

The previous analysis is based on the *assumption* that monetary policy is irrelevant for the determination of real interest rates over the "relevant horizon". This assumption, in turn, takes root in the widespread view that monetary policy is neutral "in the long run" (eg Patinkin (1956)).[20]

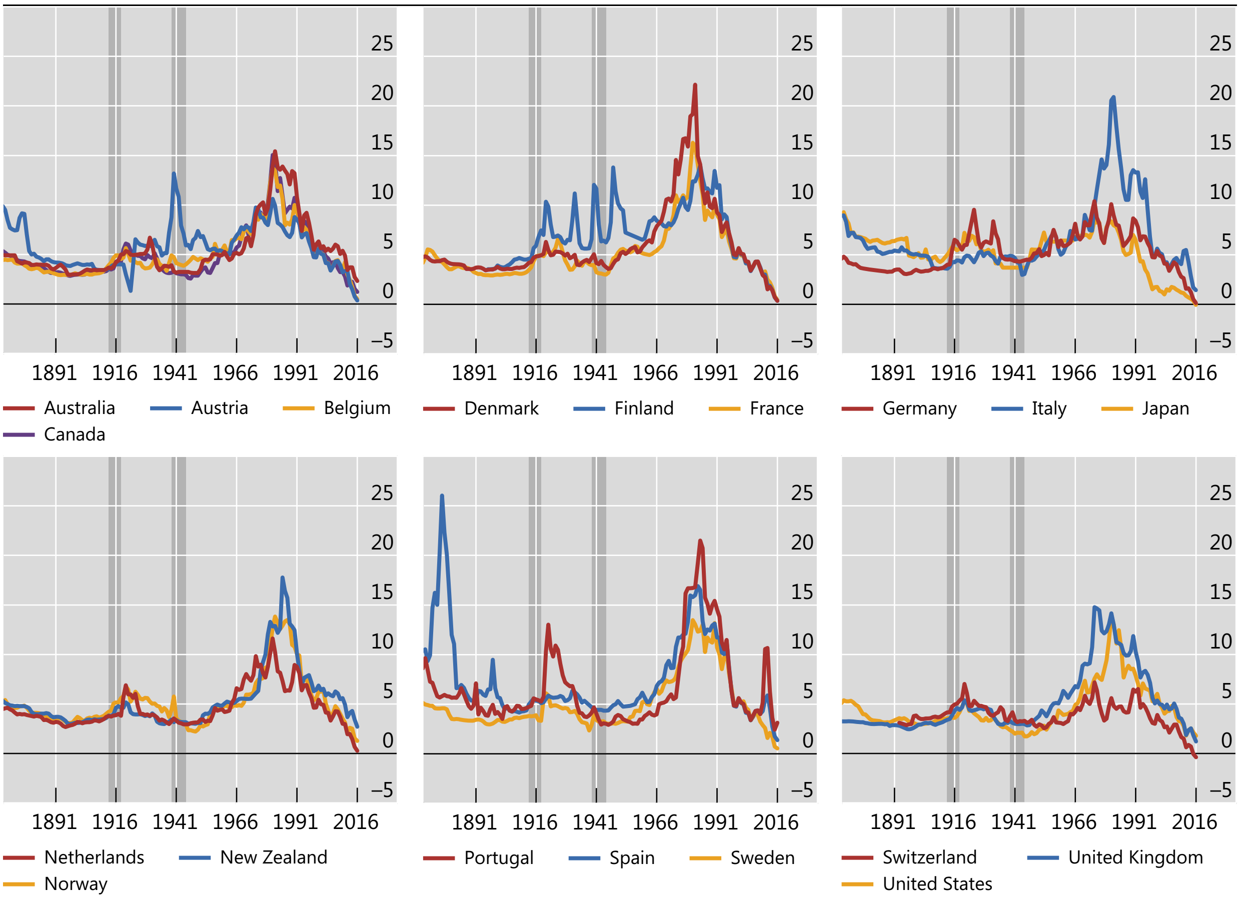
But could the role of monetary policy regimes be underestimated? There are at least two, closely related reasons why this might be the case. The first is that market rates may fail to track the unobserved theory-defined natural rate for very long periods. The second is that standard models may ignore or play down the channels through which monetary policy influences real rates over relevant horizons. Consider each in turn.

There is a broad consensus that *market* interest rates are determined by a combination of central bank and market participants' actions, given the supply of the underlying assets. Central banks set the nominal short-term interest rate and influence the nominal long-term interest rate through signals of future policy rates and asset purchases. Market participants adjust their portfolios based on expectations of central bank policy, views about the other factors driving long-term rates, attitudes towards risk and various balance-sheet constraints, not least regulation. Given nominal rates, by construction, actual inflation – effectively *predetermined* at a given point in time – determines ex post real rates, and expected inflation determines ex ante real rates.

[20] Of course, there is also a literature that questions money neutrality, going as far back as the 18th century (eg Law (1705)) and stretching to the publication of the General Theory (Keynes (1936)). In the 1960s, the seminal contributions of Mundell (1963) and Tobin (1965) postulated the failure of "super-neutrality", arguing for the influence of variations in money growth on real variables, particularly the real rate of interest. More recently, the notion of neutrality has been challenged in micro-founded monetary models (Weiss (1980), Espinosa-Vega and Russell (1998), Bullard and Russell (2004), Reis (2007), Lioui and Poncet (2008), Williamson (2014)). Moreover, when translating the analytical notion of "long run" into calendar time, Friedman (1968) noted that it could be as long as two decades.

Nominal long-term rates

In per cent Graph 5




The shaded areas indicate the world wars, 1914-1918 and 1940-1945.

Sources: Global Financial Data; national data.

Thus, at any given point in time, *interest rates necessarily reflect the interplay between the central bank's reaction function and private-sector beliefs and behaviour*. And if this is true at *any* given point in time, it must also be true at *all* points in time. Even if monetary policy is neutral "in the long run", one should expect it to influence real interest rates quite closely all the time. Saving-investment imbalances do not directly influence market rates. At best, they affect the natural rate.[21] Their impact on the market interest rate is only indirect, through the interaction between central bank and private sector agents' decisions. By identifying the evolution of real interest rates with saving and investment determinants, the implicit assumption is that the central bank and financial market participants can roughly track the evolution of the natural real rate over time.

But this is by no means straightforward. For central banks, measuring and tracking a given definition of the equilibrium interest rate – an abstract concept – is a formidable challenge. The corresponding estimates are highly uncertain, strongly model-dependent, and subject to

[21] As argued elsewhere, the view that ex ante saving-investment balances directly influence the market rate results from conflating saving and financing (Borio and Disyatat (2011)).

large revisions.[22] There is a material possibility that central banks may fail for prolonged periods. The consequent impact on real interest rates can be persistent. For instance, *even if the standard model of inflation determination is correct*, if the central bank keeps the interest rate too low, inflation will increase over time.[23] As Friedman (1968) noted, the presumption is that such a reaction function is not sustainable: in the face of explosive inflation dynamics, the central bank will be forced to abandon it. But over the intervening period, real interest rates would reflect monetary rather than saving-investment determinants as such. This, in fact, is a common reading of the Great Inflation of the 1970s.[24] Actions by market participants themselves may also contribute to persistent shifts in real interest rates, potentially compounding any central bank "mistakes" and transmitting them through the yield curve.[25]

As regards the possibility that prevailing economic models may underestimate some key channels through which monetary policy may exert persistent influence over real interest rates, two examples spring to mind. The first concerns the inflation process; the second, the interaction between monetary policy and the financial cycle.

The inflation process may be far less responsive to economic slack, and hence monetary policy, than commonly presumed (eg Forbes et al (2017)).[26] Imagine that inflation is below target and that headwinds make it hard to generate the second-round effects whereby wages chase prices.[27] Then, easing policy would have a one-off impact on the price *level*, say through currency depreciation, but only a temporary one on *inflation*. If the central bank continued to try to push inflation up, nominal and hence real interest rates would trend downwards. In the extreme, if inflation was *entirely* exogenous and trendless, the trend in the real interest rate would simply depend on whether inflation was below or above target. For instance, the real rate would tend to fall continuously if inflation started below target, as the central bank repeatedly cut nominal interest rates in the vain attempt to boost it towards target.

Monetary policy may also have a long-lasting impact on the real economy, and hence real interest rates, through the financial cycle.[28] There is now a broad consensus that price

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22 Borio et al (2014, 2017), for example, show that whereas typical output gap measures prior to the financial crisis indicated that US output was close to potential, subsequent revisions indicate that the level of activity was substantially above it.

23 Strictly speaking, of course, the inflation response depends on the expectations process. Adaptive expectations, for instance, would result in a continuous increase, possibly at an accelerating rate (Fleming (1976)). In the case of rational expectations, as typified by New Keynesian models, an interest-rate peg leads to indeterminacy in the inflation path and the sign of the immediate response of inflation to monetary shocks also becomes indeterminate (Cochrane (2017)). Such possibilities are therefore ruled out either outright or through equilibrium selection mechanisms that imply these outcomes are not robust or learnable (García-Schmidt and Woodford (2015), Evans and McGough (2015))

24 Lubik and Matthes (2016), for example, estimated a model of learning and argued that misperceptions about the state of the economy on the part of the Federal Reserve led to sustained deviations from equilibrium real rates during the Great Inflation of the 1970s.

25 This is quite apart from the impact of direct controls of interest rates. For instance, administered rates were quite common in the postwar period, until the financial liberalisations of the late 1970s-early 1980s.

26 Indeed, there is a lot of evidence that the Phillips curve has been quite flat for a long time. See, for instance, Stock and Watson (2007), Ball and Mazumder (2011), IMF (2013), Faust and Wright (2013), Faust and Leeper (2015), Kiley (2015) and Blanchard (2017). See Borio (2017a) for a recent discussion.

27 As discussed elsewhere (eg Borio (2017a)), this could reflect a loss in labour's "pricing" power as a result of much greater competition from lower-cost producers or technology, ie the greater contestability of markets linked to globalisation.

28 See Juselius et al (2017). In addition, a growing literature has documented the impact of monetary policy on risk premia operating through a risk-taking channel. For a discussion of the risk-taking channel, see Borio and Zhu

stability is not sufficient for financial stability, as the GFC confirmed most recently. If, as long as inflation is low and stable, central banks do not lean against the build-up of financial imbalances but ease aggressively and persistently after the bust, this will tend to impart a downward bias to nominal and real interest rates. Moreover, if, as a result, debt continued to rise in relation to GDP or did not adjust sufficiently, a "debt trap" might even emerge: it would become harder to raise interest rates without causing damage to the economy (Borio and Disyatat (2014)). Seen through the standard framework lens, this would look like an *exogenous* decline in the natural rate, whereas in fact it would simply *reflect* the path-dependent interaction of monetary policy with the economy.

The gold standard regime provides prima facie evidence that the role of monetary factors may well have been underestimated. During this regime, central banks did not target inflation or output directly; rather, they targeted convertibility – internal and external (eg Wicksell (1906)). As a first approximation, they kept policy rates roughly constant unless the convertibility constraint came under threat, at which point they raised them (eg Flandreau (2008)).[29] In other words, gold acted only as a weak anchor for policy, and there was not much *systematic* reaction to macroeconomic developments. The anchor worked only over long periods, to the extent that convertibility was threatened, especially in the country at the centre of the whole system.[30] And yet, during this historical phase, inflation remained range-bound: volatility aside, not least reflecting the high incidence of commodity and food prices in the CPI index, underlying prices fell or rose gradually over long periods.

The tension with today's prevailing paradigm is apparent. Seen through that lens, the period of relative price stability would suggest that the market rate tracked the natural rate quite closely (see below). And yet, not only would this have happened despite no explicit central bank attempt to stabilise prices. The relative stability of the real rate also sits uneasily with the concomitant high variability of the "usual suspects" expected to drive saving-investment balances (Graph 2 and Annex Graph A.3). Indeed, it is not obvious why such drivers should have been much more stable during that historical phase than postwar, as the data confirm. Another possibility is that stable real rates largely reflected stable nominal rates coupled with a weak link between the gap between the market and natural rate, as defined in the traditional framework, on the one hand, and inflation, on the other. That is, the monetary regime itself partly explains the evolution of real interest rates.

The recent experience with the effective lower bound may also be interpreted in a similar way, although here the picture is fuzzier. One view stresses that monetary policy in the traditional sense, as captured by the policy rate, was forced to be largely unresponsive to economic developments, and yet this did not result in inflation spirals or signs of indeterminacy (eg Cochrane (2017)). Another view focuses instead on the extraordinary easing of financial conditions in the wake of unconventional measures – balance sheet policies,

(2012) and Adrian and Shin (2010); for a broader analysis of the financial cycle and the role of monetary policy, see Borio (2014, 2017b).

29 This is the best description for advanced economies, especially the country at the core of the system (the United Kingdom). In the periphery medium-term trends in interest rates were more common, as the currency pegs gained credibility (see below). See Flandreau and Zumer (2004).

30 In his political economy lectures, Wicksell (1906) recognises this and discusses the related issues in some detail. He notes, for instance, that the direct impact of increased gold supplies may be relatively small compared with the indirect influence operating through interest rates and the convertibility constraint. He then postulates an unobservable and time-varying natural rate to explain periods in which price declines coincide with falling interest rates and contractions in gold production. This contrasts with economists more firmly rooted in the monetarist tradition, who ascribe a bigger role to exogenous increases in gold in circulation in influencing the price level by boosting expenditures (eg Fisher (1911) and, more recently, Bordo (1999)). For a discussion of these issues, and of Wicksell's shifting views, see Laidler (1991).

negative interest rates and forward guidance (eg Borio and Zabai (2016)) – which failed to bring inflation back to target as expected. Hence central banks' disappointment. This relative unresponsiveness of inflation could be rationalised ex post through corresponding shifts in unobserved natural rates. But it could also reflect other factors, such as the forces of globalisation and possibly technology making the inflation process less sensitive to monetary policy actions and exerting secular disinflationary pressures (eg Borio (2017b)). If so, repeated attempts to push inflation towards target could lead to persistent declines in real interest rates.

Overall, therefore, there are good reasons to suspect that the role of the natural rate in guiding the evolution of actual real rates could be much weaker than often presumed. Indeed, the very concept of the natural rate has not gone unchallenged. It is well known, for instance, that Keynes in his General Theory rejected it. He argued that there was no single natural rate of interest that balanced the economy at full employment.[31] In his liquidity preference theory, in a way not very different from what was described above, the long-term interest rate was the outcome of central bank and market participants' decisions. Importantly, though, depending on market participants' expectations and willingness to take on risk, the interest rate could persist at some arbitrary level for a long time. It is telling that both Wicksell's conception of the wedge between the market and the natural rate, and Keynes' alternative framework of interest rate determination, are premised on a *capital market failure* – agents fail to set rates at the appropriate level. This contrasts with the now standard New Keynesian frameworks, where the underlying "friction" is *price* (and possibly *wage*) *stickiness*.[32]

## 3.2 Previous work

We are not the first to explore the possibility that monetary factors may impart persistent effects on real interest rates in the recent literature. In their survey of the well documented persistence of real interest rates, Neely and Rapach (2008) conclude that existing theories have not adequately explained its origin. They argue and provide supportive evidence that monetary shocks contribute to persistent fluctuations in real interest rates – and by implication that monetary policy is not neutral in the long run. A number of papers have also documented the link between persistent real interest rate shifts and changes in monetary regimes. On a sample of 13 industrialised countries, Rapach and Wohar (2005) find that most of the structural breaks in mean real interest rates coincide with breaks in inflation, which they interpret as suggestive of monetary policy's influence. In related work, Caporale and Grier (2005) find that the appointments of Federal Reserve Chairmen Paul Volcker in 1979 and Alan Greenspan in 1987 coincided with shifts in mean real interest rates even after controlling for changes in the mean inflation rate.

