Government debt, deficits and interest rates 1870-2016.*

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Abstract

This paper examines the effect of changes in the public debt-GDP ratio on long, 10 year, interest rates in a panel of 17 countries over the period 1870-2016 controlling for other variables, in particular the world interest rate. Over this long period one can argue that most of the big changes in public debt were the product of factors largely exogenous to national interest rate determination, such as war, depression or financial crisis.The issue is of current relevance since the covid-19 pandemic has caused large increases in the ratio of public debt to GDP in many countries. The estimates suggest that it is the change in debt, rather than the level of debt or the deficit, that matters for long interest rates. World interest rates have long and short run effects on interest rates which are very well determined and close to one. Current inflation has a small but significant effect.

Keywords: Public debt, Government deficits, interest rates, world interest rates, macro-history.

JEL Codes: C23, E43, F36, H63

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1 Introduction

There is a widespread belief that government deficits and national debt above certain limits have a negative effect on the economy, raising interest rates and lowering growth. For instance, the European Union Maastricht criteria for euro convergence specify that the government deficit to GDP ratio must not exceed 3% and the debt to GDP ratio must not exceed 60%. This paper examines this belief by looking at the effect of both the ratio of government deficit to GDP and of public debt to GDP on long, 10 year, government bond interest rates. It uses the Jorda-Schularick-Taylor, JST, macrohistory database, which provides data over 1870-2016 for a panel of 17 countries.[1]

Although the focus of this paper is on the long term relationship, the issue of the effect of debt on interest rates is of some relevance in 2020 given that the covid-19 pandemic has induced increases in public expenditure at the time when tax revenue is falling because of lockdown.

Over this long historical span, these countries saw large changes in public debt, which were plausibly exogenous to national interest rate determination, being the product of war, depression or financial crisis. The long interest rate is the focus because it is typically the rate at which the government finances debt and is more likely to be market determined than the short interest rate, which is used for policy purposes. In the market the equilibrium interest rate will be determined by the balance between borrowers and savers. The large exogenous shocks, like wars and crises, which cause government borrowing to increase, will also influence private borrowing for investment and private saving. Although there is no data on private debt over this period that would allow investigation of the hypothesis, one might suppose that large negative shocks like wars would increase uncertainty and depress private borrowing and increase private saving. Thus in the interest rate equation the coefficient of debt does not capture a pure ceteris paribus effect but the joint effect of what tends to happen at the same time as the changes in debt.[2] Pesaran & Smith (2014) discuss the arguments in favour of allowing for such indirect effects that arise due to the historical correlations amongst the regressors.

The empirical model used in this paper for country specific long interest rates controls not just for debts and deficits but also for the world interest rate, the cross section average of the 17 countries for that year. This captures the global balance between borrowing and saving and proves highly significant with a coefficient close to one. This is in accord with a range of recent literature, including Del Negro et al. (2018), Jorda & Taylor (2019) and Rachel & Summers (2019), which emphasises the comovement of national interest rates and the way that global forces determine their course over the medium to long run. Rachel & Summers (2019) treat the advanced economies as a fully integrated bloc and

[1] Jorda et al. (2017, 2019). The countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Great Britain, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and USA.

[2] Notice that instrumenting debt using a war/crisis variable does not solve the problem because this is correlated with the omitted variables, desired private borrowing and saving.

suggest that the 300 basis point decline in the global real rate since 1980 would have been substantially greater but for the buildup of government deficits and debt over the last generation and the increasing generosity of social insurance programs, particularly old age pensions. The role of demographic influences on interest rates is analysed in Aksoy et al. (2019).

Over this long historical span it may be reasonable to treat the bulk of the variation in the share of public debt as plausibly exogenous. This was the position of Barro (1987) who regarded wars as providing exogenous and transitory variations in UK government spending, for which it was optimal to use debt financing to smooth tax and consumption. The two arguments that might be made against the exogeneity assumption work in opposite directions. On the one hand, when interest rates are low there is an incentive to expand debt because borrowing is cheap, creating a negative relationship. Thus in recessions interest rates tend to be low and borrowing high. Similarly creditworthy countries both face lower interest rates and can borrow more. On the other hand, when interest rates are high, interest payments add to government expenditures, and potentially to the deficit and the need for debt financing, creating a positive relationship.

While normal, short run, debt management operations over the cycle are possibly endogenous, responsive to interest rate expectations, the assumption of exogeneity seems more plausible for the large changes in the share of debt that dominate the long run historical variation. It seems unlikely that a large number of countries simultaneously decided that low interest rates made 1941, 2009 or 2020 good years for massive borrowing. Similarly, much debt is of longer duration and current interest rate changes may not have much effect on debt interest payments. In addition there are other ways of responding to increased interest payments than increased debt and as we shall see the relationship between deficits and the change in debt is not that close.

Rachel & Summers (2019) are sceptical about the possibility of estimating the effect of government borrowing on interest rates because of the low power of the tests and the large number of confounding factors. The hope in this paper is that the effect of debt and deficits on interest rates can be identified by controlling for world interest rates and using heterogeneous panel estimators on a large, long span, data set that exhibits great exogenous variation. This should allow more precise estimates of the signal, which with less data may be drowned out by the noise.

