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Long-run perspectives on $r - g$ in OECD countries: An empirical analysis

Freddy Heylen [a,*], Marthe Mareels [a], Christophe Van Langenhove [a,b]

[a] Department of Economics, Ghent University, Sint-Pietersplein 6, Ghent, Belgium
[b] Research Foundation Flanders

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The difference between the implicit nominal interest rate and the growth rate of nominal GDP is a key determinant of the dynamics and the sustainability of public debt. This paper studies the determinants of $r - g$ in a panel of 17 OECD countries since the early 1980s. Whereas the focus of existing empirical studies is mainly on fiscal, monetary and financial factors behind the interest–growth difference, our approach and contribution are to highlight in particular the role of real long-run determinants, such as technical progress, employment growth, demographic change, and income inequality. This allows us to derive empirically based projections for $r - g$ beyond the next five or ten years. Our baseline expectation is that $r - g$ will stay below zero for the next two decades in most European countries that we study. An important policy implication is that the debt-carrying capacity of governments is substantially higher now than in the 1980s or 1990s. For the United States, however, our baseline projection of $r - g$ is positive.

1. Introduction

The difference between the implicit nominal interest rate and the growth rate of nominal GDP is a key determinant of the dynamics and the sustainability of public debt. The relevant nominal interest rate is a weighted average of the market rates that the government had to pay when borrowing in the past. It is calculated as total interest payments by the government in a particular year divided by outstanding public debt in the previous year. As shown by Fig. 1, while the implicit interest – growth difference was positive in the OECD most of the time in 1981–2014, it turned negative in 2015. The covid-19 recession interrupted the negative series for $r - g$ in 2020, but the broad consensus was that the recovery from this recession would make that interruption only short-lived. The data for 2021–22 confirmed that position. In all four country groups in Fig. 1, $r - g$ returned to clearly negative territory. For governments, this was of major importance. If structural, a negative $r - g$ allows governments to gradually reduce their debt in percent of GDP without having to run primary surpluses. Even with a primary deficit, debt will not explode.[1] It will be sustainable, at least if it can be assumed that the primary deficit and the level of debt have no dramatic effect on the interest rate due to crowding out effects or rising sovereign risk premia. In times of a high need for public investment, this would offer a unique opportunity.

* Corresponding author at: Department of Economics, Ghent University, Sint-Pietersplein 6, 9000 Ghent, Belgium.
E-mail addresses: Freddy.Heylen@UGent.be (F. Heylen), Marthe.Mareels@UGent.be (M. Mareels), Christophe.VanLangenhove@UGent.be (C. Van Langenhove).

[1] See for example Blanchard (2019, 2023). Assuming a constant primary deficit $\overline{d}$, and given interest and growth rates, it can be shown that the debt ratio will converge to a sustainable finite value equal to $\frac{\overline{d}(1+g)}{(g-r)}$.

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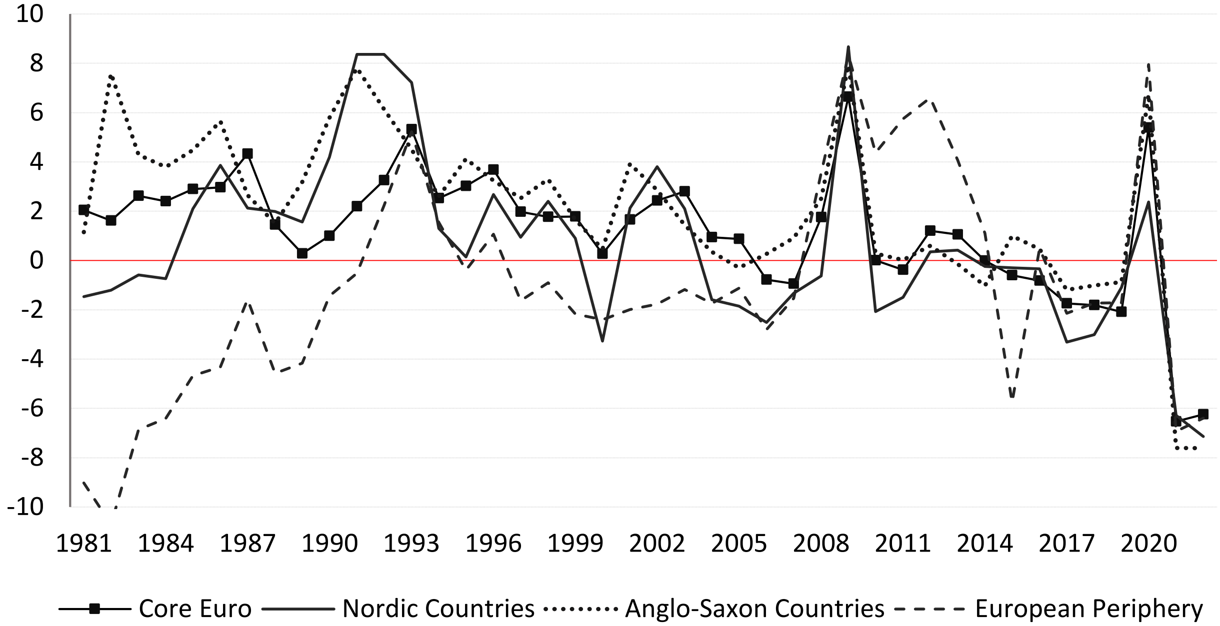

Fig. 1. Interest–growth difference in 4 country groups (1981–2022, in percentage points). Sources: OECD, IMF. Details on the construction and the sources of these variables are reported in online Appendix 1. Note: The reported series are unweighted averages for the countries included in each group. The Core euro group contains Austria, Belgium, France, Germany and the Netherlands. The Nordic group includes Denmark, Finland, Norway and Sweden. The included Anglo-Saxon countries are Canada, the United Kingdom and the United States. The European Periphery group contains Greece, Ireland, Italy, Portugal and Spain.