More generally, various studies have found results consistent with monetary factors having persistent effects on real interest rates. In a VAR framework, Galí (1992) found that expansionary monetary shocks led to very persistent declines in real interest rates, with as much as 60 per cent of the variation in the real rate explained by money supply shocks after 5 years. Similarly, King and Watson (1997) and Rapach (2003) find that an exogenous increase

[31] Keynes rejected the notion that the rate of interest equilibrated the demand and supply for loanable funds because, in his view, the generation of income and expenditure are causal and the rate of interest merely an effect: "[the] novelty [of my theory] lies in my maintaining that it is not the rate of interest, but the level of incomes which ensures equality between savings and investment." (Keynes (1937), p 241). For an in-depth discussion, see Leijonhufvud (1981) and for a more recent sceptical view of the natural rate, see Laidler (2011) and his review.

[32] "It is only [...] with sticky prices that one is able to introduce the crucial Wicksellian distinction between the actual and the natural rate of interest, as the discrepancy between the two arises only as a consequence of a failure of prices to adjust sufficiently rapidly" (Woodford (2003), p 238).

in the steady-state inflation rate, which they interpret as a change in the monetary regime, decreases the steady-state real interest rate.

Finally, Gourinchas and Rey's (2016) emphasis on the role of booms and busts in explaining short-term real interest movements is consistent with the role of monetary policy. To be sure, their interpretation focuses on the relative demand for safe assets in the aftermath of a deleveraging shock. But the association between the consumption-to-wealth ratio and subsequent short-term real risk-free interest rates could also be seen as reflecting the central bank's reaction function in boom and bust periods. That is, the abnormally low consumption-to-wealth ratio following financial busts tends to coincide with periods of aggressive monetary policy easing to support the economy, which in turn gives rise to the association with low short-term risk-free rates in the subsequent period. Like us, they also find little support for a role of productivity growth or demographics in explaining real rates over time.

## 3.3 New evidence on monetary policy regimes

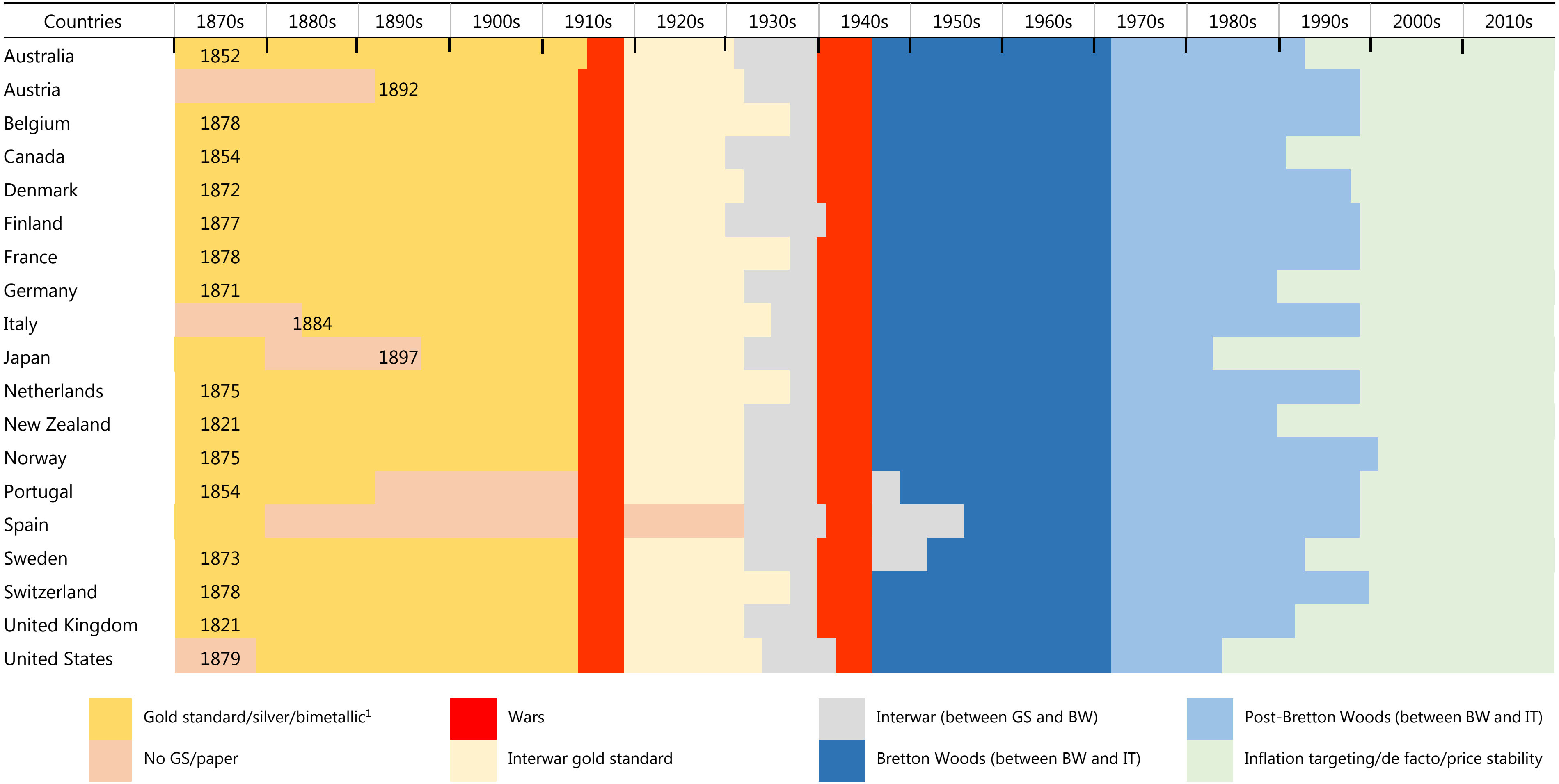
We investigate the link between real interest rates and monetary factors in two ways. The first examines whether various monetary regimes are associated with significant differences in the levels of real interest rates in individual countries. If money is neutral over the relevant horizon, then monetary regimes should not matter for real interest rates. The second takes a global perspective and explores the relative importance of global saving-investment determinants and global monetary factors. We consider each in turn.

To explore the effects of monetary regimes in individual countries, we follow the existing literature and identify seven different monetary regimes outside of the wars.[33] As Table 9 shows, regime dates are closely correlated across countries, though not perfectly. In Graph 6, the top two panels display the UK and US real interest rates and their associated regime shift dates as an example. One can already see that regime dates coincide with shifts in real rate behaviour.

[33] We mainly follow Benati (2008) and the Economic History Association (http://eh.net/) for the monetary regime definition, though the classification elsewhere in the literature is largely similar. The latest regime encompasses formal inflation targeting as well as the regime where inflation stabilisation is de facto a key objective. We do not single out the zero-lower bound period as a distinct regime, and exclude wars from our analysis.

International monetary policy regimes

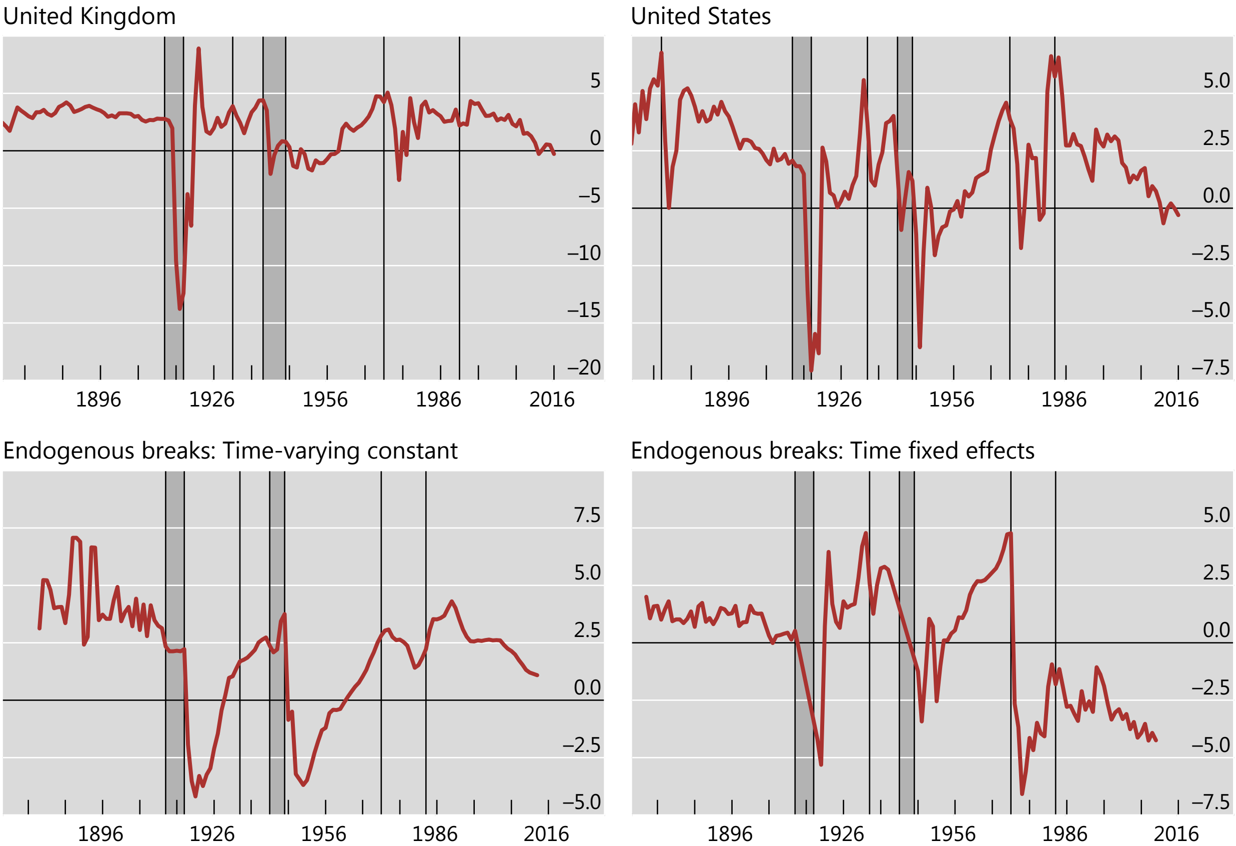
Table 9




[1] The table shows the year when a country joins the gold standard. In the empirical analysis, we do not distinguish between metallic standards. In the text, we use "gold standard" to refer to metallic standards.
Sources: Benati (2008); Meissner (2005); BIS; authors' calculations.

Real long-term interest rates and monetary policy regimes

In per cent | Graph 6




The shaded areas indicate the world wars: 1914-1918 and 1940-1945 for the United Kingdom; 1914-1919 and 1942-1945 for the United States.

The vertical lines indicate the year corresponding to a monetary policy regime shift. For the United Kingdom: 1914, 1919, 1932, 1940, 1946, 1972 and 1992; for the United States: 1879, 1914, 1919, 1934, 1942, 1946, 1972 and 1984. For the lower panels, we use the regime dates of global monetary anchor countries, namely the United Kingdom up to WWI and the United States thereafter.

Sources: Benati (2008); Meissner (2005); BIS; authors' calculations.

The same result emerges controlling for the saving-investment factors. To test this, we re-estimate the baseline specification on a 10-year rolling regression and allow for time variation in the constant term as a simple way to detect endogenous breaks. Graph 6 (lower left panel) shows that this estimated constant tends to change behaviour or reverse trend around monetary policy regime shifts. The result seems inconsistent with the notion that money is neutral and real interest rates could be explained by real factors alone.

We next examine the role of monetary policy more systematically by including regime dummies in a panel estimation. We try a number of specifications.

The first is simply to regress the long-term real interest rate on regime dummies in a panel fixed-effects specification. We define the dummies so that the coefficients indicate how the *level* of the real interest rates changes *relative* to the previous regime, with the first regime being the metallic-standard period.

## Real long-term interest rates and monetary policy regimes

Table 10

| | (1) Regimes | (2) Regimes & base | (3) Regimes & base & time |
|---|---|---|---|
| Paper | 1.74** | 5.80*** | 4.25*** |
| | (0.78) | (0.45) | (0.53) |
| Interwar gold standard | –3.81*** | –7.34*** | –4.40* |
| | (0.60) | (1.71) | (2.42) |
| Interwar non-GS | 1.25 | 1.90** | 0.29 |
| | (0.73) | (0.62) | (0.68) |
| Bretton Woods | –2.07*** | –3.74*** | –1.55* |
| | (0.69) | (1.03) | (0.81) |
| Post-Bretton Woods | 2.08*** | 1.83*** | 6.03*** |
| | (0.54) | (0.47) | (1.59) |
| Inflation targeting | –1.05*** | –1.25*** | –0.80 |
| | (0.42) | (0.50) | (0.55) |
| GDP growth | | –0.07* | –0.06* |
| | | (0.03) | (0.03) |
| Population growth | | –0.23 | 0.02 |
| | | (0.33) | (0.31) |
| Dependency ratio | | 0.05*** | 0.03** |
| | | (0.01) | (0.01) |
| Life expectancy | | 0.15* | 0.06 |
| | | (0.07) | (0.06) |
| Relative capital price | | 0.00 | 0.02 |
| | | (0.01) | (0.01) |
| Income inequality | | 0.07 | 0.11 |
| | | (0.05) | (0.06) |
| Constant | 3.76*** | –10.17** | –5.67 |
| | (0.33) | (3.53) | (3.65) |
| Adjusted R-squared | 0.16 | 0.19 | 0.45 |
| Number of observations | 2339 | 1102 | 1102 |
| Country fixed effects | yes | yes | yes |
| Time fixed effects | no | no | Yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Monetary policy regimes are country-specific, with regime dummies defined relative to the preceding regime in chronological order. The two wars are excluded. Gold standard (strictly, any metallic standards) is used as the reference regime, followed by "paper" (adopted concurrently by some countries in the earlier period), "interwar gold standard", "interwar non-gold standard" (adopted after the gold standard was abandoned and before WWII), "Bretton Woods" regime of fixed exchange rates, "Post-Bretton Woods", where central banks abandoned the pegs but did not generally focus on inflation as the nominal anchor, and "inflation targeting", which also includes a de facto focus on price stability. See details of regime classification in Table 9.

Source: Authors' calculations.

The results are consistent with the relevance of monetary policy regimes. All but one of the regime dummies are economically and statistically significant (Table 10, first column), suggesting that monetary regime changes have material implications for the levels of real rates. For example, countries that did not join the gold/metallic standard had a 1.74 percentage points higher real rate on average relative to those that did. Similarly, adopting an inflation targeting regime lowers average real rates by 1.05 percentage points relative to the post-Bretton Woods regime, and by 1.86 percentage points relative to the gold standard regime (the sum of all regime dummies). Other dummies have an analogous interpretation.

Some might argue that regime changes occur endogenously in response to shifts in equilibrium interest rates driven by real factors. To control for this possibility, we consider monetary regime dummies jointly with the saving-investment determinants (Table 10, second column). If anything, the effects of changes in monetary regimes on real rates are even larger in this more general specification. All regime changes are now associated with statistically significant changes in the level of real rates. In all but one regime change, the economic significance is in fact higher after controlling for saving-investment factors.[34]

The last, and most stringent, exercise is to control for *any* unobserved global trends that may have coincided with the regime dates. We do so by including time fixed effects (Table 10, third column). The test is designed to exclude the possibility that unobserved global saving-investment determinants drive the estimates. This stacks the cards against uncovering any effect of monetary regimes: here we are exploiting *only* their cross-sectional variation, which is rather small (Table 9). Despite this stringent criterion, we still find significant effects of many regime changes. The role of monetary regimes is quite robust.