Just as the covid-19 pandemic boosted borrowing, the global financial crisis that started in 2007 was followed by large increases in public debt in many countries. For the 17 industrial countries considered in this paper, the average public debt-GDP ratio increased from 61% in 2007 to 87%, in 2016. The US and UK increased by rather more, just over 40 percentage points. Only two of the 17, Norway and Switzerland, reduced their debt-GDP ratio. However, despite this increase in public debt, average long interest rates fell from 2.4% to 0.3%. Interest rates were not only below the rate of growth they were negative in many countries.

There is a considerable literature on the determination of global interest rates and why interest rates in the early 21st century were so low. The low interest rates after the financial crisis partly reflect the policies of the Central Banks, particularly the Federal Reserve and the European Central Bank, whose quantitative easing, through the purchase of bonds, made safe assets in short supply in the face of a savings glut. But this was superimposed on a longer term trend. World real interest rates for safe and liquid assets which fluctuated around 2 percent for more than a century, have steadily fallen over the past three decades, for reasons that remain controversial. Of course, interest rates do rise during debt crises. Greece is not in the sample considered in this paper, but Greek 10 year interest rates spiked at over 30% at the height of the eurozone debt crisis. However, by early February 2020 the yield on Greek 10 year bonds was below 1%. This was despite a Greek debt-GDP ratio over 180% and Greek bonds still being classified as junk, below investment grade, by the ratings agencies.

Some, like Blanchard (2019), argue that the low interest rates in the second decade of the 21st century mean that governments could borrow at no fiscal cost at all. In addition, the opportunities for productive public infrastructure investments in these countries could increase growth, further reducing the debt-GDP ratio. Others, like Boskin (2020), argues against this view and concludes that the evidence still suggests that large increases in the debt ratio could lead to much higher taxes, lower future incomes and intergenerational inequity. In particular, he argues that Blanchard fails to take account of the effect of increasing debt on interest rates and growth. Thus it is of some interest to estimate the effect of debt on interest rates.

The focus in this paper is the effect of debt and deficits on long interest rates, but there is another literature on the effect of debt on growth. Reinhart and Rogoff (2010) estimate a debt-GDP threshold, in which ratios above 90% have a negative effect on growth, though this estimate has been widely criticised, for instance by Herndon et al. (2014). Chudik et al. (2017) using a sample of forty countries over the period 1965-2010 find no evidence for a universally applicable threshold effect in the relationship between public debt and economic growth, although they do find significant negative effects of public debt buildup on output growth. Most of this literature has focussed on the post World War II period, but in certain respects this period is atypical of the longer historical record which is considered in this paper.

Section 2 provides some background. Section 3 considers the alternative estimators. Section 4 describes the data. Section 5 reports the results of the empirical analysis. Section 6 has some concluding comments.

2 Background

Barro (1987) provides the classic theory and estimates. Using UK data and treating debt as exogenous, he finds a positive effect of transitory government expenditure on long rates. Temporary increases in government purchases, showing up in the sample as increases in military outlays during wartime, had positive effects on long term interest rates. Smith (2020) examines the role of military expenditures in determining the UK national debt over the period 1700-2016 and confirms Barro's conclusion of the dominant role of military expenditure changes.

Eichengreen et al. (2019) consider public debt from a longer term historical perspective, showing how the purposes for which governments borrow have evolved over time. The periods when debt-to-GDP ratios rose explosively tended to result from wars, depressions and financial crises. Many of these episodes resulted in debt-management problems resolved through debasement and restructuring. There were also successful debt consolidations, where governments inheriting heavy debts ran primary surpluses for long periods in order to reduce those burdens to sustainable levels. They analyze the economic and political circumstances that made these successful debt consolidation episodes possible. Hall and Sargent (2020) consider the financing of eight US wars and two insurrections using the Barro (1979) and Lucas & Stokey (1983) models of optimal financing.

Given data on countries $i = 1, 2, ..., N$, for time periods $t = 1, 2, ..., T$, we can write the government budget constraint in terms of net debt at the end of period $t+1$, $D_{i,t+1}$. Debt equals the primary deficit (the negative of the primary surplus $S_{i,t+1} = T_{i,t+1} - G_{i,t+1}$, taxation less government expenditure not including interest payments),[3] plus interest on the previous periods debt, where r_{it} is the nominal interest rate, minus the increase in money supply, $(M_{i,t+1} - M_{it})$. That is:

$$D_{i,t+1} = -S_{i,t+1} + (1 + r_{i,t+1})D_{it} - (M_{i,t+1} - M_{it}). \tag{1}$$

Dividing through by nominal GDP, and using $Y_{t+1} = (1 + g_{t+1})Y_t$ where g_{t+1} is the growth rate of nominal GDP we get:

$$\frac{D_{i,t+1}}{Y_{it+1}} = -\frac{S_{i,t+1}}{Y_{i,t+1}} + \frac{1 + r_{i,t+1}}{1 + g_{i,t+1}} \frac{D_{it}}{Y_{it}} - \frac{(M_{i,t+1} - M_{it})}{M_{it}} \frac{M_{it}}{(1 + g_{i,t+1})Y_{it}}.$$