Russia's invasion of Ukraine, however, dramatically changed that picture. It slowed the recovery from the covid-19 recession and induced sharp food and energy price increases, pushing inflation in many countries to levels not seen since the 1970s. To fight inflation, many central banks aggressively changed course. In addition to (announcing) a reduction of their balance sheets, they raised their policy rates several times in 2022 and 2023. Both interventions pushed long-term interest rates to the highest level in a decade and further slowed economic growth. Add to this the negative impact of the new situation on governments' primary balances, for example due to rising expenditures on defence and in support of households during the energy crisis. It could drive interest rates even higher. The obvious question followed whether the years of negative $r - g$ and related fiscal comfort were over.

Given that most of the action came via interest rate changes, we may be guided by existing work on the natural interest rate r^*. That is the real rate that is consistent with output at its potential level and constant inflation. The literature generally reveals a downward trend in r^* since the 1980s, to bottom low levels in the most recent years (e.g. Holston et al., 2017; Andrade et al., 2021; Gagnon et al., 2021). If it can be assumed that the underlying drivers of r^*, such as the rate of technical progress, time preference and demographic tendencies are not fundamentally affected, low interest rates could persist. This is also the baseline expectation in recent work on r^* by authors from the IMF (2023a). They conclude that once the current inflationary episode has passed, interest rates in advanced economies are likely to revert toward pre-pandemic levels. A disadvantage, however, is that estimates of the natural interest rate are generally based on structural theoretical models and their assumptions, and not estimated freely.

Our main objective in this paper is empirical, with a direct focus on $r - g$. More precisely, we explain the gap between the implicit interest rate on public debt and the growth rate of GDP in a panel of 17 OECD countries in 1981–2018. Although we will also control for a set of short-run and nominal determinants and unobserved common factors, the specification of our empirical model is inspired mainly by theory on the real long-run drivers of the interest rate and the economic growth rate. This long-run perspective allows us, as a second objective, to make projections for $r - g$ in the next two decades. In these projections we account for the mutual influence between the level of public debt and the interest rate, and thus the risk of so-called snowball mechanisms. We also incorporate the rise of inflation and the aggressive monetary tightening in many countries in 2022–2023.

Our paper contributes to two strands of recent literature. First, several other studies have recently analyzed the difference between the implicit nominal interest rate on public debt and nominal GDP growth for varying samples of countries, e.g. Turner and Spinelli (2011) and Heimberger (2023) for OECD countries, Escolano et al. (2017) and Mauro and Zhou (2021) for advanced and emerging economies, and Checherita-Westphal and Domingues Semeano (2020) for euro area countries. Whereas the focus of these papers is mainly on fiscal, monetary and financial factors behind the interest–growth gap, our approach and contribution are to highlight in particular the impact of real long-run variables, such as technical progress, different components of demographic change (including the growth of labour supply) and income inequality. This also allows us to derive empirically based projections for $r - g$ beyond the next five or ten years. Second, our paper's results are relevant for the discussion on public debt sustainability and on fiscal rules as currently going on in Europe (see e.g. Mauro and Zhou, 2021; Blanchard et al., 2021; IMF, 2021; ESM, 2021). The strong increase of public debt during the covid-19 crisis, the tightening of monetary policies to fight inflation, and the added pressure on government balances following rising geopolitical tensions since 2022 have set off alarm bells among many policy makers and observers. Projections for $r-g$ are key to determine the primary balance required for the achievement of 'optimal' public debt targets and sustainability.

Anticipating on our main results, we find that the major shocks that hit many economies in 2022–2023 have not fundamentally changed the game. Although it is subject to substantial uncertainty, our baseline expectation is that the structural determinants of $r-g$ related to demography, technical progress, employment growth, and inequality, will keep the interest–growth difference below zero for the next two decades in most European countries that we study. In that spirit, our results offer support to the basic position taken recently by for example Blanchard (2023), IMF (2023a) and The Economist (2022a), at least when it comes to Europe. The United States are a major exception to our main findings. For this country our baseline projection of $r-g$ until 2040 is positive. Our finding that $r-g$ may remain negative in the next decades in many countries supports the argument that the debt-carrying capability of governments is structurally higher now than in the past.

The remainder of this paper is organized as follows. Section 2 surveys the literature on the determinants of $r-g$. Section 3 presents our empirical approach and results. Section 4 contains our projections for $r-g$ in the next two decades. Section 5 summarizes our main findings and raises some policy implications.

2. Determinants of r and $r-g$: Review of the literature

We first discuss the impact of structural determinants suggested by long-run growth theory. We focus on the role of technical progress, demography (including labour supply), inequality, and fiscal policy and public debt. Then, we address the effect of a set of additional variables of a more short-term nature: monetary policy, inflation, and specific crises.

2.1. Long-run determinants

In standard growth theory a higher *rate of technical progress* consistently implies a higher long-run economic growth rate and a higher real interest rate. Its theoretical impact on $r-g$ is therefore ambiguous.

As an illustration, consider the benchmark neoclassical model of Mankiw et al. (1992). In steady state equilibrium, aggregate economic growth in this model is equal to $n+x$, with n the (employed) population growth rate and x the rate of technical progress. An increase in the rate of technical progress has a one-to-one positive effect on equilibrium growth. Given the assumption of perfect competition and absence of uncertainty or frictions, the equilibrium real interest rate in the model will be equal to the marginal product of capital (*MPK*), net of depreciation. Mankiw et al. show that $MPK = \frac{\alpha(n+x+\delta)}{s_k}$, with n and x as defined before, α the capital share in output, δ the capital depreciation rate, and s_k the fraction of output invested in physical capital. All these determinants are taken exogenous in their model. The positive effect of faster technical progress on the interest rate is then easy to see. Its effect on the interest – growth difference, however, is ambiguous. Whether $r-g$ rises or falls in x depends on whether $\frac{\alpha}{s_k}$ is greater or smaller than 1, at least in a 'perfect' world. The more market imperfections and risk disturb the close relationship between *MPK* and r, as shown by Mankiw (2022), the more likely it is that $r-g$ falls in x.