Inspecting the time fixed effects (Graph 6, lower right panel), one can also see an association between monetary policy regimes and the *trends* of real interest rates, in addition to average levels. Monetary-regime switch dates typically coincide with turning points of the time fixed effect series. Unless there is an unobserved global real factor that accidentally coincides with (or, even harder to imagine, endogenously prompts) monetary regime switches, then the monetary regimes themselves seem to be dictating real rate behaviour.

Overall, our analysis suggests that monetary regimes are significantly associated with shifts in the level of real interest rates. Indeed, our monetary regime dummies systematically perform better than most of the saving-investment determinants. In addition, there appears to be a relationship between monetary regimes and trends in real interest rates.

One interpretation of our results is that changes in monetary policy regimes may be associated with changes in risk premia, in particular inflation risk premia, which have not been purged from our measure of real rates. We explore this in a couple of ways. One is to use short-term real rates, for which risk premia should be less of a factor, instead of long-term ones. The results are robust to this (Table B.3.4 in the Annex). The second way is to include rolling estimates of higher moments of output growth and inflation, which should be correlated with movements in risk premia. Again, the results do not change much.[35] Thus, while

[34] One might also argue that some third factor could be driving both changes in monetary regime and real interest rates. We find it generally hard to identify such factors, but oil price shocks could be one example. Our results, however, do not lend much support for their role: both the post-Bretton Woods and inflation targeting regimes were associated with rapid increases in oil prices, yet in the former the regime dummy is positive while in the latter it is negative. If oil prices affected real rates, they should do so in the same direction across monetary regimes.

[35] In related work, Nakamura and Steinsson (2017) show that their substantial and persistent money non-neutrality result is robust to changes in risk premia. For their part, Christensen and Rudebusch (2017) examine the inflation-linked bond term structure and find that a falling short-term risk-free rate could explain about half of the decline in long-term real yields over the last 20 years.

changes in risk premia may account for some of the correlation between monetary regime changes and real interest rate movements, they do not seem to account for all of it.[36]

We next turn to the global perspective. The results in Section 2 have shown that there is an important global component to real interest rates that is correlated with some of the global saving-investment determinants. Here we extend the analysis to include also global monetary factors and compare their importance with the global saving-investment determinants. Our hypothesis is that in a financially integrated world, the role of anchor currencies is important for the dynamics of world interest rates.

As extensively documented, the country acting as global monetary anchor has changed over time. Up to World War I, under the classical gold standard, the United Kingdom played the main anchor role (eg Bloomfield (1959) and De Cecco (1974)). After World War I the United States started to play a similar role, given the abundance of its gold holdings and the United Kingdom's struggle to adhere to the old parity. The United States then consolidated its unrivalled role in the post-World War II period, starting with the Bretton Woods agreement in 1944. We therefore focus on these two countries.

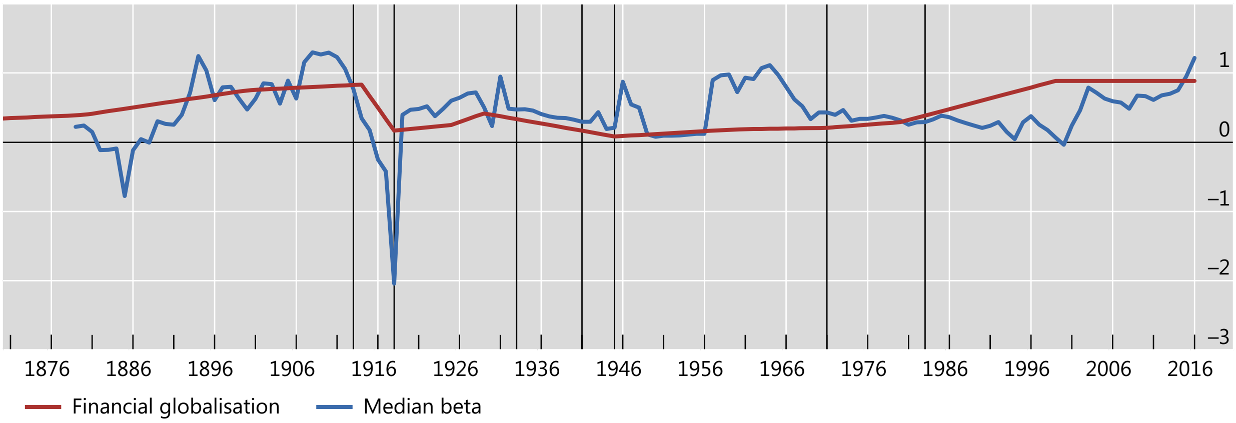
In addition, the degree of financial integration has evolved substantially over time. As discussed earlier, our sample includes two waves of tighter financial and real integration – the first starting in the latter half of the 19th century and the second starting from the early 1980s. As expected, financial globalisation waves tend to coincide with a higher correlation of real interest rates across countries (Graph 7).

We proceed in two steps. First, we construct a global monetary anchor variable, which reflects the policy stance of the financially dominant country. Following the previous discussion, we define the global monetary anchor as the UK policy rate up to World War I and the US counterpart thereafter. We regress the US and UK short-term real interest rates on their respective saving-investment determinants – both country-specific and global components. We take the residuals from these regressions (ie the part of US and UK short-term real rates that cannot be explained by saving-investment determinants) as a "clean" measure of US and UK monetary policy, respectively. In the second step, we plug this clean measure into the baseline panel regressions for the long-term real interest rates for all countries except the United States and the United Kingdom, controlling for both country-specific and global saving-investment determinants. This allows us to test whether the clean measure of monetary policy retains explanatory power. We also conduct a purely global analysis by regressing the GDP-weighted global real long-term interest rate (excluding the United States and United Kingdom) on the global monetary anchor and global saving-investment determinants.

The results indicate that the anchor countries' monetary policy matters for long-term real interest rates in the full sample and all the subsamples with one exception – the (mostly) classical gold standard (Table 11). This is the case both for the cross-country panel and time-series global regressions. Meanwhile, most of the saving-investment determinants still perform poorly, particularly in the cross-country panel: they have the wrong signs and/or switch signs across subsamples.

[36] More generally, to the extent that monetary regimes do affect risk premia, this is potentially another source of money non-neutrality and consistent with the risk-taking channel of monetary transmission. For example, Bianchi et al (2017) find episodes of persistently high asset valuation in the United States to be associated with persistently low real fed funds rate and low equity risk premia.

Financial globalisation and the cross-country real interest rate correlation Graph 7




The financial globalisation index is from Obstfeld and Taylor (2003), and is a stylised measure based on historical introspection. The index is extrapolated from 2000 assuming an unchanged degree of financial globalisation.

Median beta is a time-varying measure of 10-year real interest rate correlation across countries. We first regress each country's real rate on a composite series made up of the UK real rate up to World War I and the US real rate thereafter, on a 10-year rolling sample. We then take a cross-country median.

The vertical lines indicate the year corresponding to a monetary policy regime shift. For the United Kingdom: 1914; for the United States: 1919, 1934, 1942, 1946, 1972, 1984 and 2009.

Sources: Benati (2008); Meissner (2005); Obstfeld and Taylor (2003); BIS; authors' calculations.

The global monetary policy variable performs just as well in the global specification, but among the saving-investment factors the global dependency ratio appears equally promising (Table 12). To safeguard against the possibility that these results are driven by unidirectional trends, we simply add a linear time trend to the regressions. As can be seen, while the results for the global monetary policy variable are hardly affected, the dependency ratio loses significance in the pre-WWII sample. This indicates that the results for the global dependency ratio primarily reflect correlation between unidirectional trends in the two measures within this specific subsample.

## Global monetary policy and real long-term interest rates in the rest of the world

Table 11

| | Dependent variable: individual countries' real long-term interest rates | | | |
|---|---|---|---|---|
| | Full sample | Gold standard | Pre-WWII | Post-WWII |
| Global monetary policy | 0.29*** | –0.08 | 0.39** | 0.30*** |
| | (0.04) | (0.07) | (0.14) | (0.06) |
| G: GDP growth | 0.01 | –0.05 | –0.11** | 0.04 |
| | (0.04) | (0.03) | (0.04) | (0.08) |
| G: pop. growth | –1.60** | –2.03 | –1.38 | 0.72 |
| | (0.58) | (1.64) | (1.61) | (0.54) |
| G: dependency r. | 0.03 | 0.21 | –0.12 | 0.03 |
| | (0.04) | (0.12) | (0.19) | (0.04) |
| G: life exp. | –0.13* | –0.12 | 0.04 | 0.21* |
| | (0.05) | (0.12) | (0.28) | (0.1) |
| G: capital price | –0.10*** | –0.07 | –0.10 | –0.16*** |
| | (0.02) | (0.08) | (0.07) | (0.04) |
| G: inequality | –0.19* | 0.22 | 0.33 | –1.07*** |
| | (0.10) | (0.23) | (0.31) | (0.14) |
| C: GDP growth | –0.08* | –0.02 | –0.13* | –0.02 |
| | (0.04) | (0.02) | (0.07) | (0.03) |
| C: pop. growth | –0.15 | –0.13 | 0.20 | 0.53 |
| | (0.61) | (0.28) | (0.52) | (0.40) |
| C: dependency r. | –0.03 | 0.06 | 0.05 | 0.02 |
| | (0.01) | (0.07) | (0.09) | (0.02) |
| C: life exp. | 0.03 | 0.11 | 0.19 | 0.32** |
| | (0.07) | (0.06) | (0.17) | (0.09) |
| C: capital price | 0.02 | 0.09*** | –0.03 | 0.02 |
| | (0.01) | (0.01) | (0.05) | (0.01) |
| C: inequality | 0.08 | –0.06* | –0.18 | 0.19** |
| | (0.11) | (0.03) | (0.19) | (0.07) |
| Constant | 12.49 | –14.93 | 6.03 | –6.04 |
| | (6.94) | (16.14) | (31.66) | (7.46) |
| Number of observations | 889 | 159 | 324 | 556 |
| Adjusted R-squared | 0.21 | 0.79 | 0.21 | 0.48 |

Standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01. Horse race between three potential determinants of real long-term interest rates: (i) global monetary policy (set in the centre countries, the United States and United Kingdom); (ii) global aggregates of saving-investment factors (denoted by G); and (iii) country-specific component of the saving-investment factors (denoted by C). Global saving-investment factors calculated as the weighted cross-country averages of each factor based on real GDP at purchasing power parity.

Global monetary policy and global real long-term interest rates

Table 12

| | Dependent variable: global real long-term interest rate excl US & UK | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No linear trend | | | | Linear trend included | | | |
| | Full sample | Gold standard | Pre- WWII | Post-WWII | Full sample | Gold standard | Pre-WWII | Post WWII |
| Global monetary policy | 0.22*** | 0.07 | 0.28*** | 0.31*** | 0.16** | 0.08 | 0.39*** | 0.31*** |
| | (0.06) | (0.13) | (0.10) | (0.08) | (0.06) | (0.10) | (0.08) | (0.08) |
| G: GDP growth | 0.12** | –0.06 | 0.03 | 0.10 | 0.11** | –0.05 | 0.04 | 0.06 |
| | (0.05) | (0.04) | (0.07) | (0.07) | (0.05) | (0.03) | (0.05) | (0.07) |
| G: pop. growth | –1.24*** | 1.57*** | –0.24 | 0.25 | –1.53*** | 3.10*** | 0.59 | 0.28 |
| | (0.28) | (0.55) | (0.68) | (0.33) | (0.29) | (0.51) | (0.55) | (0.33) |
| G: dependency r. | 0.17*** | 0.01 | 0.48*** | 0.14*** | 0.16*** | –0.06 | –0.13 | 0.15*** |
| | (0.03) | (0.13) | (0.15) | (0.03) | (0.03) | (0.10) | (0.15) | (0.03) |
| G: life exp. | 0.12*** | –0.31* | 0.72*** | 0.26** | 0.42*** | 0.09 | 0.64*** | 0.69** |
| | (0.05) | (0.13) | (0.18) | (0.10) | (0.11) | (0.13) | (0.14) | (0.10) |
| G: capital price | –0.08*** | 0.07* | 0.02 | –0.17*** | –0.14*** | 0.07** | –0.17*** | –0.20*** |
| | (0.03) | (0.04) | (0.06) | (0.04) | (0.03) | (0.03) | (0.06) | (0.04) |
| G: inequality | 0.20** | –0.25*** | 0.54*** | –0.90*** | 0.14 | –0.58*** | –0.14 | –0.90*** |
| | (0.10) | (0.09) | (0.15) | (0.12) | (0.10) | (0.09) | (0.16) | (0.12) |
| Constant | –21.00*** | 21.15 | –86.04*** | –20.04** | –26.21*** | 23.92* | 5.35 | –37.27** |
| | (5.66) | (18.00) | (21.62) | (8.72) | (5.80) | (13.69) | (22.14) | (15.30) |
| Trend | | | | | –0.11*** | –0.19*** | –0.36*** | –0.11 |
| | | | | | (0.04) | (0.04) | (0.06) | (0.08) |
| Number of observations | 139 | 42 | 66 | 65 | 139 | 42 | 66 | 65 |
| Adjusted R-squared | 0.46 | 0.73 | 0.45 | 0.80 | 0.49 | 0.84 | 0.67 | 0.81 |

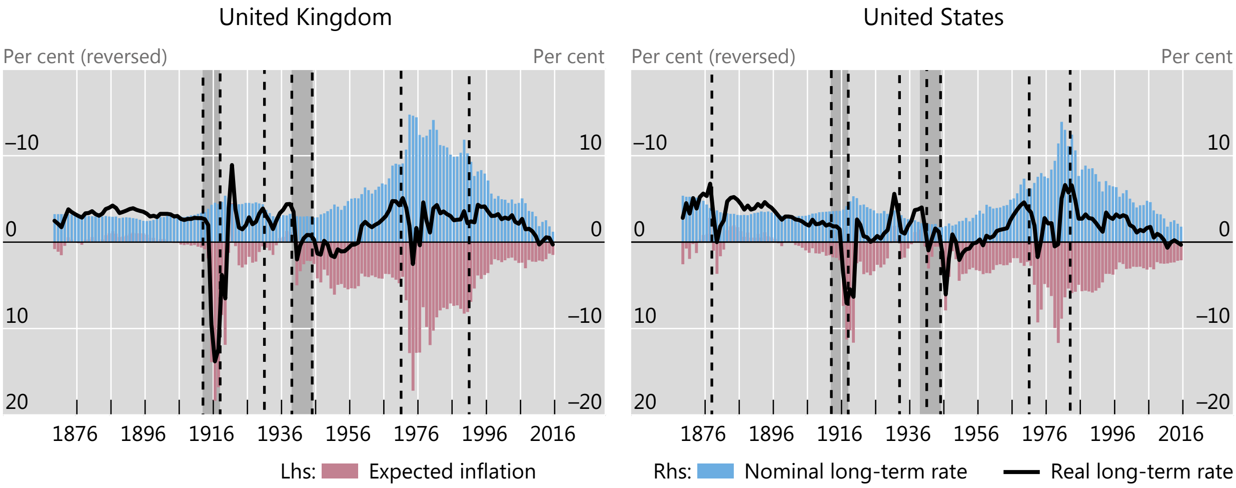
Standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01. Horse race between three potential determinants of *global* real long-term interest rate: (i) global monetary policy (set in the centre countries, the United States and United Kingdom); (ii) global aggregates of saving-investment factors (denoted by G); and (iii) country-specific component of the saving-investment factors (denoted by C). Global saving-investments factors calculated as the weighted cross-country averages of each factor based on real GDP at purchasing power parity. The global real long-term interest rate similarly constructed but we exclude the United States and the United Kingdom from the calculation.