This can be written as:

$$\Delta d_{it+1} = -s_{i,t+1} + f_{i,t+1} d_{it} - \frac{m_{i,t+1}}{1 + g_{i,t+1}} k_{it}; \tag{2}$$

where $d_{i,t+1} = D_{i,t+1}/Y_{i,t+1}$, $s_{i,t+1} = S_{i,t+1}/Y_{i,t+1}$, $m_{i,t+1} = \Delta M_{i,t+1}/M_{it}$, $k_{it} = M_{it}/Y_{it}$, $(1 + f_{i,t+1}) = (1 + r_{i,t+1}) / (1 + g_{i,t+1})$.

This makes it clear that the change in the debt-GDP ratio and the deficit as a share of GDP are different. Other factors are involved in the relationship between them: money growth, income growth, interest rates and previous debt levels. Thus, in principle, one can distinguish the influence of changes in debt and deficits on interest rates. How close the relationship is in practice is considered in Section 4. It is clear that while changes in the interest rate may influence the change in debt by increasing interest payments, this link depends on how the increased interest payments are financed.

[3] It should be noted that the actual data used in this paper are for the total surplus, not the primary surplus.

The inter-temporal budget constraint requires that the market value of government debt is equal to the present discounted value of expected future primary surpluses. It is expectations that are crucial for solvency. Bohn (2007) argues that solvency cannot be inferred from the statistical properties of debt because the inter-temporal budget constraint and transversality condition impose little restriction on the time series properties of s_{it} or d_{it}. The reason for this is that the h-period-ahead conditional expectation of an mth-order integrated variable is at most an mth-order polynomial of the time horizon h. The discounting in the transversality condition is exponential in h. Exponential growth dominates polynomial growth of any order. Hence the discount factor $(1+r)^{-h}$ will asymptotically dominate $E_t(s_{t+i})$.

Higher debt could prompt higher nominal rates either through a higher risk premium, to compensate for the probability of default, or higher expected inflation. Budget deficits raise nominal demand and hence potentially raise inflation but need have little impact on default expectations since governments have the power to repay domestic debt through taxation or printing money. The level of domestic debt need have no impact on demand or expected inflation as long as taxes and debt interest balance. Higher debt may be a signal that the deficit can be safely bond financed and the government has no need to resort to inflationary money financing.

What is crucial for the risk premium is the lender's expectations about the credibility of the borrower's commitment to pay. Debt can grow rapidly as long as the lenders expect to be paid. From 1688 to 1815 successive wars caused British national debt to grow steadily from zero to over 200% of GDP. As discussed in Smith (2020), lenders were happy to acquire the debt and the debt could increase rapidly without large increases in interest rates, because Britain was a credible borrower even in wartime. However, if lenders believe that the government is following a time inconsistent policy, and may default on future payments, they will not acquire the debt without a risk premium to compensate for the probability of default. This has implications for estimation, since the effects of debt acquisition may be heterogeneous: the same increase in debt could have very different implications for interest rates for borrowers who differ in credibility.

Cochrane (2019) applies the present value decompositions from asset pricing to the present value equation for debt. He finds that about half of the variation in the market value of debt-GDP ratio corresponds to varying forecasts of future primary surpluses, and about half to varying discount rates, while variation in expected growth rates is unimportant. He also comments that war finance clearly has different roots than cyclical surpluses and deficits, and war debts are likely resolved in different ways from other deficits.

During the period considered here, wars are important. Grossman & Han (1993, 1999) provide a theory of war finance and sovereign debt. As emphasised above, the ability of a sovereign state to issue war debt depends critically on the lenders' expectations about the servicing of these debts. The lender faces two distinct risks. Firstly there is the danger that the borrower will default if defeated, the victor typically does not pay the debts of the vanquished. Secondly, even if it is not defeated, but suffers negative material consequences from the war, the borrower may not fully service their debt. Thus debt service is contingent on circumstances, a form of risk sharing between lender and borrower, which provides the borrower some insurance. They show that the two functions of war debt - inter-temporal consumption smoothing, through tax smoothing, and risk sharing - are complementary.

3 Estimators

The JST macrohistory dataset is a panel where both the cross section dimension, $i = 1, 2, ..., N$, and the time series dimension, $t = 1, 2, ..., T$, are quite large. Such panels present a range of choices about the treatment of: cross section dependence, dynamics and heterogeneity over units or time. Different treatments of heterogeneity correspond to different estimators and thus examining the sensitivity of results to the choice of estimator is an important robustness test.

Cross section dependence is modelled by using world averages, particularly of the long interest rate, for each year as explanatory variables.[4] The dynamics is modelled using an error correction model, ECM, type of autoregressive distributed lag, ARDL, model. ARDL estimates are robust to the orders of integration or cointegration of the variables and this is an important issue given the range of countries considered. In the baseline model, the change in long interest rates, Δr_{it} is explained by a set of explanatory variables, denoted $\mathbf{x}_{it}$, discussed in the next section, and the lagged change in interest rates since momentum effects might be important.