Another benchmark macroeconomic model, the infinite-horizon representative agent model pioneered by Ramsey (1928) and embedded in growth theory by Cass (1965) and Koopmans (1965), generates the same prediction for real GDP growth in equilibrium. In the Ramsey-Cass-Koopmans model it is also equal to $n+x$. The determinants of the interest rate depend on assumptions regarding the characteristics and the objective function of households. Heijdra (2017) assumes households that consist of infinitely-lived individuals and that optimize the intertemporal utility of their representative member. The Euler equation in the model then pins down the equilibrium real interest rate as $r = \rho + n + \theta x$, with ρ the rate of time preference, θ the inverse of the intertemporal elasticity of substitution, and x and n as defined before. An increase in technical progress raises households' future income. Since they want to smooth consumption over time, they will save less (borrow more) now, which implies a higher equilibrium interest rate.[2] Again, it thus occurs that faster technical progress raises both the economic growth rate and the interest rate. Its effect on $r-g$ is again ambiguous. Under the above assumptions of the Ramsey-Cass-Koopmans model it depends on whether θ is greater or smaller than 1. With log utility and θ tending to 1, there is no effect on $r-g$ in this model.

When it comes to the data, a change in the rate of technical progress (TFP growth) will have a direct one-to-one long-run effect on productivity and output growth, everything else equal. Its influence on the real interest rate, however, is an issue of debate. Eggertsson et al., (2019,p. 38) and Rachel and Summers (2019, p. 42) suggest a more than proportional reaction of the real interest rate to changes in productivity growth. Rachel and Smith (2017, p. 14) rather assume a one-to-one relationship. Lunsford (2017) and Lunsford and West (2019) by contrast find no positive correlation between productivity growth and the real interest rate in the US. Hamilton et al. (2016) arrive at a similar conclusion. They call themselves skeptical of analysis that puts productivity growth at the centre of real interest rate determination. If they are right, one would expect the relationship between changes in technical progress (TFP growth) and $r-g$ to be negative. In a direct empirical test of this relationship in the euro area countries since 1985, Checherita-Westphal and Domingues Semeano (2020) confirm this negative relationship.

[2] The higher θ, the greater the households' preference for smooth consumption. The negative impact of a rise in x on savings will then be stronger. So will be its positive impact on r. Other models with optimizing individuals come to the same conclusion that faster technical progress would raise the interest rate because individuals save less. Eggertsson et al. (2019) for example find this in an overlapping generations model.

A huge literature has investigated the impact of demography and *demographic change (ageing)* on economic growth and the real interest rate. Most of the research focuses on changes in four variables: the growth rate of population, the fraction of dependent older people, the fraction of dependent young people, and life expectancy.

The impact of *population growth* is strongly in line with that of technical progress, as discussed above, at least if it can be assumed that population growth will subsequently continue in employment. A rise in n directly affects the growth rate of GDP, and may thus reduce $r-g$. On the other hand, a higher (employed) population growth rate may also raise the interest rate. First, it increases the marginal product of capital. Second, at least in the specification of the Ramsey-Cass-Koopmans model described above, a higher population growth rate makes individuals save less. The reason is that in a growing household the individual return from savings will be lower since it will have to be shared with more family members in the future. Lower savings would imply a rise in the interest rate.[3] Combining both results, the theoretical effect from changes in population growth n on $r-g$ is again ambiguous. Unless n has a very strong impact on the marginal product of capital and the interest rate, one should expect this impact between −1 and 0. In the context of demographic change, falling population growth would then imply higher $r-g$ and bad news for the dynamics of public debt. Policies to enhance labour market participation and employment would reduce $r-g$.

Two developments explain a rapidly *rising old age dependency rate* (fraction of retirees in population). The first is the gradual *retirement of the large baby boom generation*, which implies growing numbers of new retirees. The second is *increasing life expectancy*, allowing those retirees to enjoy more years in retirement. Theoretically, these two elements will mainly affect the interest–growth difference via their impact on savings.[4] On the one hand, because retirees save less than workers, a change in the composition of population towards more retirees should imply lower aggregate savings and higher interest rates. On the other hand, the expectation to live longer requires all individuals to collect more resources for future consumption. Along this channel, ageing may imply higher aggregate savings and lower interest rates. Li et al. (2007) confirm these two theoretical channels in panel data regressions for 149 countries in 1963–2003. As to their net effect, existing studies are fairly concordant in their conclusion that the second effect with lower interest rates dominates. Krueger and Ludwig (2007), Attanasio et al. (2016), Marchiori et al. (2017) and Gagnon et al. (2021), among others, obtain this conclusion from simulating demographic change in calibrated overlapping generations models for different (groups of) countries. Carvalho et al. (2016) find the same result in a calibrated life-cycle model. In general, all these models replicate a significant fraction of the drop in the real interest rate during the last decades. Interestingly, they also find very low real interest rates to persist for at least one or two more decades. Aksoy et al. (2019) find a net negative effect of growing fractions of people older than 60 on the interest rate in an estimated panel VAR model for 21 OECD countries in 1970–2014. Last, in their analysis of $r-g$ in the euro area, Checherita-Westphal and Domingues Semeano (2020) also report a negative effect from the old-age dependency ratio. The fact that neither Aksoy et al. (2019) nor Checherita-Westphal and Domingues Semeano (2020) control for increasing life expectancy may rationalize this negative effect.

Increased life expectancy may also imply that the standard distinction in traditional life-cycle theory between working and retired individuals (savers and dissavers) has become too simple. The perspective of a long life may motivate young retirees to continue saving. Studying a time series of four cross-sections of households in Finland, Kankaanranta (2019), for example, finds evidence supporting this hypothesis. Net household worth continues to increase in the years after retirement. Jappelli (1999) found the same result for college-educated Italian households. So did more recently the Minneapolis Fed's Opportunity & Inclusive Growth Institute (see Horwich, 2022). In our empirical specifications we will therefore distinguish 'young' and 'old' retirees in percent of total population.

A fourth demographic variable is the *youth dependency rate*, the fraction of children in total population. Since these are consumers without earned income, one would expect a higher youth dependency rate to imply a lower aggregate savings rate, a higher interest rate and a higher $r-g$. Li et al., (2007, footnote 12), however, find no significant effect on savings. Referring to other empirical studies on the effect of youth dependency, they conclude that there is no consensus, and results are typically not robust.