## 3.4 A monetary narrative of the evolution of real interest rates

It may be useful to put together the various pieces of the jigsaw puzzle and provide a very stylised narrative of the evolution of real interest rates in which monetary policy regimes play a prominent role (Graph 8).[37]

[37] For a more detailed discussion of the interaction between monetary, financial and real economy regimes over the historical phase covered here, see Borio (2014).

Evolution of nominal and real long-term interest rates — Graph 8




Dashed lines represent monetary policy regime dates of respective countries.

Shaded regions indicate World War I, 1914-1918 and World War II, 1940-1945 for GB and 1942-1945 for US.

Sources: Benati (2008); Meissner (2005); Global Financial Data; authors' calculations.

During the classical gold standard, as already noted, central banks tended to keep nominal interest rates rather constant, without responding much to macroeconomic conditions or inflation. However, short-term volatility aside, this did not prevent inflation from remaining relatively stable over longer horizons. As a result, also real interest rates were generally rather stable throughout.

During World War I, just as during World War II, governments made sure interest rates remained low and, with capital controls in place, increases in inflation drove them down, reaching troughs.

In the 1920s, the United States took over as the global anchor, thanks to its growing economic and financial might as well as plentiful gold supplies. As central banks began to entertain macro stabilisation objectives, interest rates declined somewhat. Still, central banks' comparatively passive behaviour combined with stable inflation meant that both nominal and rates again remained relatively stable. In a way similar to the Great Moderation that preceded the recent GFC, financial imbalances built up. The Great Depression, in part a financial boom gone wrong (Eichengreen and Mitchener (2004), Rogoff (2015), Gourinchas and Rey (2016)), induced central banks to cut rates drastically in an effort to support demand and push prices up. In the years preceding World War II, conditions gradually normalised.

The postwar period saw monetary and financial repression: nominal rates were kept quite low through a mixture of government intervention and controls, domestic and international. As economies normalised and central banks gained further room for manoeuvre, rates gradually edged up.[38] But once inflation started to take hold in the 1960s and gained momentum in the 1970s, real interest rates fell substantially.

The early 1980s ushered in both financial liberalisation and a much more determined anti-inflation resolve, most evident in Volcker's decision to allow interest rates to rise substantially.

[38] The political will to tackle inflation played a role. In 1951, the Federal Reserve reached an agreement with the Treasury, paving the way to pursue an independent disinflationary policy and raising the policy rate (Federal Reserve Bank of Richmond (2011)). Similarly, the newly elected Conservative government in the United Kingdom saw a higher Bank Rate as part of the policy package needed to address inflation (Ross (1992)).

Real interest rates naturally increased too and appeared very high compared with the previous phase (eg G10 (1995)).

Since then, real interest rates have been declining following a combination of factors (eg Borio (2017a)). A first factor, at work in the first sub-phase, is a natural normalisation from the levels needed to fight the Great Inflation. Stickiness in inflation expectations, as market participants had been burnt during the high inflation, no doubt slowed the process (eg Erceg and Levin (2003)). A second factor, in part reminiscent of the interwar years, is the asymmetric response to successive financial booms and busts, most notably those that culminated with the banking strains in the early 1990s and then again, most spectacularly, the GFC. Central banks focused on tight inflation objectives, as well as short-run macroeconomic stabilisation, and did not respond to the build-up of financial imbalances (eg Borio (2014, 2017b). The third factor, especially at play post-GFC, has been the central bank's difficulty in pushing inflation towards target post-crisis, not least as a result of the long-term headwinds induced by globalisation and, possibly, technology (Borio (2017a)).

## Conclusion

Nowadays the prevailing view among academics and policymakers is that the decline in real interest rates since the early 1980s to historically low peacetime levels reflects a decline in the natural (equilibrium) interest rate. In this view, changes in (ex ante) saving-investment balances have pushed down the real interest rate consistent with full employment (output at potential). The empirical evidence for this hypothesis has so far relied primarily on two approaches. One approach assumes that observed real interest rates roughly track, on average and over long periods, natural rates; it then links their observed decline to potential underlying determinants of saving-investment balances, such as demographic factors or the relative price of capital, mainly through informal inspection or calibrated models. Another approach filters out the natural rate from market rates based on critical assumptions, including the hypothesis that inflation responds stably and systematically to domestic economic slack and that the real interest rate is a key factor influencing aggregate demand.

In this paper we have argued that the role of maintained hypotheses in this type of evidence is uncomfortably strong. Accordingly, we have adopted a more data-driven approach, which links *observable* proxies for the underlying determinants of saving-investment balances to real interest rates, both market rates and traditional estimates of natural rates. Importantly, we examine the corresponding relationships also beyond the standard recent sample (from the early 1980s), in order to limit the risk of finding spurious relationships. To do so, we go back in history, all the way to the late 1800s, for as many as 19 countries.

Our results cast doubt on the traditional interpretation. While there is a reasonable, although by no means watertight, link between the posited underlying saving-investment determinants and the real interest rate in the recent reference period, the link does not survive beyond the standard sample. By contrast, we find robust evidence of the relevance of monetary policy regimes, defined by the central banks' interest rate-setting behaviour (reaction function).

There are two ways in which this result, *taken at face value*, could be interpreted. One is to suggest that the information content of the proxies for the saving-investment determinants may have changed over time for structural reasons. We have not pursued this line of argument. While no doubt possible, it is not immediately obvious to us why that should be the case. Indeed, the unsystematic nature of the instability in the individual saving-investment coefficients would suggest otherwise. Another interpretation is that the maintained hypotheses deserve further investigation. For instance, the link between economic slack and inflation has come under closer scrutiny for some time. And the problem would be compounded if the link between real interest rates and aggregate demand was sometimes unreliable (eg Borio and Hofmann (2017)). Taken together, these factors would raise questions about the theoretical and, above all, practical usefulness of the concept of the natural interest rate for policymaking. These issues clearly deserve further examination.

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# Annex A: Data and plots

## A.1 Data sources and coverage

Data sources

Table A.1.1

| Variables | Series | Data sources |
|---|---|---|
| Nominal interest rates | Policy interest rates (official policy interest rates, or closest proxies) | BIS and Global Financial Data |
| | Short-term interest rates (3-month government bill yields, or closest proxies) | Global Financial Data, Jordà et al (2017), Bordo et al (2001) and national authorities |
| | Long-term interest rates (10-year government bond yields or closest proxies) | Global Financial Data and national authorities[39] |
| Macroeconomics | GDP annual growth | National authorities, Global Financial Data, and the Maddison Project (http://www.ggdc.net/maddison/maddison-project/home.htm) |
| | CPI annual growth | National authorities, Global Financial Data, and Mitchell's International Statistics |
| Productivity | Total factor productivity, capital share, labour productivity and capital density | Bergeuad et al (2016) (http://www.longtermproductivity.com) |
| Demographics | Population sizes by age brackets | United Nations, Human Mortality Database (http://www.mortality.org), and Mitchell's International Historical Statistics |
| | Population growth and life expectancy at birth | Human Mortality Database, Our World in Data (https://ourworldindata.org/), The Human Life-Table Database (http://lifetable.de) |
| | Labour force participation above age 65 | OECD, Costa (1998) |
| Relative price of capital | Investment goods price index divided by consumption price index | Eichengreen (2015) |
| Inequality | Top 1% income share, or closest proxies | Roine and Waldenström (2015) and World Wealth & Income Database (http://wid.world/), supplemented by Lindert (2000) and the Chartbook of Economic Inequality (https://www.chartbookofeconomicinequality.com) |
| US equity risk premium | Implied equity risk premium from a 2-stage augmented dividend discount model | A Damodaran (http://pages.stern.nyu.edu/~adamodar/) |
| Monetary policy regimes | Dummy of policy regimes | BIS, Benati (2008), Meissner (2005), Eh.net (https://eh.net/) |

[39] Our long-term interest rate data are very similar to those in Mauro et al (2006).

Data coverage

Table A.1.2

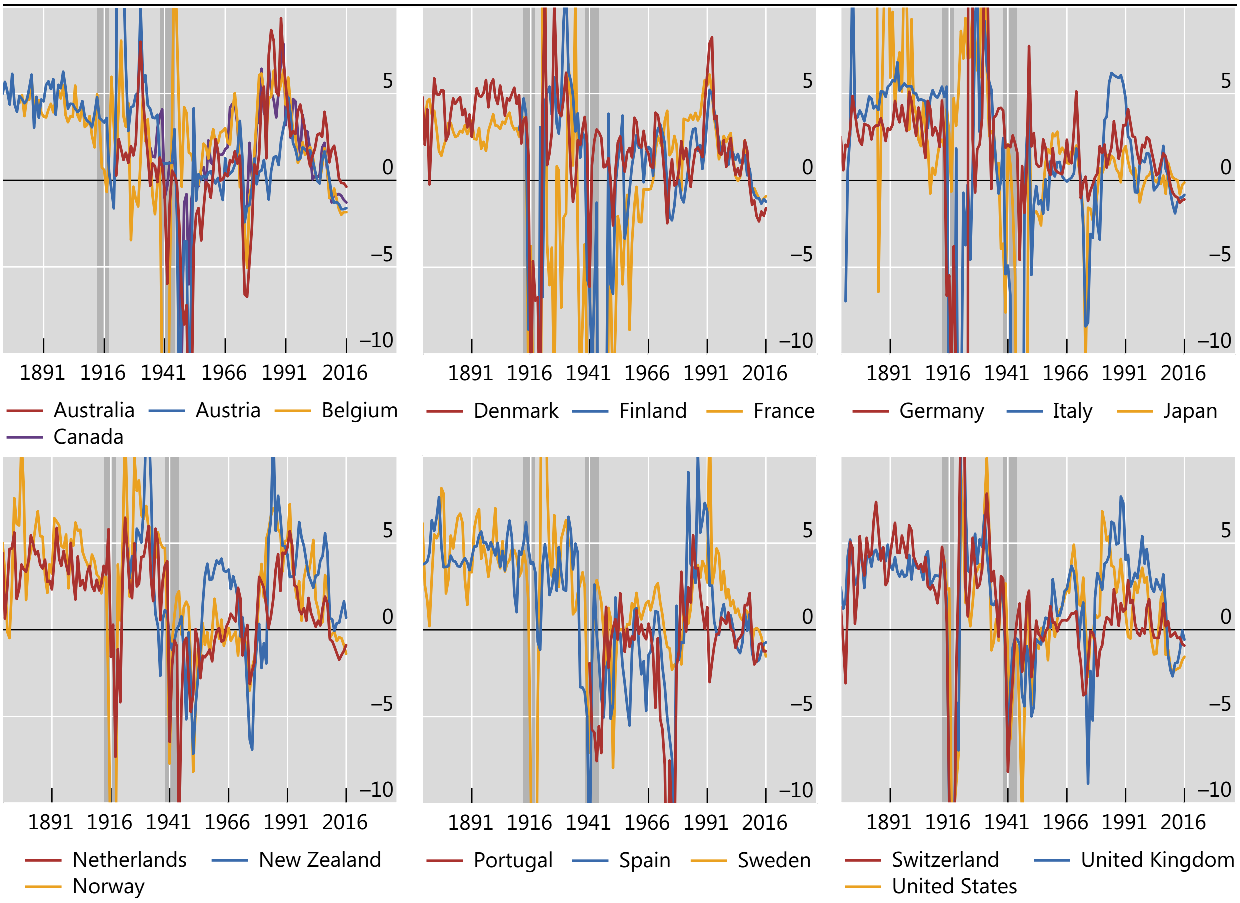
| Countries | Policy rate | Short rate | Long rate | GDP | CPI | Productivity | Demographics: Pop size by ages | Demographics: Life expectancy | Relative price of capital | Inequality | Population growth | Labour force participation (> 65) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 1921- | 1872- | 1872- | 1870- | 1870- | 1890- | 1870- | 1885- | 1872- | 1921- | 1922- | 1966- |
| Austria | 1874- | 1874- | 1874- | 1871- | 1870- | NA | 1870- | 1870- | NA | NA | 1948- | 1994- |
| Belgium | 1881- | 1881- | 1881- | 1870- | 1871- | 1890- | 1870- | 1870- | NA | NA | 1870- | 1983- |
| Canada | 1935- | 1934- | 1881- | 1871- | 1871- | 1890- | 1870- | 1870- | 1872- | 1920- | 1922- | 1976- |
| Denmark | 1870- | 1875- | 1870- | 1870- | 1870- | 1890- | 1870- | 1875- | 1872- | 1870- | 1870- | 1983- |
| Finland | 1911- | 1911- | 1911- | 1870- | 1901- | 1890- | 1870- | 1870- | 1872- | 1870- | 1879- | 1963- |
| France | 1870- | 1870- | 1870- | 1870- | 1870- | 1890- | 1870- | 1870- | NA | 1915- | 1870- | 1870- |
| Germany | 1870- | 1870- | 1870- | 1870- | 1870- | 1890- | 1871- | 1875- | 1872- | 1891- | 1957- | 1870- |
| Italy | 1872- | 1885- | 1872- | 1870- | 1870- | 1890- | 1870- | 1872- | 1872- | 1901- | 1873- | 1970- |
| Japan | 1882- | 1879- | 1879- | 1871- | 1870- | 1890- | 1884- | 1870- | 1877- | 1886- | 1948- | 1968- |
| Netherlands | 1870- | 1870- | 1870- | 1870- | 1870- | 1890- | 1870- | 1870- | NA | 1914- | 1870- | 1971- |
| New Zealand | 1923- | 1973- | 1918- | 1871- | 1908- | NA | 1870- | 1901- | NA | 1921- | 1902- | 1986- |
| Norway | 1870- | 1870- | 1870- | 1870- | 1870- | 1890- | 1870- | 1870- | 1872- | 1875- | 1870- | 1972- |
| Portugal | 1941- | 1941- | 1941- | 1870- | 1931- | 1890- | 1870- | 1940- | NA | 1976 | 1941- | 1974- |
| Spain | 1870- | 1880- | 1870- | 1870- | 1870- | 1890- | 1870- | 1882- | NA | 1981- | 1909- | 1972- |
| Sweden | 1870- | 1870- | 1870- | 1870- | 1870- | 1890- | 1870- | 1870- | 1872- | 1903- | 1870- | 1963- |
| Switzerland | 1870- | 1870- | 1893- | 1870- | 1870- | 1890- | 1870- | 1876- | NA | 1933- | 1877- | 1991- |
| United Kingdom | 1870- | 1870- | 1870- | 1870- | 1870- | 1890- | 1870- | 1870- | 1872- | 1870- | 1870- | 1870- |
| United States | 1914- | 1870- | 1870- | 1870- | 1870- | 1890- | 1870- | 1880- | 1872- | 1913- | 1934- | 1870- |