The estimators used differ in the degree of homogeneity imposed. The mean group, MG, estimator, Pesaran & Smith (1995), averages over the heterogeneous country specific coefficient estimates in

$$\Delta r_{it} = a_i + \mathbf{b}_i^{'} \Delta \mathbf{x}_{it} - \lambda_i (r_{i,t-1} - \boldsymbol{\theta}_i' \mathbf{x}_{i,t-1}) + \delta_i \Delta r_{i,t-1} + u_{1,it}, \qquad (3)$$

where λ_i are the adjustment coefficients and θ_i the long run effects. The non-parametric standard errors based on the country specific estimates of the coefficients are robust to serial correlation or heteroskedasticity in the individual equations. However, the MG estimators may be sensitive to outliers.

The pooled mean group, PMG, estimator, Pesaran, Shin & Smith (1999), has heterogeneous short run coefficients but homogeneous long run coefficients

$$\Delta r_{it} = a_i + \mathbf{b}_i^{'} \Delta \mathbf{x}_{it} - \lambda_i (r_{i,t-1} - \boldsymbol{\theta}' \mathbf{x}_{i,t-1}) + \delta_i \Delta r_{i,t-1} + u_{2,it}. \qquad (4)$$

This can allow for no long-run effect in some countries if $\lambda_i = 0$.

The one way fixed effects, FE1, estimator has homogeneous slopes but heterogeneous intercepts

$$\Delta r_{it} = a_i + \mathbf{b}^{'} \Delta \mathbf{x}_{it} - \lambda (r_{i,t-1} - \boldsymbol{\theta}' \mathbf{x}_{i,t-1}) + \delta \Delta r_{i,t-1} + u_{3,it}. \qquad (5)$$

[4] Cross section averages also filter out common factors as in the Pesaran (2006) correlated common effect estimator.

We will not use another possible estimator, the two way fixed effects, FE2, which adds a time effect, which can capture any flexible trend which has the same effect on each unit:

$$\Delta r_{it} = a_i + a_t + \mathbf{b}^{'} \Delta \widetilde{\mathbf{x}}_{it} - \lambda(r_{i,t-1} - \boldsymbol{\theta}' \widetilde{\mathbf{x}}_{i,t-1}) + \delta \Delta r_{i,t-1} + u_{4,it}, \quad (6)$$

where $\widetilde{\mathbf{x}}_{it} = (\pi_{it}, d_{it}, s_{it})'$ excludes the country invariant cross section means. Information criteria prefer FE1 including means, which can also be given a more interesting economic interpretation.

The PMG and FE may be subject to the heterogeneity bias discussed in Pesaran & Smith (1995) which would bias λ towards zero, slower adjustment. This bias does not decline with the sample size. The MG is not subject to this bias thus may be expected to show faster adjustment. Since T is quite large the Nickel (1980) small sample bias for the FE1 estimator, which works in the opposite direction to the heterogeneity bias, seems unlikely to be a problem. Heterogeneity over time will be allowed for by considering sub-periods.

4 Data

The dependent variable is the long interest rate, r_{it}. This is the rate at which governments are likely to borrow to finance their deficits and is more likely to be market determined than the short rate, which is a policy variable. A contractionary monetary and fiscal policy would involve a high short term policy interest rates, an increasing surplus and debt reductions. Conversely, expansionary policies would involve low policy rates, fiscal deficits and debt expansions.

In the light of the background discussion in section 2, the main independent variables are the inflation rate, π_{it}, the debt-GDP ratio, d_{it}, the government surplus as a share of GDP, s_{it}, and the world long interest rate, $\overline{r}_t$, calculated as the cross section mean over the sample for that year. This set constitutes the vector $\mathbf{x}_{it} = (\pi_{it}, d_{it}, s_{it}, \overline{r}_t)'$, used in section 3.

The data are taken from the JST macro history database, Jorda, Schularick and Taylor (2017). Jorda et al. (2019) provides further discussion of the rate of return data. JST provide data for 17 countries over the period 1870-2016. There are clearly issues with the measurement of economic variables over such a long span. For instance, there is considerable public accounting flexibility about the definition of the government net national debt and of the surplus/deficit. Boskin (2020, footnote 6) gives a range of reasons why official debt and deficit figures can give an inaccurate picture of governments liabilities. However, he uses the official figure for simplicity and comparability, as do we. The data are assembled from a wide variety of sources with different definitions of variables and countries vary because of boundary changes. However, JST is a carefully compiled database which has been widely used.[5] While the series may be noisy, there is a lot of variation, so the signal-noise ratio may be high.