Changes in *income inequality* are expected to affect $r-g$ via both terms of the difference. The literature is fairly unanimous that a more unequal distribution raises aggregate savings, and hence brings a lower interest rate, because the rich save more (Carroll, 1998; Dynan et al., 2004; Eggertsson et al., 2019). Using this result, Rachel and Smith (2017) and Rachel and Summers (2019), among others, put forward rising income inequality as one of the drivers of declining real interest rates during the last decades. It is not the main factor, but may yet have contributed to an interest rate decline of about 0.5 percentage points. Eggertsson et al. (2019) report the same decline as result of a falling labour share in income.

The effect of income inequality on growth is subject of more controversy. OECD (2015) reviews the theoretical and empirical literature. In theory, higher inequality may promote growth when the possibility to obtain higher rewards fosters incentives to work, invest and undertake risks. On the other hand, it may reduce growth when it inhibits poor individuals to invest in human capital, or when it is a source of political instability or social unrest. Recent empirical work tends to converge on finding a net negative effect from inequality on the long-run growth rate (e.g., OECD, 2015; Berg et al., 2018). For our purpose, combining the empirical effects from rising inequality on both r and g would leave us with ambiguous expectations regarding its effect on $r-g$. We know of no study having investigated this.

[3] Note, however, that a different setup of the Ramsey-Cass-Koopmans model may eliminate the impact of n on the equilibrium interest rate. Barro and Sala-i-Martin (2004) for example assume individuals with finite life belonging to (growing) immortal families. These families optimize the overall utility from consumption of the group, i.e. utility accumulated over all family members. The equilibrium interest then equals $r = \rho + \theta x$.

[4] An effect on growth may follow indirectly via interest rate effects on investment.

A great many researchers have looked into the effects of fiscal policy on real interest rates and long-run growth. Key fiscal variables of interest for our purpose are the *level of public debt* and the *primary financial balance*. The literature shows strong consensus that high levels of government debt and deficits reduce national savings and lead to higher interest rates. The hypothesis of Ricardian equivalence is mostly rejected. Summarizing seven studies in the literature, Rachel and Summers (2019, Table 2) report a 38 basis points increase in the interest rate, on average, after a 1 percentage point increase in the ratio of the public *deficit* to GDP. The interest rate rises by 3.5 basis points, on average, after a 1 percentage point increase in the ratio of public *debt* to GDP. Effects may be stronger, though, at very high debt levels. When lenders fear that public debt is no longer sustainable, rising risk premia will push up interest rates further. This leads to faster debt accumulation, which makes it even more likely that debt is unsustainable and may cause an additional increase in risk premia and interest rates (Paniagua et al., 2017; Blanchard, 2019; Lorenzoni and Werning, 2019).

In addition to the interest rate channel, most of the literature exploring the effects of higher public debt and deficits will conclude that $r-g$ rises also through the growth component. Growth may suffer for several reasons. A first one directly follows from higher interest rates, which deter investment in physical and human capital. Second, to ensure debt sustainability, governments facing growing interest payments may be forced to raise taxes or cut public investment, both undermining the economy's productive potential. Third, loss of fiscal policy as a stabilization instrument may imply larger macroeconomic volatility and uncertainty, which may also undermine investment and growth. Many empirical studies (e.g. Reinhart and Rogoff, 2010; Eberhardt and Presbitero, 2015; Woo and Kumar, 2015; Chudik et al., 2017) confirm this negative effect of public debt on subsequent growth. In his *meta*-analysis, however, Heimberger (2022) also points to contradictory results. Also here, thresholds may exist, i.e. public debt to GDP ratios beyond which effects on growth are significantly worse. Some studies put forward 90% (Reinhart and Rogoff, 2010; Woo and Kumar, 2015). Others, however, reject the idea that there should be a common threshold across countries (Eberhardt and Presbitero, 2015; Chudik et al., 2017; Heimberger, 2022).

2.2. Short-run determinants, control variables and unobserved common factors

Even though our paper is mainly focused on real long-run determinants of $r-g$, we also include and control for a number of short-run and/or nominal variables. The literature highlights a few. Furthermore, we recognize the possible impact of relevant but hard to observe (and to measure) common factors behind the evolution of r or g in our studied group of countries.

Checherita-Westphal and Domingues Semeano (2020) point at the impact of *monetary policy*. They find significant positive effects on $r-g$ from the 3-month nominal interest rate, as well as from alternative policy related variables (Euribor, marginal lending facility rate). In addition, they test for the impact of asset purchases by the ECB and find them to reduce $r-g$. These results are in line with the existing empirical literature that unconventional monetary policy has contributed to lower sovereign bond yields and to higher economic growth and inflation (see e.g. Boeckx et al., 2017; Hesse et al., 2018).

Although both the implicit interest rate r and the growth rate g in the equation for the dynamics of public debt are nominal variables, their reaction to *inflation* is very different. Nominal GDP growth will reflect higher prices of goods and services immediately and fully. The implicit interest rate on public debt, however, will only capture changes in inflation with a delay, depending on the maturity of outstanding government bonds, and possibly also the prevalence of financial repression. As a result, rising inflation will at least in the short and medium run have a negative effect on $r-g$. As time goes on, and the market rate on new issued bonds also incorporates higher inflation, this negative effect is expected to disappear. In the same vein, Mauro and Zhou (2021) explain how higher inflation and financial repression in emerging economies caused a lower interest–growth difference in these economies compared to advanced countries in 1975–1995. Escolano et al. (2017) report similar findings.

To capture *business cycle effects*, we follow the standard approach in the literature and include the output gap.

Last but not least, researchers have pointed to the possible influence on r or g of developments at the global level which are deemed important, but which are hard to measure and which may affect each country differently. Different effects may, for example, result from other policies or distinct structural characteristics such as the degree of openness of the economy or the characteristics of the financial system. As examples of such developments, one may think of the global trend towards financial liberalization since the 1980s, the increasing concentration and rise of market power of (big) firms, the preference shift towards higher saving by emerging market governments after the Asian crisis in 1998, and shifts in risk aversion and the increase in the demand for safe assets due to regulatory changes after the financial crisis (Rachel and Smith, 2017; Farhi and Gourio, 2018; Jordà et al., 2019; Glick, 2020; Heimberger, 2023). When not accounted for empirically, these common factors will become part of the error term and affect the quality of the estimation results. We discuss how we deal with this in the next section.