## A.2 Data plots of real interest rates

### Real policy rates

In per cent

Graph A.2.1



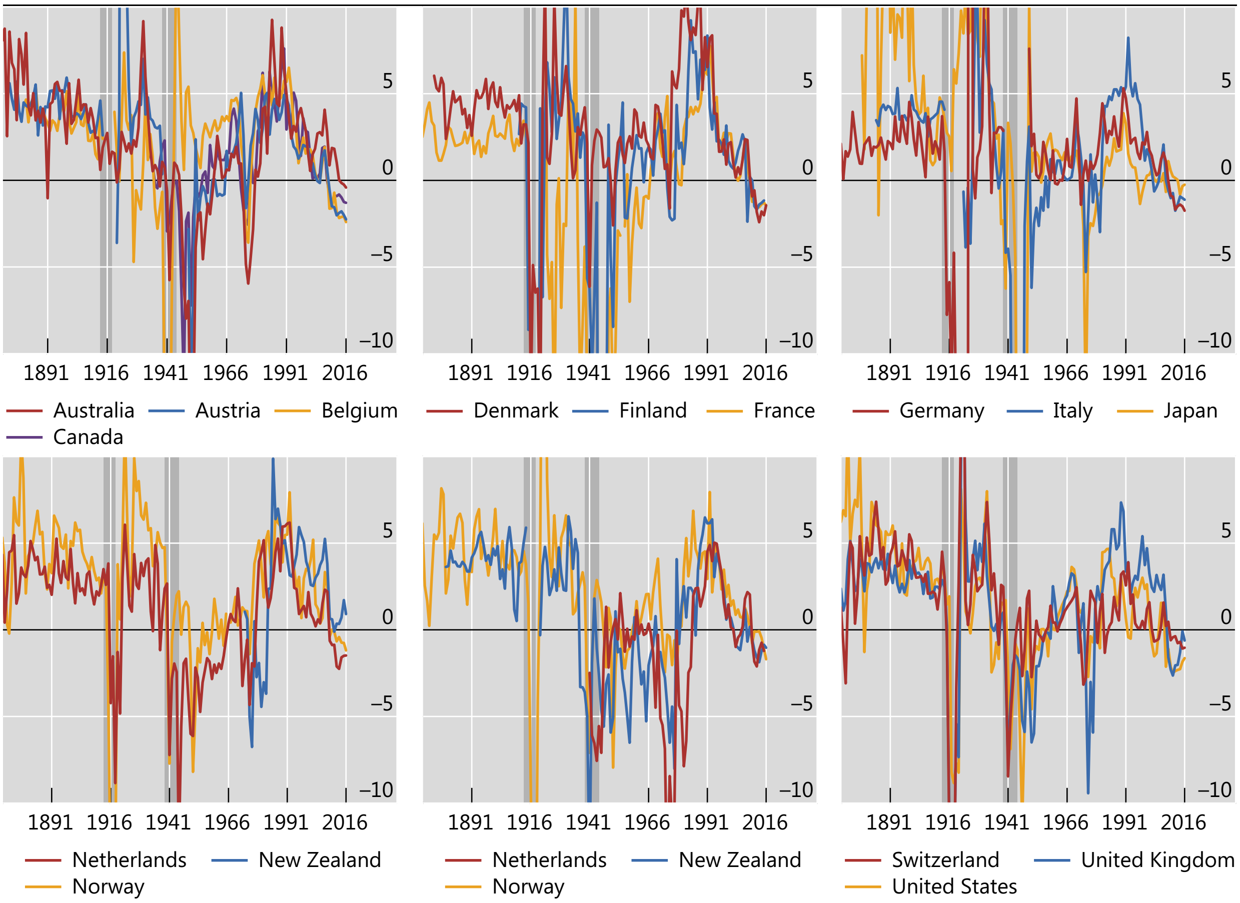

The shaded areas indicate the world wars, 1914-1918 and 1940-1945.

Sources: Global Financial Data; national data.

## Real short-term rates

In per cent

Graph A.2.2

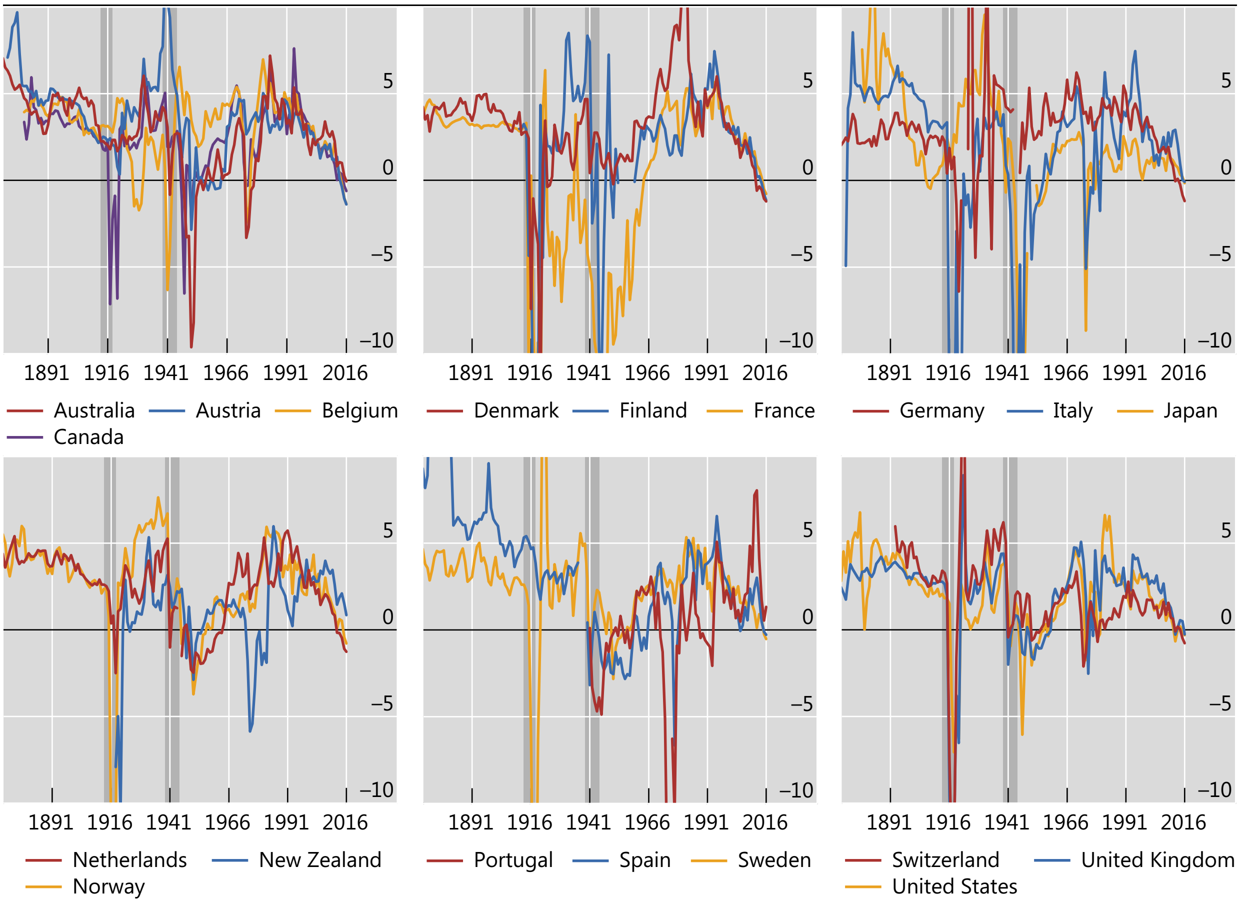



The shaded areas indicate the world wars, 1914-1918 and 1940-1945.

Sources: Bordo et al (2001); Jordà et al (2017); Global Financial Data; national data.

## Real long-term rates

In per cent Graph A.2.3

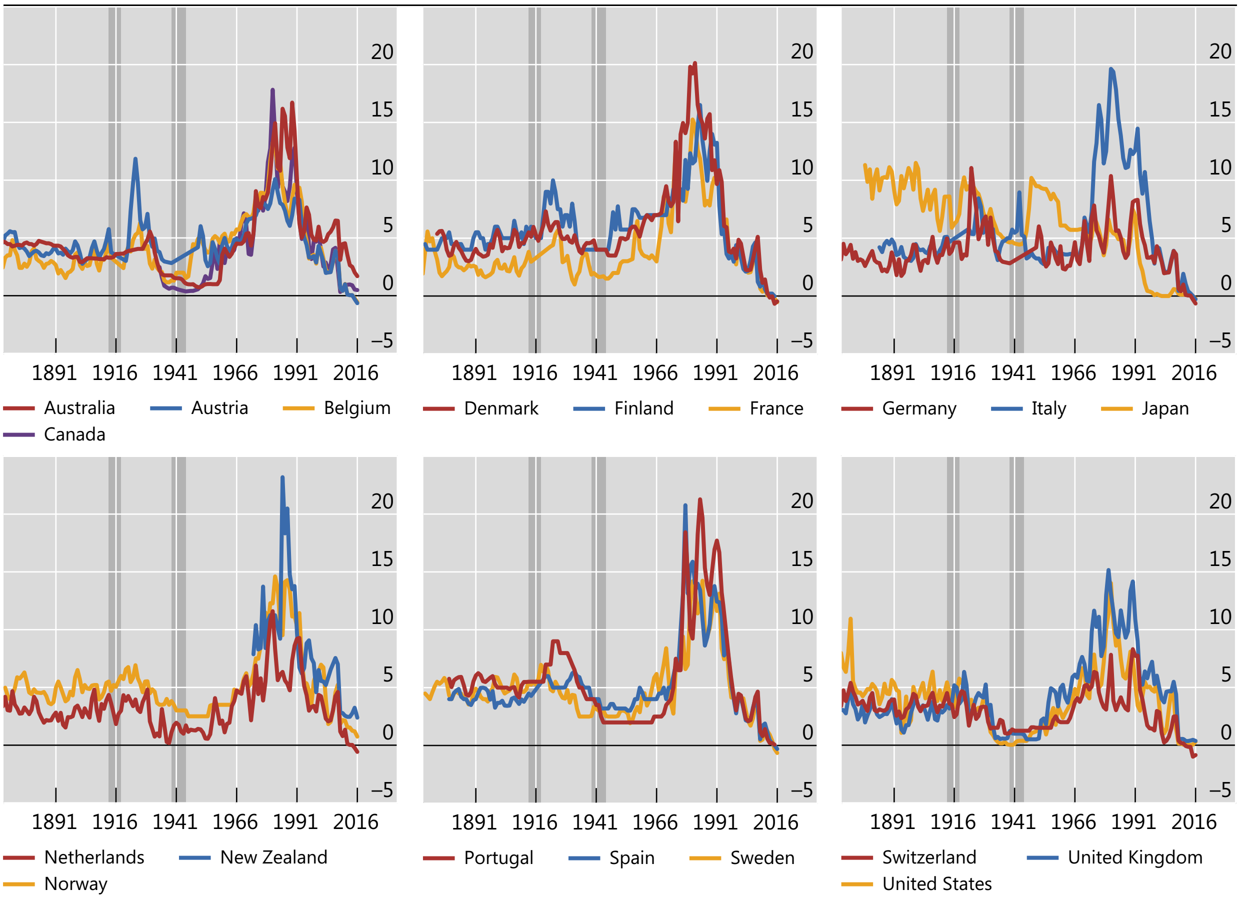



The shaded areas indicate the world wars, 1914-1918 and 1940-1945.

Sources: Global Financial Data; national data.

## Nominal short-term rates

In per cent | Graph A.2.4



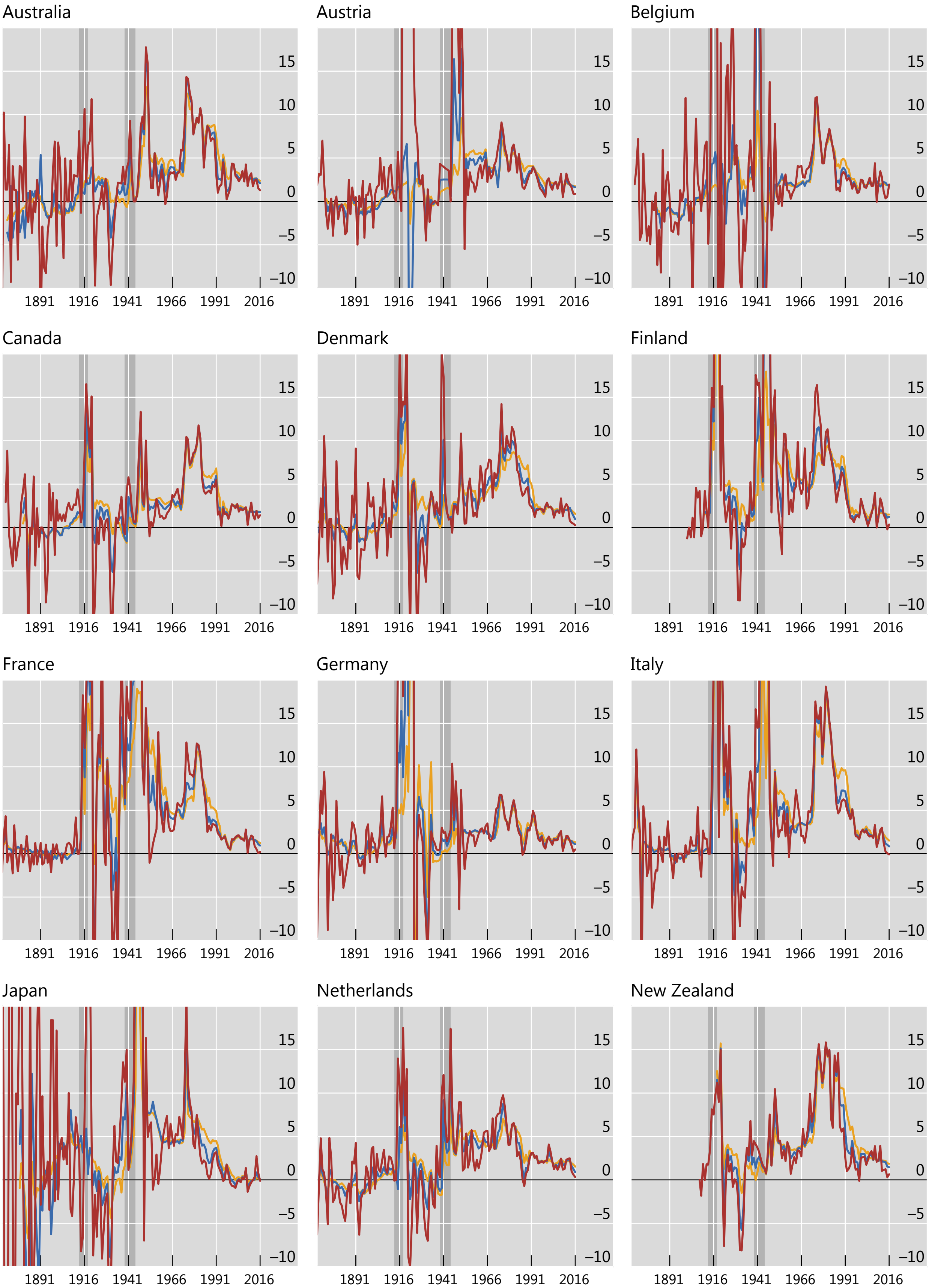

The shaded areas indicate the world wars, 1914-1918 and 1940-1945.

Sources: Global Financial Data; national data.