The interest rate is on long term government bonds, with a maturity typically around 10 years, but sometimes longer like the British Consols which were

[5] There is detailed documentation of the sources at http://www.macrohistory.net/data/ .

perpetuals. From about 1950 the maturity is fairly accurately defined at about 10 years. If r_{it} is the yield on bonds and the rate of CPI inflation is

$$\pi_{it} = 100 * \Delta \ln CPI_{it},$$

then the *ex post* real long rate is calculated as

$$rr_{it} = 100 * \{(1 + r_{it}/100)/(1 + \Delta \ln CPI_{it}) - 1\}.$$

Table 1 shows descriptive statistics for the variables. The number of observations is not the same for all variables and there is a sample selection issue, since the data tend to be missing at times of crisis. For some variables the cross section means, calculated from available data for that year, are also shown. Since there is some missing data, the mean of the cross-section means is not the same as the mean of the variable. The table gives values for the long interest rate, r_{it}, its mean, $\overline{r}_t$, the short rate rs_{it}, the rate of inflation, π_{it}, its mean, $\overline{\pi}_t$, the real long interest rate, rr_{it}, its mean, $\overline{rr}_t$ the debt-GDP ratio, d_{it}, its change, Δd_{it} and the surplus-GDP ratio, s_{it}. All are in percent. For the variables, other than Δd_{it}, one generally cannot reject a unit root, not surprisingly given the big breaks in the data. For instance, in the case of long interest rates, regressing the change on a constant, lagged level and lagged change, the only country to reject a unit root at the 5% level is Portugal where rejection probably comes from a number of bouts of high interest rates with return to low rates, creating an impression of mean reversion.

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Table 1. Descriptive statistics, percentages .

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%	Mean	SD	Min	Max
r_{it}	5.53	3.06	-0.14	23.72
$\overline{r}_t$	5.52	2.26	1.00	13.39
rs_{it}	4.80	3.23	-2.00	21.27
π_{it}	4.72	43.32	-47.28	2077.88
$\overline{\pi}_t$	4.72	11.57	-6.88	125.46
rr_{it}	2.40	7.12	-69.26	55.03
$\overline{rr}_t$	2.35	4.58	-17.94	15.59
d_{it}	53.45	39.12	1.90	269.80
Δd_{it}	0.30	6.57	-57.31	70.59
s_{it}	-1.86	5.28	-75.17	20.08

Not only does the debt-GDP ratio vary widely, so does its change, reflecting the exogenous crises that drive its variation. Five percent of the changes are greater than 9.3 percentage points and five percent below -7.3.

The descriptive statistics raise an important issue. The estimates of the *ex post* real rate are very sensitive to the fat tails of the inflation distribution. Inflation ranges between -50% and +2000% and the real rate between -70% and +55%, despite the fact that at times of very high inflation there was often no long rate quoted, so no real rate included in this sample. What matters for the nominal rate on long term bonds is the ex ante real rate based on expected inflation. Inflation shocks, positive or negative, generate large unexpected windfall gains and losses. They must be unexpected since everyone would invest if they expected a real gain of 55% and nobody would invest if they expected a real loss of 70%, which are the minimum and maximum of the observed real rate.

Given the fat tails in the estimated real rate, the analysis will be conducted using the nominal rather than the real long rate as the dependent variable. The interpretation for this is that the explanatory variables, including current inflation, world interest rates and lagged interest rates, are providing information about future longer term inflation. Consider a model for the long interest rate, where expected inflation over the h year life of the bond, $E(\pi_{i,t+h} \mid z_{it})$, is conditional on information at time t, z_t, which includes the variables that also determine the real rate:

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\begin{aligned}
r_{it} &= E(\pi_{i,t+h} \mid z_{it}) + \beta' z_{it} + \varepsilon_{it}, \\
E(\pi_{i,t+h} &\mid z_{it}) = \phi z_{it}, \\
r_{it} &= (\phi + \beta)' z_{it} + \varepsilon_{it}.
\end{aligned}
$$

The coefficient of debt, in this interpretation, picks up both the direct effect of debt increases on the nominal rate, through the real risk premium required to persuade lenders to hold more debt, and the indirect effect of the debt increase on expected inflation. The nominal equation with inflation included as an explanatory variable could be regarded as the real equation removing the restriction of a minus one coefficient on current inflation, or equivalently relaxing the strong assumption that $E(\pi_{i,t+h} \mid z_{it}) = \pi_{it}$.

There will inevitably be considerable uncertainty about how inflation expectations are formed over such a long period, which includes quite different regimes. Over parts of this period, certainly during the gold standard regime, inflation was not persistent but dominated by transitory noise, so the current inflation rate was a very poor indicator of future inflation. Thus one would not expect expected inflation or nominal interest rates to respond to current inflation. Alogoskoufis & Smith (1991) examine the persistence of inflation under the different exchange rate regimes using a similar span of data.

To clarify the role of global interest rates, consider the extent to which nominal long interest rates moved together over this period. Some data are missing and only 11 countries had data on long interest rates for the whole 147 years.[6] For these 11 countries 80% of the variance of the nominal long rate is explained by the first principal component. This is close to the mean, giving almost identical weights, around 0.32, to interest rates in all countries except for Japan 0.13 and Portugal 0.23. All the correlations are positive, the mean of the 55 correlations is 0.75 the median 0.87. Of the 11 correlations less than 0.5, 10 are with Japan, the other between the UK and Portugal is 0.498. Thus

[6] These are Australia, Canada, Denmark, France, Great Britain, Italy, Japan, Netherlands, Portugal, Sweden and USA. The other countries are Belgium, Finland, Germany, Norway, Spain, Switzerland.

it seems plausible that a world interest rate drives the rates of the individual countries. For estimation, the world interest rate for each year is estimated as the unweighted average over all the countries that have data for that year. In the early part of the period the UK rate was central, in the later part the US rate, but since they all move closely together the world rate seems a safe choice.