3. Empirical analysis of $r-g$

3.1. Empirical model

The empirical model that we estimate emerges directly from the theoretical discussion of the determinants of $r-g$ in the previous section. It can be summarized as follows:

$$(r-g)_{it} = \alpha_i + \beta' X_{it} + v_{it} \tag{1}$$

$$v_{it} = \lambda_i f_t + \varepsilon_{it} \tag{2}$$

where $(r-g)_{it}$ is the interest–growth difference on general government debt in country i and year t. On the right of Equation (1), α_i denotes the country-specific fixed effect for country i, X_{it} the vector of explanatory variables, β a vector of parameters to be estimated, and v_{it} the error term. In Equation (2) we allow for the impact of unobserved common factors, captured by f_t, with a country-specific effect λ_i. In the spirit of Pesaran (2006) we include the cross-sectional average of the dependent variable as our proxy for f_t.[5] The model given by (1) and (2) can thus be seen as an extension of the fixed effects estimator that allows for cross-sectional dependence in the error term due to unobserved common factors.

Table 1 provides a detailed description and summary statistics of all explanatory variables that we consider. Data on $r-g$ were shown earlier in Fig. 1.

3.2. Data and time series properties

Unsurprisingly, considering the likely impact of unobserved common factors that we discussed at the end of Section 2, the CD test of Pesaran (2004) confirms the existence of positive *cross-sectional correlation* in $r-g$, both in levels and in first differences. This observation justifies the specific error structure that we adopt in Equations (1) and (2). Furthermore, unit root tests reveal a great deal of *nonstationarity* in most variables in our model: three demographic variables, the fiscal variables, inequality (Gini), and the short-term nominal interest rate. We also find $r-g$ to be non-stationary in a large majority of countries. Online Appendix 2 provides the details. When we report our regression results and assess their quality, we take this observation into account and also execute unit root tests on the residuals of our regressions. Valid results require that the non-stationary variables in our model are cointegrated, i.e. that the residuals of the estimated model are stationary. Anticipating, we can confirm that this condition is satisfied. It has the important implication that the ordinary least squares approach that we adopt in the next section will yield superconsistent estimates of the coefficients on the non-stationary variables. Our estimated model will then also allow valid predictions.[6]

3.3. Main results

Table 2 contains our main regression results. The six columns differ mainly in (i) the included proxy for the variable n in growth theory, (ii) whether non-linearity is allowed in the impact of old age dependency and in the impact of the public debt ratio, and (iii) the way in which we control for (possibly unobserved) external factors behind $r-g$. We first motivate these specifications, and then discuss our main findings.

The first two columns include the growth rate of total working age population as proxy for n. It obtains an insignificant positive coefficient. Column (3) adds the growth rate of employment. Its effect shows up significantly negative. Their opposite coefficients, which are not significantly different in absolute value, explain why from column (4) on we replace employment and working age population growth by their difference, i.e. the growth rate of the employment rate.

Inspired by the literature in Section 2 (e.g. Kankaanranta, 2019) and the observation that the impact of the total old age dependency rate is highly insignificant in column (1), we leave room to different effects from the fractions of younger versus older retired individuals in all other columns. The younger group includes all individuals with an age between 65 and 75, the older group all those older than 75. Furthermore, from column (2) on we allow for different effects of the public debt ratio above a threshold of 90%. Alternative estimations with different thresholds never led to econometrically better results. Last, note that column (2) also introduces public asset purchases (QE) by the central bank.

When it comes to controlling for possibly unobserved external factors behind a country's $r-g$, column (1) shows the results of a straightforward one-way fixed effects estimation, including the cross-sectional average of $r-g$, but imposing the same coefficient on this variable for all countries. From column (2) on, we allow a different coefficient per country, and thus a different response to our proxy for the common factor(s). Column (5) adds another external determinant. Given the dominant impact of the United States on financial markets and the business cycle in other OECD countries, it can be expected that the interest rate and growth in these other countries are affected by the behaviour of $r-g$ in the United States. In (5) we impose the same coefficient on all countries, whereas (6) allows country-specific coefficients. These extensions further increase the explanatory power of the regression. The common coefficients in columns (1) and (5) are statistically significant at the 10% level or better. When we allow country-specific coefficients in the other columns, these are significant at the 5% level in the majority of countries.[7] The estimated coefficients for the observed explanatory variables are largely unaffected when we control for these external factors.

Considering our results in Table 2, we can draw the following conclusions:

[5] Including cross-sectional averages for all explanatory variables and allowing country-specific factor loadings on all these averages, which is the standard approach in the CCEP estimator of Pesaran (2006), was not possible. This led to an enormous increase in the number of parameters to be estimated and loss of degrees of freedom, affecting the efficiency of the estimator.

[6] At the same time, it should be recognized that having a cointegration relationship does not exclude that also right-hand-side variables adjust to establish the equilibrium. This is clearly so for the public debt ratio. In our projections in Section 4, we also take that into account by letting the public debt ratio adjust to changes in r-g.

[7] Details are available upon request. Note that to be able to keep the US as one of the cross-sections in the panel, we also needed a relevant 'foreign' $r-g$ to explain the US data. We include the average of $r-g$ in Germany, the UK and Canada. It obtains a positive coefficient, which is also significant at the 5% level. Keeping the US in the panel is important. Only then, we can derive projections for the US.

Table 1
Description of considered explanatory variables and summary statistics.