## Inflation and inflation expectations

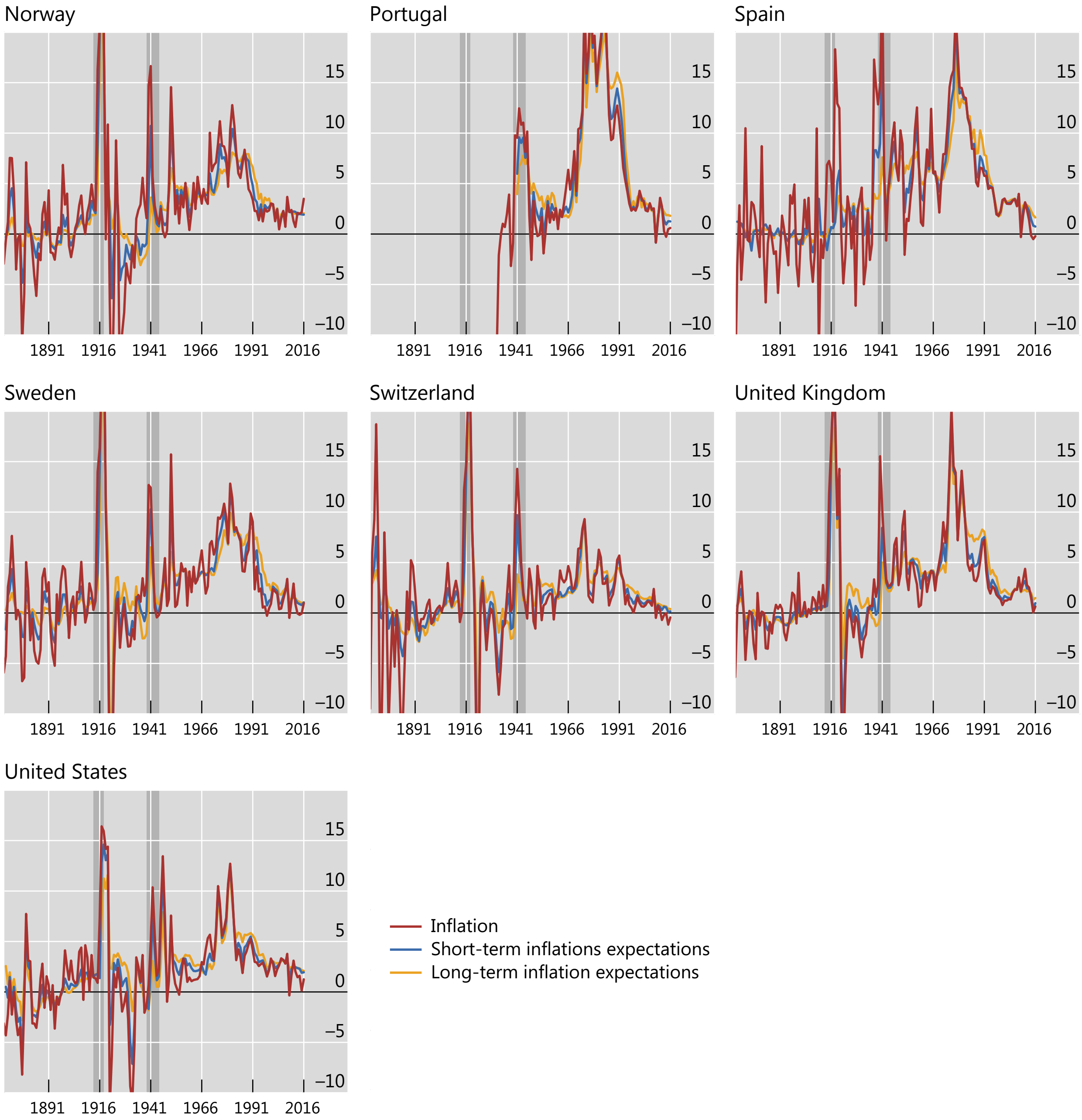
In per cent

Graph A.2.5



## Inflation and inflation expectations (continued)

In per cent | Graph A.2.5

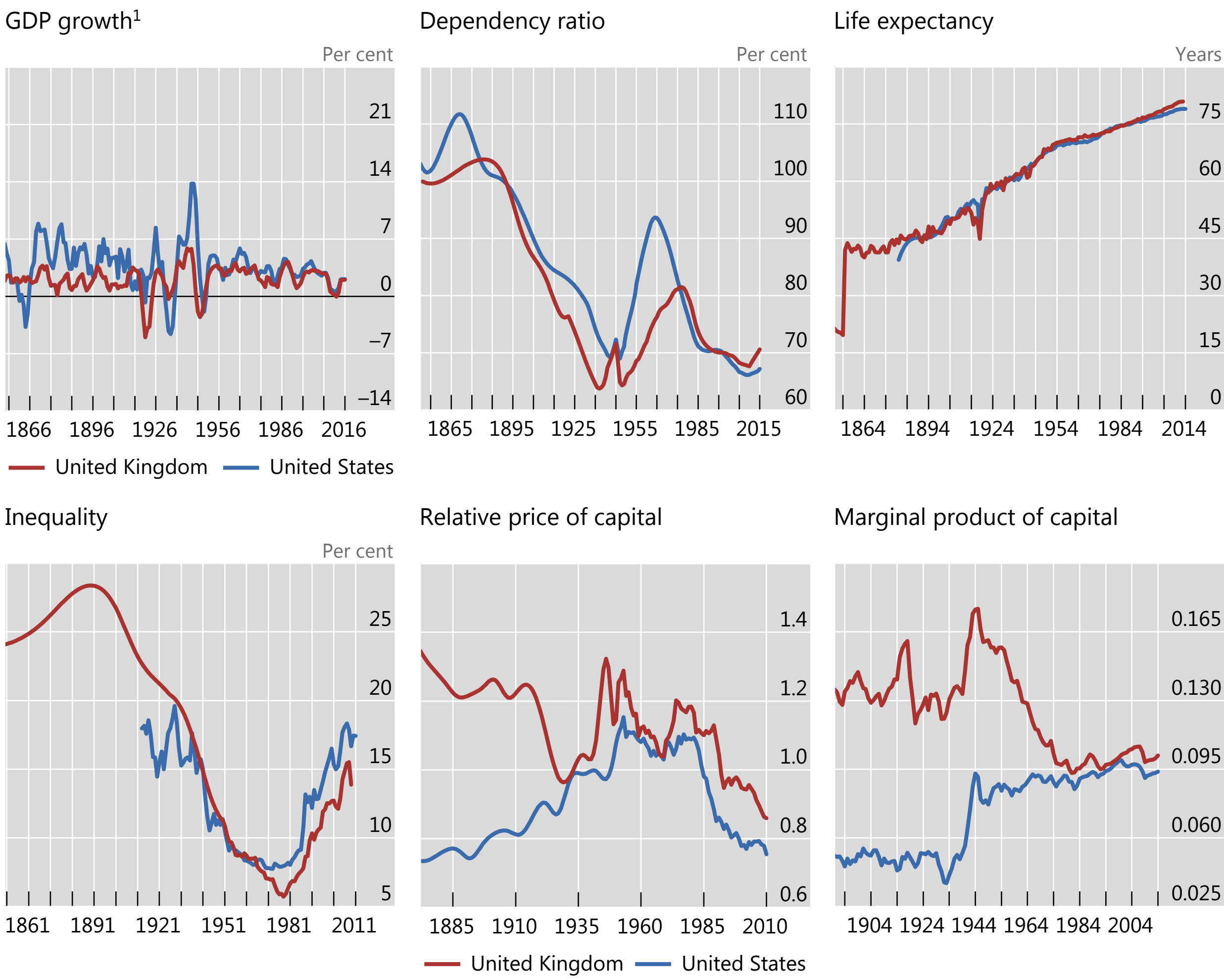



The shaded areas indicate the world wars, 1914-1918 and 1940-1945.

Sources: Global Financial Data; national data.

# A.3 Saving-investment factors for the United States and United Kingdom

Saving-investment factors: United States and United Kingdom | Graph A.3




[1] Five-year moving average.

Sources: Bergeuad et al (2016); Costa (1998); Eichengreen (2015); Roine and Waldenström (2015); Chartbook of Economic Inequality; International Historical Statistics; World Wealth & Income Database; OECD; United Nations, Human Mortality Database; national data; authors' calculations.

# Annex B: Robustness results

## B.1 Bivariate panel regression with time trends

This exercise checks for any spurious correlation between real interest rates and each of the saving-investment factors due to the presence of global trends. We do so by including linear time trends in each subsample. As the results below show, in comparison to Table 4, the estimates are indeed sensitive to adding such a trend, suggesting that inference is fragile as it is solely based on matching unidirectional trends.

Bivariate panel regressions with time trends

Table B.1

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| Marginal product of capital (+) | 2.90 | 23.09*** | –16.01 | –17.94 | –14.59 | –18.36 |
| GDP growth (+) | –0.10*** | 0.01 | –0.07* | 0.02 | 0.09* | –0.01 |
| TFP growth (+) | –0.08* | 0.02** | –0.01 | 0.09** | 0.18*** | 0.05 |
| Population growth (+/–) | –0.20 | 0.07 | 0.07** | –0.98*** | 0.07 | –0.67 |
| Dependency ratio (+) | –0.01 | –0.03 | –0.00 | 0.00 | 0.08** | –0.11** |
| Life expectancy (–) | –0.12*** | 0.11 | 0.36*** | 0.00 | –0.31 | 0.70** |
| Relative price of capital (+) | –0.00 | 0.06 | –0.09 | 0.02** | –0.05 | –0.02 |
| Inequality (–) | 0.12*** | –0.09 | –0.21 | –0.32*** | 0.15 | –0.03 |
| Time trend | Yes | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denote results significant at the 1/5/10% level. Significant coefficients with signs consistent with saving-investment theory are highlighted in green. Other significant coefficients are highlighted in red.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations

## B.2 Average dependent and independent variables

In this robustness exercise, we re-estimate the baseline and bivariate specifications using moving averages of all variables, in order to smooth out cyclical variations. Using both five-year and 10-year moving averages, the results are very similar to those from the main specifications. The two tables below report the results for five-year moving averages; the inferences from those based on 10-year averages are similar.

**Baseline specification using five-year averages** Table B.2.1

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.10 | –0.13 | –0.23 | 0.02 | –0.07 | –0.15 |
| | (0.08) | (0.10) | (0.25) | (0.11) | (0.05) | (0.10) |
| Population growth (+/–) | –1.20 | –1.78 | –0.90 | –0.62 | –0.15 | –1.75* |
| | (0.68) | (1.50) | (0.77) | (0.64) | (0.45) | (0.89) |
| Dependency ratio (+) | 0.02 | –0.05* | –0.00 | 0.01 | 0.07* | –0.16*** |
| | (0.02) | (0.02) | (0.17) | (0.02) | (0.03) | (0.04) |
| Life expectancy (–) | 0.06 | –0.16 | 0.56* | 0.26** | 0.62*** | –0.30* |
| | (0.05) | (0.11) | (0.26) | (0.10) | (0.07) | (0.14) |
| Relative price of capital (+) | 0.02 | 0.17*** | 0.10 | 0.02 | 0.01 | 0.03 |
| | (0.02) | (0.05) | (0.11) | (0.01) | (0.03) | (0.06) |
| Income inequality (–) | 0.09 | 0.15 | –0.27 | –0.28*** | –0.00 | –0.05 |
| | (0.11) | (0.11) | (0.37) | (0.07) | (0.26) | (0.25) |
| Constant | –3.52 | 13.45* | –24.67 | –15.13* | –46.94*** | 39.11*** |
| | (4.76) | (6.31) | (18.96) | (6.91) | (9.31) | (10.73) |
| Adjusted R-squared | 0.05 | 0.59 | 0.45 | 0.39 | 0.76 | 0.23 |
| Number of observations | 247 | 36 | 42 | 149 | 62 | 87 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

## Bivariate panel using five-year averages

Table B.2.2

| | (1)<br>Full sample | (2)<br>Gold standard | (3)<br>Interwar | (4)<br>Postwar | (5)<br>Pre-Volcker | (6)<br>Post-Volcker |
|---|---|---|---|---|---|---|
| Marginal product of capital (+) | 0.06 | 0.41*** | –0.11 | –0.37*** | –0.20 | 0.17 |
| | (0.05) | (0.03) | (0.50) | (0.08) | (0.40) | (0.25) |
| GDP growth (+) | –0.13 | 0.08 | 0.05 | –0.23** | –0.11 | 0.25* |
| | (0.08) | (0.07) | (0.15) | (0.11) | (0.12) | (0.14) |
| TFP growth (+) | –0.09 | –0.00 | 0.20 | –0.11 | 0.03 | 0.52** |
| | (0.13) | (0.07) | (0.23) | (0.17) | (0.17) | (0.23) |
| Population growth (+/–) | –0.05 | –0.15 | 0.20** | –1.88*** | –1.78*** | –1.41* |
| | (0.15) | (0.17) | (0.07) | (0.40) | (0.43) | (0.68) |
| Dependency ratio (+) | 0.03** | –0.02 | –0.21** | –0.05** | 0.06 | –0.05 |
| | (0.01) | (0.04) | (0.09) | (0.02) | (0.09) | (0.04) |
| Life expectancy (–) | –0.03** | –0.11** | 0.41*** | 0.20*** | 0.48*** | –0.14 |
| | (0.01) | (0.05) | (0.11) | (0.05) | (0.09) | (0.10) |
| Relative price of capital (+) | 0.01 | 0.05 | –0.05 | –0.04** | –0.10* | 0.04 |
| | (0.01) | (0.04) | (0.10) | (0.02) | (0.05) | (0.02) |
| Income inequality (–) | –0.00 | –0.05 | –0.62*** | –0.33*** | –0.73*** | –0.16* |
| | (0.04) | (0.12) | (0.18) | (0.11) | (0.18) | (0.09) |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

## B.3 Short-term market rates as the dependent variable

This set of tests replicates all our key specifications using short-term market interest rates instead of long-term ones. As short-term real rates rely less on short-term inflation forecasts, they should be more robust to any measurement errors in expected inflation. As the tables below indicate, the results for the short-term rate are very similar in sign and size to those for the long-term rate (Tables 5 and 6 in the main text). This is so in both the baseline and dynamic fixed-effects panel specifications. For the global specification, the dependency ratio now loses significance or flips sign in some samples. The relative price of capital fares slightly better than in the long-term rate specification, but only at country-specific level. Overall, the lack of stable relationships is still apparent. By contrast, monetary policy regime changes remain a significant determinant of the average levels of short-term real rates.