To examine the relationship between the country specific interest rates and the global average,. the change in the long interest rate, Δr_{it}, was regressed on the change in the average, $\Delta \overline{r}_t$ its lag $\overline{r}_{t-1}$,, the lagged interest rate, $r_{i,t-1}$, and the lagged change, $\Delta r_{i,t-1}$. The mean group estimates were:

$$\begin{array}{rccccc} \Delta r_{it} = & -0.000 & +0.9674 & \Delta \overline{r}_t & +0.133 & \overline{r}_{t-1} \\ & (0.052) & (0.057) & & (0.022) & \\ & -0.133 & r_{i,t-1} & +0.055 & \Delta r_{i,t-1} & +u_{it} \\ & (0.022) & & (0.034) & & \end{array}$$

Both the average short run effect and the average long run effect are very close to one. The average standard error of regression is 0.69, just over half a percentage point. There is strong evidence for a short run effect of the world interest rate in every country. The change in the global average interest rate was always very significant, with the smallest t ratio being 5.59 and 10 of the 17 having t ratios over 10. The evidence for a long run relationship in every country is weaker. The Pesaran, Shin and Smith (2001) bounds test with unrestricted intercept, no trend, and one independent variable, rejected the null of no long run relationship at the 5% level, using the I(1) critical values, in 8 countries and using the I(0) critical value in 3 more countries. The countries where the convergence to the world interest rate was not significant were a motley group: Denmark, Finland, Spain, Switzerland, the UK and the US.

Above it was noted that, in principle, deficits and the change in debt are distinct. To examine how distinct they are in practice, a simple fixed effects regression was estimated explaining the change in the debt-GDP ratio by the surplus as a share of GDP. Both are proportions, standard error in parentheses. Although they are significantly related, only about half the surplus is reflected in the change in debt and the R^2 is small.

$$\begin{array}{rccccrl} \Delta d_t = & \alpha_i & -0.504 & s_t & +\widehat{u}_{it} & R^2 = & 0.122 \\ & & (0.029) & & & SER = & 0.061 \end{array}.$$

Adding two lags of surplus only increases the R^2 to 0.135. This indicates that there is potentially enough independent variation in the surplus and the change in debt to separately measure their effects.

5 Empirical results

The baseline model makes the long interest rate, r_{it} a first order ECM function of the inflation rate, π_{it}, the debt-GDP ratio, d_{it}, the government surplus/deficit as a share of GDP, s_{it}, the world long interest rate, $\overline{r}_t$, calculated as the cross section mean over the sample for that year and the lagged change in interest rates. Table 2 gives the results for the MG, PMG and FE1 estimators. The standard errors on FE1 tend to be smaller, as one would expect, but this does not generally change the judgements on significance, which are similar for the three estimators. The change in inflation is always significant at the 5% level, but with very small coefficients that are far from unity. The change in debt-GDP ratio and change in world interest rate are always significant with coefficients around one. The lagged dependent variable is always very significant and the speed of adjustment is, as one would expect from the heterogeneity bias, fastest for the MG slowest for FE1. The change in surplus is never significant and the lagged change in the interest rate is significant only for FE1.

The long-run effect of the world interest rate on national interest rates is always very significant with a coefficient around one. The estimated long run effect of debt is negative, but is never significant. The result can be interpreted as indicating that there is no equilibrium level of the debt-GDP ratio. This is consistent with the large variety of debt-GDP ratios observed in the data and with the observation that very different levels of debt-GDP are consistent with similar interest rates. The long-run effect of surplus is never significant and the long-run effect of inflation is significant only for FE1, again with a small coefficient. The FE1 with mean interest rates seems to remove a lot of the cross section dependence. Both Akaike and Schwarz information criteria prefer the FE1 with average interest rates to a FE2 with time effects. The Pesaran CD test for no cross-section dependence based on the correlations in the FE1 was -1.83, p=0.0668, though the bias corrected scaled LM test based on the squared correlations rejects, see Pesaran (2015).

The interest rate is in percent, with a mean of 5.5%, the debt-GDP ratio is a proportion, with a mean of 0.53. Thus the unit coefficient on the change in debt indicates that a one percentage point, pp, increase in the debt-GDP ratio will cause a 0.01 change in the interest rate, one basis point, bps. This is of the same order of magnitude, though at the low end, of the estimates, 1-6bps with an average of 3.5bps, given in table 2 of Rachel and Summers (2019). The estimates in Table 2 suggest that it is the change in debt that matters, not the deficit or the level of debt.[7]

[7] Dropping the change and lagged surplus from the equation had relatively little effect and the coefficient (standard error) of the change in debt was 0.627 (0.226) and the long run effect -0.676 (0.431).

Table 2. Dependent variable: change in long rates, coefficients and (standard errors); alternative estimators.