Variable	Definition	Mean	Std. Dev.	Q1	Q3	Min.	Max.
TFP growth	yearly growth rate of TFP (in %)	0.469	1.75	−0.390	1.35	−7.07	17.50
working age population growth	yearly growth rate of population aged 15–64 (in %)	0.504	0.568	0.151	0.85	−1.98	2.66
employment growth	yearly growth rate of employment (persons, in %)	0.261	1.80	−0.527	1.28	−9.00	6.45
old age dependency	population 65 and older in % of total population	15.51	2.64	13.54	17.26	9.58	22.68
young age dependency	population aged 0–14 in % of total population	18.28	2.79	16.45	19.64	13.17	30.31
life expectancy	life expectancy at birth at time *t*-20 (in years)	73.78	2.74	71.74	75.87	63.69	79.34
gini index	Gini index for disposable income (scale from 0 to 100, with 0 perfect equality)	28.90	4.3	25.40	32.83	20.30	38.70
inflation	yearly change of the GDP deflator (in %)	3.58	4.09	1.33	4.25	−5.21	26.31
output gap	(actual – potential output) in % of potential output	−0.942	3.39	−2.40	0.969	−18.20	7.870
short-term interest rate	3-month government T-bill rate (in %)	5.89	5.25	1.56	9.39	−0.70	24.61
primary balance	primary balance of general government (in % of GDP)	−0.124	3.83	−2.18	2.03	−29.81	15.72
public debt ratio	gross government debt (in % of GDP)	66.94	30.01	43.83	85.96	11.50	186.24
QE	public sector assets bought by the central bank (flow) in % of outstanding public debt	0.427	1.61	0.00	0.00	−1.78	16.16

Note: For a description of data sources, see online Appendix 1. Most extreme data in this table (for TFP growth, inflation, the short-term interest rate, the output gap, the primary balance and public debt) relate to Ireland and Greece in periods of crisis (EMS crisis, financial crisis, sovereign debt crisis in the euro area,…). As we explain later, our regression results are robust to these outliers in the data.

(i) As mentioned before, and indicated at the bottom of the table, all our estimated equations are cointegrating relationships. This conclusion also holds at the individual country level. Underlying country-specific test results reject the hypothesis of non-stationary residuals for almost all countries.[8]

(ii) From our discussion in Section 2 we learned that technical progress and employment growth are key determinants of both the interest rate and the economic growth rate. The significantly negative coefficients on TFP growth and on the growth of the employment rate suggest that the effect on g is clearly stronger. Our results regarding the effects of TFP growth thus seem to match the findings of Lunsford (2017) and Lunsford and West (2019). Growth promoting policies that target TFP or employment may imply a higher r, but their net effect on $r-g$ seems clearly and robustly negative.[9]

(iii) Demographic change does affect $r-g$, although not all variables matter. We find no robust effects (neither statistically, nor economically) when the fraction of children or the fraction of young retirees (age 65 – 75) rises at the expense of the fraction of people at working age. For given life expectancy, however, a rising proportion of old retirees (75+) does imply a significant increase of $r-g$ in most of our regressions. We conclude that young retirees do not seem to save significantly less than people at working age. Only old retirees seem to dissave as predicted by lifecycle theory, confirming e.g. Kankaanranta (2019) and Horwich (2022). Last but not least, our results show a strong and significant negative effect on $r-g$ from rising life expectancy. This finding confirms the results of calibrated OLG models studying the effects of demographic change, but has been neglected in earlier empirical work studying $r-g$.

(iv) We obtain a significant negative coefficient on inequality (Gini) in all regressions. This observation is in line with findings in the literature that a more unequal income distribution raises aggregate savings and reduces the interest rate. Also this effect has been neglected by earlier empirical work on the interest–growth difference.

(v) All our regressions confirm that a rise in the public debt ratio correlates with a higher $r-g$. The size of the estimated coefficient is slightly below the average of 3.5 basis points reported by Rachel and Summers (2019). In most regressions, we also find that public asset purchases by the central bank reduce $r-g$. Our findings for the impact of changes in the primary balance, and for the existence of a threshold effect when public debt exceeds 90% of GDP, are less robust. The primary balance obtains the expected negative coefficient, but that coefficient is smaller than in existing literature and not always significant. One explanation may be that we control for employment growth. It is exactly in columns (3) – (6) that the primary balance obtains a weaker estimated coefficient. Another reason is most likely our focus on the implicit interest rate instead of the market rate in existing studies (cf. infra). Public debt above 90% of GDP tends to raise $r-g$ more than below 90%, but this difference is statistically significant in only two regressions in Table 2.

(vi) Due to its direct positive effect on nominal GDP growth and its very slow impact on the implicit nominal interest rate, higher inflation correlates negatively with $r-g$ in all our regressions. Its estimated coefficient is not significantly different from −1.

[8] The adopted Hanck (2013) panel unit root test would imply a 'yes' for cointegration as soon as non-stationarity of the residuals is rejected for at least one country. It could thus be that the residuals are non-stationary in most countries. However, that is not the case in our empirical model. For example, in regression (6), which we use for our projections in Section 4 of this paper, we reject non-stationarity of the residuals in 14 out of 17 countries at the 5% level, and in a 15th country at the 10% level. In the other two countries non-stationarity can be rejected at the 15% level.

[9] In Appendix 4B, where we run separate regressions for r and g, we confirm this finding of a much stronger influence on growth than on the interest rate.

Table 2
Empirical analysis of $r-g$ (17 OECD countries, 1981–2018).[1]