### Baseline specification using short-term interest rates

Table B.3.1

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.17** | –0.19 | –0.23** | 0.11 | 0.07 | 0.04 |
| | (0.06) | (0.15) | (0.07) | (0.11) | (0.11) | (0.06) |
| Population growth (+/–) | –1.14** | –0.27 | 1.03 | –0.71 | 0.25 | –1.36 |
| | (0.49) | (0.67) | (0.72) | (0.50) | (0.31) | (1.30) |
| Dependency ratio (+) | 0.03 | –0.04 | 0.18 | 0.03 | 0.21*** | –0.15 |
| | (0.02) | (0.04) | (0.10) | (0.04) | (0.04) | (0.10) |
| Life expectancy (–) | –0.05 | –0.26** | 0.51* | 0.27* | 0.24* | –0.67*** |
| | (0.04) | (0.10) | (0.24) | (0.14) | (0.12) | (0.13) |
| Relative price of capital (+) | 0.01 | 0.15*** | –0.06 | 0.01 | –0.05* | 0.04 |
| | (0.02) | (0.04) | (0.04) | (0.02) | (0.02) | (0.05) |
| Income inequality (–) | 0.04 | –0.16 | –0.25 | –0.34*** | –0.13 | –0.01 |
| | (0.07) | (0.21) | (0.54) | (0.10) | (0.20) | (0.22) |
| Constant | 4.66 | 22.58** | –36.88 | –17.79 | –33.23*** | 65.67*** |
| | (4.62) | (6.97) | (24.87) | (13.32) | (9.61) | (14.48) |
| Adjusted R-squared | 0.11 | 0.28 | 0.22 | 0.14 | 0.21 | 0.37 |
| Number of observations | 1078 | 199 | 187 | 650 | 310 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

## Short-term real rates in a dynamic fixed-effects panel specification

Table B.3.2

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| Long-run coefficients | | | | | | |
| GDP growth (+) | –0.28*** | –0.12 | –0.31*** | 0.17 | 0.08 | 0.21 |
| | (0.08) | (0.16) | (0.12) | (0.14) | (0.11) | (0.19) |
| Population growth (+/–) | –1.31** | –1.78*** | –0.69 | –1.07 | –0.94 | –2.69* |
| | (0.56) | (0.53) | (0.89) | (0.75) | (0.92) | (1.59) |
| Dependency ratio (+) | 0.04 | –0.08* | 0.08 | 0.04 | 0.20*** | –0.10 |
| | (0.03) | (0.05) | (0.06) | (0.04) | (0.06) | (0.14) |
| Life expectancy (–) | –0.14*** | –0.34*** | –0.08 | 0.27** | 0.15 | –0.34** |
| | (0.04) | (0.09) | (0.15) | (0.12) | (0.22) | (0.17) |
| Relative price of capital (+) | 0.01 | 0.26*** | –0.04 | 0.02 | –0.08*** | 0.16*** |
| | (0.02) | (0.02) | (0.03) | (0.02) | (0.03) | (0.06) |
| Income inequality (–) | –0.17*** | 0.19 | 0.32 | –0.47*** | –0.00 | 0.01 |
| | (0.04) | (0.13) | (0.32) | (0.12) | (0.30) | (0.20) |
| Short-run coefficients | | | | | | |
| Adjustment parameter | –0.31*** | –0.90*** | –0.85*** | –0.31*** | –0.56*** | –0.38*** |
| | (0.03) | (0.19) | (0.13) | (0.02) | (0.08) | (0.05) |
| Constant | 3.96** | 21.31** | 0.05 | –5.18 | –14.14 | 14.83* |
| | (1.76) | (10.61) | (11.99) | (3.45) | (13.44) | (7.57) |
| Adjusted R-squared | 0.27 | 0.43 | 0.63 | 0.25 | 0.37 | 0.24 |
| Number of observations | 980 | 174 | 159 | 640 | 300 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |
| Differences | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Differences: lagged differences from t to t-2 of all variables included in the regressions.

Source: Authors' calculations.

## Global specification using short-term interest rates

Table B.3.3

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| Global component: | | | | | | |
| GDP growth (+) | –0.07 | –0.21 | –0.23** | 0.22*** | 0.32*** | –0.05 |
| | (0.05) | (0.12) | (0.09) | (0.05) | (0.06) | (0.11) |
| Population growth (+/–) | –1.08** | –1.22 | 0.17 | 0.51 | 1.99*** | 1.36 |
| | (0.48) | (1.90) | (2.22) | (0.32) | (0.41) | (6.62) |
| Dependency ratio (+) | 0.02 | 0.14 | 1.12*** | –0.02 | 0.49*** | –1.05*** |
| | (0.03) | (0.21) | (0.30) | (0.04) | (0.07) | (0.15) |
| Life expectancy (–) | –0.29*** | –0.14 | 2.09** | 0.07 | –0.36 | –1.46** |
| | (0.05) | (0.16) | (0.94) | (0.11) | (0.23) | (0.49) |
| Relative price of capital (+) | –0.18*** | 0.04 | 0.15 | –0.20*** | 0.14* | 0.24*** |
| | (0.04) | (0.10) | (0.27) | (0.04) | (0.07) | (0.06) |
| Income inequality (–) | –0.49*** | –0.11 | 0.41 | –1.22*** | –2.99*** | 0.41 |
| | (0.12) | (0.12) | (1.19) | (0.09) | (0.51) | (0.25) |
| Country specific component: | | | | | | |
| GDP growth (+) | –0.12* | –0.20 | –0.20* | –0.00 | 0.01 | –0.06 |
| | (0.06) | (0.16) | (0.10) | (0.10) | (0.09) | (0.08) |
| Population growth (+/–) | –0.15 | –0.06 | 0.99 | –0.52 | –0.17 | –0.36 |
| | (0.53) | (0.29) | (0.90) | (0.50) | (0.38) | (1.01) |
| Dependency ratio (+) | 0.04 | –0.06 | 0.02 | 0.05 | 0.02 | 0.08 |
| | (0.02) | (0.04) | (0.17) | (0.03) | (0.05) | (0.11) |
| Life expectancy (–) | –0.01 | 0.13 | 0.38* | –0.22 | –0.82*** | 0.57 |
| | (0.09) | (0.12) | (0.21) | (0.14) | (0.21) | (0.55) |
| Relative price of capital (+) | 0.04** | 0.12*** | –0.02 | 0.03** | –0.03 | 0.08* |
| | (0.02) | (0.03) | (0.04) | (0.01) | (0.02) | (0.04) |
| Income inequality (–) | –0.11* | –0.18 | –0.31 | –0.01 | –0.26 | 0.24 |
| | (0.06) | (0.21) | (0.54) | (0.12) | (0.28) | (0.25) |
| Constant | 26.76*** | 1.18 | –210.76** | 8.27 | 7.98 | 184.56*** |
| | (5.22) | (24.97) | (92.95) | (9.20) | (18.77) | (38.69) |
| Adjusted R-squared | 0.23 | 0.33 | 0.27 | 0.36 | 0.38 | 0.53 |
| Number of observations | 1078 | 199 | 187 | 650 | 310 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016. Global components calculated as the averages of each variable based on real GDP at purchasing power parity.

Source: Authors' calculations.

## Short-term interest rates and monetary policy regimes

Table B.3.4

| | (1) Regimes | (2) Regimes & base | (3) Regimes & base & time |
|---|---|---|---|
| Paper | 2.91** | 6.11*** | 4.60*** |
| | (1.34) | (1.66) | (1.30) |
| Interwar gold standard | –3.18** | –6.11* | –1.42 |
| | (1.31) | (2.79) | (3.03) |
| Interwar non-GS | –1.79** | –1.51 | 0.51 |
| | (0.74) | (0.92) | (1.20) |
| Bretton Woods | –1.79** | –3.87** | –2.77** |
| | (0.64) | (1.43) | (0.97) |
| Post-Bretton Woods | 2.58*** | 2.20*** | 2.25 |
| | (0.50) | (0.45) | (2.59) |
| Inflation targeting | –1.68*** | –0.70 | –1.20* |
| | (0.44) | (1.11) | (0.64) |
| GDP growth | | –0.11* | –0.07 |
| | | (0.05) | (0.05) |
| Population growth | | –0.31 | –0.06 |
| | | (0.52) | (0.53) |
| Dependency ratio | | 0.06** | 0.05** |
| | | (0.02) | (0.02) |
| Life expectancy | | 0.12 | 0.04 |
| | | (0.10) | (0.08) |
| Relative capital price | | 0.02 | 0.04** |
| | | (0.02) | (0.02) |
| Income inequality | | –0.05 | 0.01 |
| | | (0.05) | (0.05) |
| Constant | 3.64*** | 4.70*** | 0.65 |
| | (0.17) | (1.23) | (1.43) |
| Adjusted R-squared | 0.21 | 0.21 | 0.51 |
| Number of observations | 2219 | 1078 | 1078 |
| Country fixed effects | yes | yes | yes |
| Time fixed effects | no | no | Yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Monetary policy regimes are country-specific, with regime dummies defined relative to the preceding regime in chronological order. The two world wars are left out. Gold (metallic) standard is used as the reference regime, followed by "paper" (adopted concurrently by some countries during the metallic standard), "interwar gold standard", "interwar non-gold standard" (adopted after the gold standard was abandoned and before WWII), "Bretton Woods" regime of fixed exchange rates, "post-Bretton Woods" where central banks have abandoned the pegs but have not focused on inflation as the nominal anchor, and the final regime "inflation targeting" which also includes de facto price stability focus. See details of regime classification in Table 9.

Source: Authors' calculations.

## B.4 Excluding periods after the world wars

Although we have excluded the wars from all our empirical analysis, it might be argued that the reconstruction periods following the wars could unduly influence the results. In this exercise, we drop five years immediately after both world wars from the estimation sample. Doing so does not materially affect the conclusions for any of our previous results. The table below shows only the baseline specification result.

Baseline specification, dropping five years after the world wars from sample — Table B.4

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.07** | –0.00 | –0.10*** | 0.09 | 0.06 | 0.03 |
| | (0.03) | (0.02) | (0.02) | (0.08) | (0.09) | (0.05) |
| Population growth (+/–) | –1.52*** | –0.50 | –0.62** | –1.39** | –1.37** | –0.68 |
| | (0.47) | (0.50) | (0.27) | (0.49) | (0.61) | (0.71) |
| Dependency ratio (+) | 0.01 | –0.03 | –0.14*** | 0.04 | 0.15*** | –0.03 |
| | (0.02) | (0.02) | (0.02) | (0.03) | (0.02) | (0.07) |
| Life expectancy (–) | –0.04 | –0.20*** | 0.13** | 0.21** | 0.37* | –0.32*** |
| | (0.02) | (0.05) | (0.05) | (0.08) | (0.18) | (0.09) |
| Relative price of capital (+) | 0.01 | 0.11** | –0.08** | –0.00 | –0.07* | 0.01 |
| | (0.01) | (0.03) | (0.03) | (0.01) | (0.04) | (0.03) |
| Income inequality (–) | 0.02 | –0.01 | 0.09 | –0.24*** | –0.09 | 0.10 |
| | (0.04) | (0.05) | (0.26) | (0.06) | (0.24) | (0.15) |
| Constant | 5.70* | 15.33*** | 6.97* | –13.61 | –34.95* | 31.18*** |
| | (2.81) | (2.61) | (3.19) | (7.91) | (16.89) | (7.95) |
| Adjusted R-squared | 0.11 | 0.51 | 0.31 | 0.21 | 0.38 | 0.26 |
| Number of observations | 999 | 202 | 164 | 633 | 293 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1924-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening, 1980-2016.

Source: Authors' calculations.

## B.5 Alternative expectations of inflation and GDP growth

This robustness check considers an alternative approach to measuring inflation and growth expectations. We allow for the possibility that agents might anticipate future average 10-year inflation and GDP growth correctly, eg they might be able to foresee the protracted period of slower growth associated with the Great Recession and revise expected inflation down. We follow the approach by Gali and Gertler (1999), who impose the rational expectations hypothesis through an orthogonality condition. In our context, the idea is to rewrite (1) as

$$i_t = \varphi_1 E_t[\pi_{t+1,t+10}] + \varphi_2 E_t[g^Y_{t+1,t+10}] + r^*(\tilde{X}_t;\ \beta) + r_t^{MP}$$

where $i_t$ is the nominal yield on government bonds, $\pi_{t+1,t+10}$ and $g^Y_{t+1,t+10}$ are the average 10-year ahead inflation and GDP growth rates, respectively, and $\tilde{X}_t$ excludes the GDP growth rate. Under rational expectations, errors in forecasting inflation are uncorrelated with information, $Z_t$, dated $t$ or earlier. This gives the orthogonality condition

$$E_t[(i_t - \varphi_1 \pi_{t+1,t+10} - \varphi_2 g^Y_{t+1,t+10} - r^*(\tilde{X}_t;\ \beta) - r_t^{MP})Z_t] = 0$$

which can be used to estimate the parameters via GMM. With rational expectations, we would expect to find $\varphi_1 = 1$.

### Allowing for anticipated inflation with GMM estimation

Table B.5

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| Average 10-year ahead inflation (+, =1 if perfect foresight) | 0.99*** | 0.38*** | 0.02 | 1.52*** | –0.73 | –0.88 |
| | (0.16) | (0.07) | (0.34) | (0.40) | (0.55) | (2.16) |
| GDP growth (+) | –1.63*** | –0.50 | 0.99 | 0.37 | –3.65*** | –4.37 |
| | (0.44) | (0.63) | (0.65) | (1.22) | (1.00) | (4.09) |
| Population growth (+/–) | 0.15 | 0.04 | –0.40** | –0.14 | –0.73 | 0.80 |
| | (0.52) | (0.66) | (0.16) | (0.56) | (0.53) | (1.02) |
| Dependency ratio (+) | 0.05 | 0.39*** | 0.16 | –0.18*** | 0.34** | 0.33 |
| | (0.04) | (0.09) | (0.11) | (0.06) | (0.14) | (0.32) |
| Life expectancy (–) | 0.01 | –0.01 | –0.18 | 0.41 | –0.05 | –3.21 |
| | (0.05) | (0.02) | (0.24) | (0.42) | (0.41) | (2.27) |
| Relative price of capital (+) | 0.01 | 0.01 | –0.01 | 0.01 | 0.09** | –0.06 |
| | (0.01) | (0.02) | (0.02) | (0.04) | (0.04) | (0.06) |
| Income inequality (–) | –0.03 | 0.20*** | 0.30 | –0.49*** | –0.26 | 0.02 |
| | (0.09) | (0.08) | (0.21) | (0.18) | (0.31) | (0.34) |
| Constant | 3.96 | –36.60*** | –3.19 | –14.30 | 4.62 | 252.69 |
| | (5.56) | (9.33) | (14.83) | (33.67) | (33.78) | (175.80) |
| Adjusted R-squared | NA | 0.92 | 0.19 | NA | –0.03 | 0.32 |
| Number of observations | 727 | 39 | 65 | 589 | 303 | 295 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level. The set of instruments include all variables in $\tilde{X}_t$, as well as the current and lagged values of the year-on-year inflation and GDP growth rates.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

Allowing for potentially rational expectations does not increase the relevance of the saving-investment factors in explaining real interest rates. Again, the parameters for the saving-investment factors often have the wrong sign, are statistically insignificant or vary across samples. This suggests that any mismeasurement of inflation expectations due to a high degree of agents' foresight is unlikely to be the culprit. In fact, the results seem inconsistent with the rational expectations hypothesis: $\varphi$ is quite far from unity and statistically insignificant in most subsamples. Less than fully rational inflation expectations may be one reason why monetary policy seems to have effects that last beyond the normal business cycle.

Lastly, we also re-estimate the baseline regression computing real interest rates simply as the difference between nominal rates and ex post inflation. The general pattern remains the same: no saving-investment factor is systematically associated with real interest rates in the way predicted by theory. Similar findings across various measures of expected inflation suggest that our general conclusion is robust to mismeasurement problems.

## B.6 Savers' ratio as an independent variable

This robustness check evaluates alternative definitions of the dependency ratio. In particular, we consider the "savers' ratio", used in Lunsford and West (2017), defined as the fraction of the population aged between 40 and 64. This measure is inversely related to the dependency ratio used in the baseline (and thus the expected sign should be negative). As reported in the table below, this new variable is significant and correctly signed in the postwar subsamples, but does not hold up in prior periods. We also experimented with the old-age dependency ratio (namely dropping the youngest population from the calculation), and found very little evidence of a systematic relationship (the result is not reported).