	MG	PMG	FE1
Short run: $\boldsymbol{b}$			
$\Delta\pi_{it}$	0.010	0.008	0.009
	(0.004)	(0.0002)	(0.002)
Δd_{it}	1.030	0.863	0.698
	(0.387)	(0.339)	(0.256)
Δs_{it}	1.424	1.189	1.254
	(1.033)	(0.881)	(0.641)
$\Delta\overline{r}_t$	0.946	0.823	0.945
	(0.053)	(0.055)	(0.030)
$\Delta r_{i,t-1}$	0.047	0.035	0.055
	(0.037)	(0.034)	(0.018)
Adjustment: $-\lambda$			
$r_{i,t-1}$	-0.176	-0.117	-0.106
	(0.014)	(0.015)	(-0.009)
Long run: $\boldsymbol{\theta}$			
π_{it}	0.016	0.018	0.053
	(0.020)	(0.013)	(0.022)
d_{it}	-0.475	-0.011	-0.723
	(0.715)	(0.285)	(0.449)
s_{it}	3.938	-0.100	2.573
	(5.281)	(2.259)	(3.816)
$\overline{r}_t$	0.951	1.107	0.922
	(0.104)	(0.036)	(0.063)
N Obs	2207	2207	2207

A range of robustness tests were carried out using the FE1 estimator. Changes and lagged levels of world averages of inflation and debt were also included but were not significant,[8] nor were changes and lags of log per capita GDP and log population. Since the very small coefficient on inflation might reflect the thick tails of its empirical distribution, the equation was re-estimated by fixed effects using just the 2157 observations where inflation lay within $\pm 20\%$. The estimate (standard error) of its short run effect was 0.013 (0.003) and its long run effect 0.093 (0.032); still very small. There is no indication of asymmetric effects of debt changes. When a dummy for debt increasing and its interaction with the change in debt-GDP ratio was included they were not individually or jointly (p=0.237) significant.

The results are not robust to treating these countries as closed economies and excluding world interest rates. When the change and lagged level of world interest rates are removed from the FE1 model, the R^2 for the equation ex-

[8] Because the panel is unbalanced and debt levels differ a lot over countries, it could be that adding another country to the average could distort the results. However results using average debt of the 8 countries for which there was continuous data gave similar results,

plaining the change in interest rates falls massively from 0.388 to 0.081. The short run coefficient of debt (standard error) falls from a significant positive effect, 0.698 (0.256), to an insignificant one, 0.031 (0.312); while the long-run effect of debt goes from being insignificantly negative, -0.724 (0.449), to being significantly so, -5.005 (0.986). Not only would one want to include world rates on theoretical and empirical grounds, but excluding it produces the very implausible result that in the long run increased debt levels are associated with lower national interest rates. The change in coefficient implies that they are also associated with lower world interest rates.

Returning to the main model, the evidence for the influence of world interest rates on individual countries is very strong. The effect of the change in average rate is significantly positive in every country, while the lagged average rate was positive in every country and significant in all but Finland, Japan, and the UK. The coefficient of the lagged dependent variable was significant, using standard critical values, in all but Finland. For the other variables the evidence is less clear. The change in inflation was significant only in Norway and Portugal, lagged inflation was never significant. The effect of the change in debt-GDP was positive and significant in Spain. Lagged debt was positive and significant in Belgium and Portugal, negative and significant in Denmark, Switzerland, Japan and Australia. Thus a lot of the evidence on the effect of the change in debt comes from pooling the countries. The change in surplus was positive and significant in Canada, lagged surplus was positive and significant in Denmark and Canada negative and significant in France. The lagged change in interest rates was significantly positive in four countries, significantly negative in two.

The R^2 for the FE1 is 0.388, which seems a reasonable fit for explaining changes in interest rates over such a long span, heterogeneous panel. Although the estimates of the less well determined coefficients are quite dispersed, the heterogeneity across countries does not cause a large reduction in fit. The FE1, with 27 parameters, has a standard error of 0.6860, compared with 0.6195 for the heterogeneous estimator with 187 parameters. For FE1, the hypothesis that all the intercepts are equal give a F(16,2180) statistic of 1.68 which only just rejects homogeneity at the 5% level, though the statistic may not be reliable given differing variances across countries and some remaining cross-section dependence. The mean group estimate of the adjustment coefficient is very tightly estimated at 0.18 with a standard error of 0.01 and this standard error is robust to serial correlation or heteroskedasticity of the individual country specific equations. The mean group estimator can be sensitive to outliers, but this does not seem to be the case here since the range of the coefficient on the lagged dependent variable is -0.10 to -0.29.

To examine stability over time, the model was estimated on three subsamples: the gold standard, 1870-1913, the turbulent years, 1914-1946, and post World War II, 1947-2016. Given that the differences between the three estimators in Table 2 are not large and to conserve degrees of freedom, the fixed effect estimator is used. The FE1 estimates of the coefficients are given in Table 3 and, in contrast to Table 2, the coefficients of the lagged variables rather than the long run effects are reported.

Table 3. Dependent variable: change in long rates, coefficients (and standard errors); FE1 estimates by sub-period.