	(1)	(2)	(3)	(4)	(5)	(6)
TFP growth	−0.956***	−0.943***	−0.929***	−0.927***	−0.918***	−0.863***
	(0.062)	(0.056)	(0.050)	(0.050)	(0.052)	(0.055)
Working age population growth	0.176	0.226	0.429*			
	(0.358)	(0.326)	(0.256)			
Employment growth			−0.598***			
			(0.040)			
Growth of the employment rate [2]				−0.592***	−0.585***	−0.515***
				(0.041)	(0.039)	(0.037)
Old age dependency	0.004					
	(0.105)					
Old age dependency 65–75		−0.124	−0.018	0.003	0.015	0.016
		(0.121)	(0.102)	(0.113)	(0.113)	(0.091)
Old age dependency 75+		0.412*	0.387**	0.396***	0.380**	0.131
		(0.202)	(0.151)	(0.146)	(0.150)	(0.150)
Young age dependency	0.064	0.063	−0.073	−0.070	−0.073	−0.046
	(0.082)	(0.091)	(0.056)	(0.056)	(0.055)	(0.075)
Life expectancy	−0.274**	−0.428***	−0.633***	−0.638***	−0.610***	−0.483***
	(0.123)	(0.135)	(0.112)	(0.111)	(0.117)	(0.120)
Gini	−0.343***	−0.307**	−0.247***	−0.247***	−0.233***	−0.209***
	(0.111)	(0.107)	(0.065)	(0.065)	(0.068)	(0.040)
Primary balance	−0.137***	−0.158***	−0.037	−0.043*	−0.041	−0.078**
	(0.038)	(0.030)	(0.025)	(0.025)	(0.025)	(0.031)
Public debt ratio	0.027***	0.022**	0.031***	0.032***	0.032***	0.019***
	(0.009)	(0.009)	(0.008)	(0.007)	(0.006)	(0.005)
Public debt ratio x Dummy90+		0.006*	−0.00004	0.001	0.0005	0.005***
		(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
QE		−0.105**	−0.048*	−0.050**	−0.053**	−0.040**
		(0.043)	(0.025)	(0.025)	(0.027)	(0.020)
Inflation	−1.104***	−1.094***	−1.068***	−1.070***	−1.073***	−0.990***
	(0.054)	(0.050)	(0.042)	(0.041)	(0.041)	(0.039)
Output gap	−0.143***	−0.136***	−0.054**	−0.054**	−0.060**	−0.055**
	(0.038)	(0.038)	(0.024)	(0.023)	(0.025)	(0.027)
Short-term interest rate	0.453***	0.445***	0.393***	0.392***	0.384***	0.337***
	(0.041)	(0.029)	(0.025)	(0.025)	(0.025)	(0.029)
Cross-sectional average *r-g*	0.270***	CS [3]	CS [3]	CS [3]	CS [3]	CS [3]
	(0.046)					
$(r-g)_{US}$					0.062*	CS [4]
					(0.036)	
Observations	643	643	643	643	643	643
Country fixed effects	yes	yes	yes	yes	yes	yes
Time fixed effects	no	no	no	no	no	no
R^2 adjusted	0.84	0.85	0.89	0.89	0.89	0.92
Cointegration [5]	yes	yes	yes	yes	yes	yes

Notes: 1. Estimated and Driscoll and Kraay (1998) corrected standard errors in brackets. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
2. Difference between the growth rate of employment and the growth rate of working age population
3. CS: the model has been estimated with country-specific coefficients on the cross-sectional average $r-g$.
4. CS: the model has been estimated with country-specific coefficients on $r-g$ in the US. As relevant 'foreign' $r-g$ to explain the US data in the panel, we include the average of $r-g$ in Germany, the UK and Canada.
5. yes: the Hanck (2013) test rejects the null of a unit root in the estimated residuals. Underlying country-specific ADF tests are with drift. The number of lags has been determined using the AIC and may differ by country.

This finding suggests a robust favourable (negative) impact of inflation on public debt dynamics. However, if monetary policy makers react and raise the short-term interest rate to fight inflation, this favourable impact will be much smaller. In all regressions we observe a significantly positive effect from the short-term interest rate close to 0.4.

3.4. Robustness

We tested the robustness of our regression results in several ways. We show the outcome of most tests in online Appendix 4.

(i) We added time fixed effects. This had no notable impact on the regressions, except for QE which lost its statistical significance. Due to the concentration of QE in a limited number of years in about all countries, time dummies could probably pick up its effect on $r - g$.
(ii) We tested the impact of including or excluding individual countries. Dropping single countries from our sample never had a notable impact on the estimation results.[10]
(iii) We accounted for the possible endogeneity of some explanatory variables and switched to an instrumental variables approach. The observation of cointegration in all regressions, and thus a stationary residual, implies that there can be no meaningful correlation between the residual and the non-stationary explanatory variables. This conclusion does not hold, however, for those variables in Table 1 for which we rejected a unit root: TFP growth, the growth rate of the employment rate, inflation and the output gap. With GDP growth in the dependent variable, all these four variables may be subject to reverse causality. As a robustness test we instrumented these variables. Online Appendix 3 shows the list of instruments and their significance in the first-stage regression. The results of the IV regression in Appendix 4A occur highly robust for about all variables, except the primary balance. This variable keeps its expected negative sign, but loses statistical significance. The earlier mentioned effects of TFP growth and employment growth can thus be interpreted as causal.
(iv) We added several dummy variables to the empirical model to capture the effects of specific crises (EMS crisis in the early 1990s, financial crisis in 2007–2008, European sovereign debt crisis in 2010–2013) or institutional changes (euro area membership) that affected a group of countries simultaneously. Including these dummy variables made no notable difference for our results, however, when also other variables such as the output gap and the primary balance were included. These results are available upon request.
(v) We estimated our model with an alternative dependent variable. Instead of the implicit nominal interest rate r, we used the nominal market rate on 10-year government bonds (r_m) to compute the interest–growth difference. We could again conclude that our earlier findings are highly robust for most variables, now including the primary balance, both with respect to their estimated sign and their statistical significance. Only the Gini coefficient lost the significance that it had in all regressions reported so far. Furthermore, we observed a few (expected) changes in the size of some estimated coefficients, most likely due the fact that the market rate on new public debt will reflect changes in the drivers of the interest rate more and faster than the implicit interest rate on the outstanding stock of debt. The threshold effect of a high public debt ratio becomes stronger, the effect of public asset purchases by the central bank (QE) becomes more negative. Also, the effect of inflation turns significantly lower than 1 in absolute value. For details, see Appendix 4B.
    This Appendix also includes separate regressions for r and g, shedding light on the main channels through which the determinants affect $r - g$. TFP growth, employment growth and inflation mainly operate via g and have only weak positive effects of r. Life expectancy and the Gini coefficient mainly operate via r. The fiscal variables, QE, the short-term interest rate, and old age dependency affect both components of $r - g$.
(vi) We tested the robustness of our results by including alternative variables to measure the impact of the fiscal situation in countries. In Appendix 4C we first replace the primary balance by the gap between the primary balance and its required level to stabilize the debt ratio (see Chrysanthakopoulos and Tagkalakis, 2024). We call this gap the 'fiscal effort'. Next, we replace the short-term interest rate by the foreign currency long-term sovereign debt rating index, as indicator for the government's ability to repay its debt (Kose et al., 2022). In line with expectations, we find for both the 'fiscal effort' and the sovereign debt rating highly significant negative effects on $r - g$. Their effects are even stronger in regressions explaining $r_m - g$. Our conclusions for the other variables do not change at all, except for the Gini coefficient in the regression including the sovereign debt rating. However, this is due also to the fact that the 1980s are no longer included in this regression, due to lack of data for the debt rating.
(vii) Last, we included a lagged dependent variable and estimated a dynamic specification of our empirical model. We report the result in column (7) in Appendix 4A. Again, our main findings are unaffected. Estimated long-run relationships do not change.