Baseline specification with savers' ratio — Table B.6

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.10** | –0.00 | –0.07 | 0.06 | 0.06 | 0.03 |
| | (0.04) | (0.02) | (0.05) | (0.06) | (0.07) | (0.05) |
| Population growth (+/–) | –0.81* | –0.27 | 0.29 | –0.55** | –0.21 | –0.69 |
| | (0.41) | (0.44) | (0.43) | (0.24) | (0.23) | (0.62) |
| Savers' ratio (–) | –0.18 | 0.41** | 0.24 | –0.46*** | –0.57* | –0.34** |
| | (0.13) | (0.16) | (0.50) | (0.09) | (0.26) | (0.14) |
| Life expectancy (–) | 0.08 | –0.17*** | 0.40 | 0.36*** | 0.29** | –0.05 |
| | (0.05) | (0.04) | (0.26) | (0.07) | (0.11) | (0.11) |
| Relative price of capital (+) | 0.01 | 0.11*** | –0.07 | –0.03** | –0.09*** | –0.01 |
| | (0.02) | (0.03) | (0.04) | (0.01) | (0.02) | (0.03) |
| Income inequality (–) | 0.11* | 0.00 | –0.01 | –0.17** | –0.25 | 0.01 |
| | (0.05) | (0.05) | (0.30) | (0.05) | (0.22) | (0.15) |
| Constant | 1.72 | 2.11 | –25.81** | –9.83** | –0.85 | 17.31** |
| | (2.90) | (3.80) | (10.90) | (3.68) | (8.16) | (6.21) |
| Adjusted R-squared | 0.08 | 0.53 | 0.22 | 0.34 | 0.30 | 0.32 |
| Number of observations | 1102 | 202 | 205 | 643 | 303 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

## B.7 Time-varying retirement age interactions with demographic variables

This exercise allows for the potential effects of a changing retirement age. We use the labour force participation rate of 65-year olds as a proxy for the expected retirement age. The baseline is then extended to include interaction terms between this proxy and the three demographic variables, as well as between the dependency ratio and life expectancy. The main findings survive. Neither specification delivers more stable relationships in any of the subsamples. The interaction terms are also statistically insignificant in most subsamples.

Baseline specification with time-varying retirement age — Table B.7

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.10* | –0.00 | –0.07 | 0.10 | 0.06 | 0.04 |
| | (0.05) | (0.03) | (0.08) | (0.06) | (0.05) | (0.05) |
| Population growth (PG) (+/–) | –0.27 | –2.04 | –0.23 | –1.72 | –1.13 | 2.27 |
| | (1.26) | (1.87) | (7.26) | (1.19) | (2.51) | (2.95) |
| Dependency ratio (DR) (+) | –0.04 | –0.33 | –0.34 | –0.45*** | –2.19*** | –2.10 |
| | (0.16) | (0.52) | (0.26) | (0.14) | (0.37) | (1.62) |
| Life expectancy (LE) (–) | 0.09 | –0.73 | 1.68 | 0.18 | –2.78*** | –1.56 |
| | (0.24) | (0.99) | (2.23) | (0.25) | (0.75) | (1.24) |
| Old-age participation (OP) (+) | 22.39 | 327.35 | –838.33 | 342.26** | 314.90 | 252.97 |
| | (94.32) | (413.54) | (1070.12) | (108.10) | (261.82) | (220.15) |
| PG x OP (+/–) | –4.47 | 17.04 | 9.02 | 8.61 | 8.10 | –9.51 |
| | (7.28) | (12.60) | (57.85) | (7.80) | (17.67) | (11.88) |
| DR x OP (+) | 0.40 | –1.52 | 8.05* | –0.72 | –3.28** | –0.13 |
| | (0.59) | (2.44) | (3.80) | (0.43) | (1.06) | (1.07) |
| LE x OP | –0.56 | –4.11 | 1.50 | –3.62** | –0.56 | –2.83 |
| | (0.72) | (4.15) | (16.62) | (1.15) | (3.27) | (1.98) |
| DR x LE (+) | –0.00 | 0.01 | –0.01 | 0.01*** | 0.04*** | 0.03 |
| | (0.00) | (0.01) | (0.01) | (0.00) | (0.01) | (0.02) |
| Relative price of capital (+) | –0.01 | 0.06* | –0.10* | 0.01 | –0.08** | 0.03 |
| | (0.01) | (0.03) | (0.05) | (0.02) | (0.03) | (0.03) |
| Income inequality (–) | 0.10 | 0.02 | –0.41 | –0.10 | –0.20 | –0.09 |
| | (0.06) | (0.03) | (0.32) | (0.08) | (0.16) | (0.16) |
| Constant | –1.48 | 20.88 | 1.22 | –27.26 | 146.48** | 119.90 |
| | (14.85) | (25.59) | (123.14) | (21.04) | (52.77) | (79.76) |
| Adjusted R-squared | 0.11 | 0.41 | 0.32 | 0.28 | 0.42 | 0.29 |
| Number of observations | 965 | 117 | 160 | 643 | 303 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

## B.8 Productivity growth as an independent variable

In this robustness check we replace GDP growth with total factor productivity growth in our baseline specification. This reduces the sample size somewhat, as the productivity variable has a smaller coverage. Again, the results are very similar to those already obtained with GDP growth. In particular, we do not find any systematic correlation between TFP growth – or indeed any of the other saving-investment factors – and real interest rates over time.

Baseline specification with productivity in place of GDP growth

Table B.8

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| TFP growth (+) | –0.07 | –0.02 | –0.03 | 0.21*** | 0.23** | 0.09* |
| | (0.06) | (0.01) | (0.04) | (0.05) | (0.08) | (0.05) |
| Population growth (+/–) | –0.86* | –0.59* | 0.28 | –0.76** | –0.13 | –0.59 |
| | (0.39) | (0.30) | (0.36) | (0.27) | (0.29) | (0.69) |
| Dependency ratio (+) | 0.02 | 0.10 | –0.02 | 0.03 | 0.14*** | –0.03 |
| | (0.01) | (0.08) | (0.09) | (0.02) | (0.02) | (0.06) |
| Life expectancy (–) | 0.05* | –0.19*** | 0.44 | 0.25*** | 0.45*** | –0.29*** |
| | (0.03) | (0.02) | (0.25) | (0.07) | (0.12) | (0.08) |
| Relative price of capital (+) | 0.00 | 0.12*** | –0.06 | 0.00 | –0.06* | 0.01 |
| | (0.01) | (0.02) | (0.05) | (0.01) | (0.03) | (0.03) |
| Income inequality (–) | 0.10 | –0.11 | 0.01 | –0.25*** | –0.12 | –0.09 |
| | (0.06) | (0.07) | (0.30) | (0.04) | (0.20) | (0.15) |
| Constant | –2.86 | 4.04 | –20.84 | –16.27** | –40.87*** | 28.79*** |
| | (2.62) | (7.32) | (22.43) | (6.65) | (10.83) | (7.38) |
| Adjusted R-squared | 0.05 | 0.65 | 0.20 | 0.23 | 0.38 | 0.27 |
| Number of observations | 1043 | 143 | 205 | 643 | 303 | 340 |
| Country fixed effects | yes | yes | yes | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening, 1980-2016.

Source: Authors' calculations.

## B.9 Risk premium as an independent variable

We proxy the risk premium with measures of fundamental risks in the economy, namely volatilities and higher moments of GDP growth and inflation, thereby also allowing for "tail risks", eg Vlieghe (2017). We compute 20-year rolling moments, and use the series as additional saving-investment factors in the baseline. As shown in the table below, none of the risk measures can explain real rate movements in the way predicted by theory.

Baseline specification augmented by fundamental risk measures — Table B.9.1

| | (1) Full sample | (2) Gold standard | (3) Interwar | (4) Postwar | (5) Pre-Volcker | (6) Post-Volcker |
|---|---|---|---|---|---|---|
| GDP growth (+) | –0.06 | 0.02* | –0.12 | 0.09* | 0.08 | 0.04 |
| | (0.04) | (0.01) | (0.07) | (0.05) | (0.05) | (0.05) |
| Population growth (+/–) | –1.04*** | –0.55 | 0.85 | –0.79* | 0.25 | –0.29 |
| | (0.30) | (0.33) | (0.51) | (0.41) | (0.23) | (0.69) |
| Dependency ratio (+) | 0.05*** | 0.17** | –0.06 | 0.08*** | 0.17*** | –0.03 |
| | (0.01) | (0.06) | (0.04) | (0.02) | (0.02) | (0.07) |
| Life expectancy (–) | 0.05* | –0.13*** | 0.25** | 0.26** | 0.32*** | –0.28*** |
| | (0.03) | (0.03) | (0.09) | (0.08) | (0.09) | (0.09) |
| Relative price of capital (+) | –0.02 | 0.11*** | 0.03 | –0.02 | –0.07*** | –0.00 |
| | (0.01) | (0.03) | (0.03) | (0.01) | (0.02) | (0.03) |
| Income inequality (–) | 0.03 | –0.07 | –0.06 | –0.25*** | –0.33** | –0.07 |
| | (0.07) | (0.04) | (0.24) | (0.07) | (0.12) | (0.15) |
| GDP growth volatility (–) | –0.44 | –0.82*** | –1.15 | –0.26 | 0.14 | 0.74 |
| | (0.32) | (0.22) | (0.78) | (0.45) | (0.43) | (0.63) |
| Inflation volatility (–) | 0.22 | 0.22 | 1.48*** | 0.09 | –0.68*** | 0.05 |
| | (0.13) | (0.12) | (0.28) | (0.12) | (0.12) | (0.12) |
| GDP growth skewness (+) | 0.15 | –0.53** | 2.82 | 0.25 | 0.27 | 0.66 |
| | (0.47) | (0.19) | (1.88) | (0.47) | (0.69) | (0.40) |
| Inflation skewness (+) | –1.53*** | –0.26 | –2.20*** | –1.69*** | –1.25*** | –0.38 |
| | (0.37) | (0.27) | (0.61) | (0.39) | (0.18) | (0.37) |
| GDP growth kurtosis (–) | –0.15 | –0.21 | –0.26 | 0.00 | –0.19 | 0.31** |
| | (0.24) | (0.15) | (0.45) | (0.23) | (0.34) | (0.13) |
| Inflation kurtosis (–) | 0.11 | 0.59** | 0.42 | 0.36** | 0.22 | –0.06 |
| | (0.20) | (0.20) | (0.43) | (0.15) | (0.13) | (0.10) |
| Constant | –2.56 | –7.10 | –10.84 | –19.79** | –29.46*** | 25.02** |
| | (2.94) | (4.04) | (10.33) | (7.95) | (6.86) | (9.68) |
| Adjusted R-squared | 0.18 | 0.77 | 0.56 | 0.32 | 0.56 | 0.29 |
| Number of observations | 983 | 147 | 173 | 630 | 290 | 340 |
| Country fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

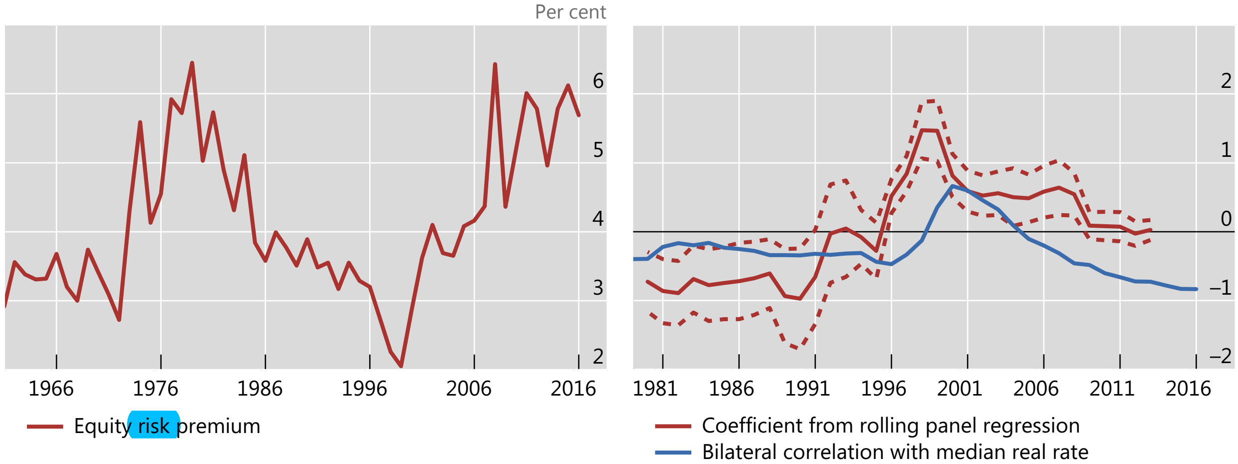
Full sample: 1870-2016; gold (metallic) standard: 1870-1913; interwar: 1920-1938; postwar: 1950-2016; pre-Volcker-tightening: 1950-1979; post-Volcker-tightening: 1980-2016.

Source: Authors' calculations.

As a second test, we also add a measure of the global equity risk premium. We use the US equity risk premium as a proxy (left panel of Graph B.9.1), since the US is a major market (also risk premium estimates for other countries are available for much shorter samples, if at all). Given this global premium proxy, we focus on the specification that allows for its global effects, namely an extension of Table 7 in the main text. The estimates are reported in Table B.9.2, where we consider two subsamples to examine stability. While the risk premium has a significant and correctly signed coefficient for the full sample, this is entirely driven by the earlier part of the sample (the coefficient on the risk premium from a rolling regression is shown in right-hand panel of Graph B.9.1). For the last 30 years, a higher risk premium actually has a positive marginal impact on real rates once one controls for other saving-investment factors. This contrasts with the narrative that emphasises the rise in the global risk premium since the turn of the century as the cause of lower risk-free rates (eg as the right-hand panel shows, the equity risk premium and median real rate are negatively correlated in the recent period).

Equity risk premium and real interest rates | Graph B.9.1

Equity risk premium | Relationship between risk premium and real rates




Dashed lines in the right hand panel indicate +/– two standard deviations.

Sources: A Damodaran, http://pages.stern.nyu.edu/~adamodar/; authors' calculations.

## Global versus country-specific determinants with risk premium

Table B.9.2

| | (1) Full sample | (2) 1961-1979 | (3) 1980-2016 |
|---|---|---|---|
| Global component: | | | |
| GDP growth (+) | 0.15** | 0.67*** | 0.15** |
| | (0.06) | (0.11) | (0.07) |
| Population growth (+/–) | 1.17 | –21.06*** | 18.45** |
| | (1.91) | (4.89) | (7.60) |
| Dependency ratio (+) | –0.12 | –0.02 | –0.10 |
| | (0.08) | (0.11) | (0.16) |
| Life expectancy (–) | 0.09 | –1.33** | 0.52 |
| | (0.20) | (0.53) | (0.34) |
| Relative price of capital (+) | –0.03 | 0.43*** | 0.02 |
| | (0.04) | (0.08) | (0.05) |
| Income inequality (–) | –0.65*** | 2.21* | –0.94*** |
| | (0.17) | (1.16) | (0.24) |
| Risk premium (–) | –0.25** | –0.65** | 0.19** |
| | (0.09) | (0.23) | (0.08) |
| Country specific component: | | | |
| GDP growth (+) | 0.03 | 0.06 | –0.02 |
| | (0.06) | (0.09) | (0.06) |
| Population growth (+/–) | –0.04 | –1.14 | –0.33 |
| | (0.57) | (0.76) | (0.65) |
| Dependency ratio (+) | 0.02 | –0.00 | 0.03 |
| | (0.03) | (0.06) | (0.07) |
| Life expectancy (–) | 0.18 | –0.98** | 0.58 |
| | (0.21) | (0.40) | (0.40) |
| Relative price of capital (+) | 0.01 | –0.06** | 0.02 |
| | (0.02) | (0.02) | (0.02) |
| Income inequality (–) | 0.09 | –0.19* | 0.13 |
| | (0.09) | (0.09) | (0.13) |
| Constant | 10.45 | 97.91** | –33.27 |
| | (18.39) | (43.62) | (28.72) |
| Adjusted R-squared | 0.13 | 0.05 | 0.08 |
| Number of observations | 540 | 200 | 340 |
| Country fixed effects | yes | yes | yes |

Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.

Full sample: 1961-2016; global components calculated as the averages of each variable based on real GDP at purchasing power parity.

Source: Authors' calculations.

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