	1872-2016	1872-1913	1914-1946	1947-2016
$\Delta\pi_{it}$	0.009	0.011	0.001	0.041
	(0.002)	(0.004)	(0.003)	(0.007)
Δd_{it}	0.698	1.345	0.110	2.004
	(0.256)	(0.432)	(0.321)	(0.626)
Δs_{it}	1.254	-3.569	-0.508	2.986
	(0.641)	(2.464)	(0.856)	(1.286)
$\Delta\overline{r}_{it}$	0.945	0.539	1.074	0.924
	(0.030)	(0.098)	(0.096)	(0.037)
$r_{i,t-1}$	-0.106	-0.148	-0.281	-0.110
	(0.009)	(0.016)	(0.035)	(0.013)
$\pi_{i,t-1}$	0.006	0.007	0.001	0.030
	(0.002)	(0.006)	(0.003)	(0.006)
$d_{i,t-1}$	-0.077	-0.093	0.104	-0.032
	(0.047)	(0.172)	(0.146)	(0.082)
$s_{i,t-1}$	0.273	-4.666	-1.086	0.852
	(0.405)	(2.380)	(0.616)	(0.855)
$\overline{r}_{i,t-1}$	0.098	0.038	0.312	0.089
	(0.011)	(0.032)	(0.058)	(0.015)
$\Delta r_{i,t-1}$	0.055	0.288	0.070	0.019
	(0.018)	(0.035)	(0.044)	(0.024)
R^2	0.388	0.343	0.332	0.454
SER	0.681	0.419	0.655	0.774
SSR	1024	99	185	679
MLL	-2285	-310	-443	-1335
N Obs	2207	588	459	1160
AIC	2.095	1.14	2.05	2.35
BIC	2.165	1.34	2.29	2.47

The change in the world interest rate is highly significant in all three periods. The lagged world rate is significant in the second and third periods, when its long run coefficient is again close to one. Consistent with the idea that globalisation has increased over time, the effect of the change in the world interest rate is much smaller in the first period and the lagged level is not significant. Both the change and level of the world interest rate are significant in the middle period despite the obstacles to capital mobility. Lagged national interest rates are always significant. The effect of the other variables is not so clear cut.

The change in inflation is significant in the first and third periods, though with very small coefficients. The change in debt-GDP is significant in the first and third periods. The change in surplus is significant in the third period, though with a positive sign, which is not what one would expect. Both the change and level of the surplus have negative effects in the first two periods though they are not significant. Lagged debt-GDP and lagged surplus are never significant,

The total standard error for the three periods is 0.674 compared to 0.681 for the pooled. Although the difference in the coefficients appears to be statistically significant F(54,2123)=2.40, the variances of the three periods are not the same, which is required for the parameter equality test. The standard errors of regression go from 42 basis points in the first period to 77 in the last.

Despite being estimated over a very long sample, the whole sample FE1 fits recent years reasonably well, despite the crisis. The average FE1 residual for the 17 countries over the 11 years 2006-2016 was 0.006, so there is no obvious bias. The standard deviation was 0.593, which is less than the standard error of regression of 0.681. The large residuals reflected the euro-zone crisis. In 2011, the predicted interest rate for Portugal was 5.6% the actual was 10.2%. This was the largest positive error in the sample. The largest negative error was also for Portugal in 2013, -3.18, interest rates came down faster than the model predicted. Italy and Spain also had large positive residuals during the crisis.

6 Conclusion

Estimates from the Jorda-Shularick-Taylor macrohistory database, for 17 countries over 1870-2016, indicate that the dominant influence on national long interest rates is world interest rates. This is in accord with the recent literature which has emphasised the importance of global forces such as Del Negro et al. (2018), Jorda & Taylor (2019) and Rachel & Summers (2019). While they emphasise the recent importance of the global dimension and the financial integration of the advanced economies, the results in this paper indicate that, as economic historians have long emphasised, global financial interactions are a long-standing feature of the international economy.

The change in the debt-GDP ratio has a significant positive effect on the nominal long interest rate. A one percentage point increase in the debt-GDP ratio causes approximately a one basis point increase in interest rates, an effect of the same order of magnitude as that reported by Rachel & Summers (2019). The level of debt is not significant, which is consistent with the fact that countries with very different debt-GDP ratios face very similar interest rates and the surplus/deficit does not seem to matter either for long interest rates. While significant, the coefficient of the change in debt in the interest rate equation is not very large, perhaps because it does not capture a pure ceteris paribus effect. Instead it captures the joint effect of what tends to happen at the same time as large changes in debt which are likely to include changes in private borrowing and saving.

The effect of inflation on interest rates was small, probably because inflation expectations were not very sensitive to current national inflation over much of the sample and global inflation is embodied in the world interest rate. The long interest rate equation seemed reasonably stable over time and there was not much heterogeneity over countries. The results for long interest rates seem to support the idea that averaging both over countries and over a long span of data can increase the precision of the estimates and reduce the effect of confounding influences.

A policy implication is that the large increases in debt-GDP ratios caused by the 2020 pandemic may not increase interest rates very much.

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