4. Projections

4.1 Underlying assumptions

Having estimated the long-term relationship between the interest–growth difference and its theoretical determinants, we are now able to make projections for $r - g$ for the next two decades. We made these projections at the end of 2022. We relied on available forecasts from:

- the IMF World Economic Outlook (October 2022)

[10] Details are available upon simple request.

- the OECD Demography and Population databases (December 2021)
- the World Bank's World Development Indicators (December 2021)
- the OECD's 'Long-term baseline projections' for the world economy until 2060 (Economic Outlook, October 2021)

and on market data to derive expectations about future short-term interest rates.

For illustrative purposes, Fig. 2 shows the historical values and our adopted projections for the future path of the factors behind $r-g$ in the United States and Germany. For the demographic variables, OECD and World Bank projections are directly available until 2040 (and beyond). For inflation, the output gap and the government's primary balance, the IMF's forecasts ran until 2027. For employment growth, the IMF provided forecasts until 2024. *For later years*, we had to make our own 'baseline' assumptions. These are the following.

- From 2028 inflation is assumed equal to the 2% objective of most central banks. The output gap is set equal to zero.
- From 2025 we assume employment in persons to grow according to the 'Long-term baseline projections' of the OECD (October 2021). By deducting the OECD's demographic forecasts for the growth of working age population, we obtain projections for the growth rate of the employment rate in our model.
- Starting from published actual data until 2021, our baseline projections for the short-term interest rate in later years are computed in accordance with the expectations theory of the yield curve and the observed 5-, 10- and 20-year government bond yields on 1 November 2022.[11] Compared to Autumn 2021 when the first central banks turned hawkish, these longer term bond yields capture a significant amount of monetary tightening.[12] Although this approach is straightforward, it should be recognized that it may also introduce an upward bias in our projections of the future $r-g$. First, the recent situation of accumulated negative supply shocks that provoked tight monetary policy is most likely not representative for the next decades. Second, long-term bond yields also include risk premia. Deriving future short-term rates from them via the expectations theory, is therefore likely to overestimate these future short rates (see for example Shiller et al., 1983).
- As a second incorporation of the change in the stance of monetary policy since 2021, we assume in our projections that all central banks stopped buying government bonds as of 2022. More than that, we impose that all assets bought since the financial crisis should be sold or redeemed gradually by 2040. Every year from 2022 to 2040 we impose in our projections a reduction of one 19th of the nominal stock of public assets held at the end of 2021. Imposing a full unwinding of the central banks' balance sheets, may be another reason for an upward bias in our future $r-g$ projections.
- The choice that we make about the evolution of the primary balance is more delicate. Our prior or baseline assumption is that the primary balance in percent of GDP remains constant at the level of the IMF forecast for 2027. For many countries this implies projected primary deficits until 2040, varying from about 0.25% in Austria and Denmark to more than 2% in Finland, Spain and the Netherlands and even more than 3% in Belgium, France and the United States. For other countries, such as Germany, Sweden, Portugal and Greece, IMF forecasts put forward a slight primary surplus in 2027. To see the impact of this choice, as well the impact of changes in the primary balance, we will later also introduce alternative assumptions. These impose on all countries either a zero primary balance or a primary deficit of 3% of GDP from 2028.

For two determinants of $r-g$, our imposed projections are subject to more uncertainty.

- First, existing predictions concerning TFP growth are mixed. Rachel and Smith (2017) expect rates to slow down in the coming years. Feyrer (2007) finds a negative impact of demographic change and ageing on technical progress. Others, however, are explicitly positive about TFP growth in the future. Techno-optimists like Mokyr (2014) have long emphasized the advantages to be expected from progress in areas such as computing, artificial intelligence, robotics, medicine, new materials, genetic engineering, etc. More recent developments may reinforce this positive expectation. McKinsey Global Institute (2021), among others, pointed to firm and household responses to the covid-19 pandemic that accelerate the adoption of new technologies. Jaumotte et al. (2023) show that the pandemic accelerated digitalisation and triggered a partial catch-up by less digitalised entities in advanced economies. Recent breakthroughs in artificial intelligence with the emergence of 'generative AI' may reinforce such developments. According to The Economist (2022b), if generative models' achievements turn artificial intelligence into a general-purpose technology, their economic impact may be huge. Researchers at Goldman Sachs (2023) estimate that AI may add 1.5 percentage points to annual productivity growth in the US and major developed countries. Heer and Irmen (2014) and Brynjolfsson and Petropoulos (2021) point to a declining labour force and low unemployment rates, pushing up wages, as an extra factor that will strengthen incentives for firms to introduce new technologies. This factor was largely absent in earlier decades.

  As input for our projections, we rely on the forecasts for future TFP growth reported by the OECD (2021) in its long-term baseline scenario. Compared to its earlier version in 2018, the OECD revised projected TFP growth downward for most countries. Imposing these revised lower growth rates might be rather pessimistic in an environment of accelerated digitalisation and breakthroughs in artificial intelligence. However, this choice is consistent with the conservative approach that we adopted in our projections for

[11] Note that this choice implies the possibility of different projected future short-term rates for the Euro area countries, even if they share the same central bank. Countries with a higher long-term interest rate in November 2022, will have higher projected future short rates. In this way, our projections for the short rate will not only incorporate the overall rise in long-term government bond yields since autumn 2021, but also the cross-country differences in risk premia that existed at the beginning of November 2022. We consider this an advantage.

[12] In almost all countries, highly similar levels were observed in the first half of 2023 when we concluded our analysis.

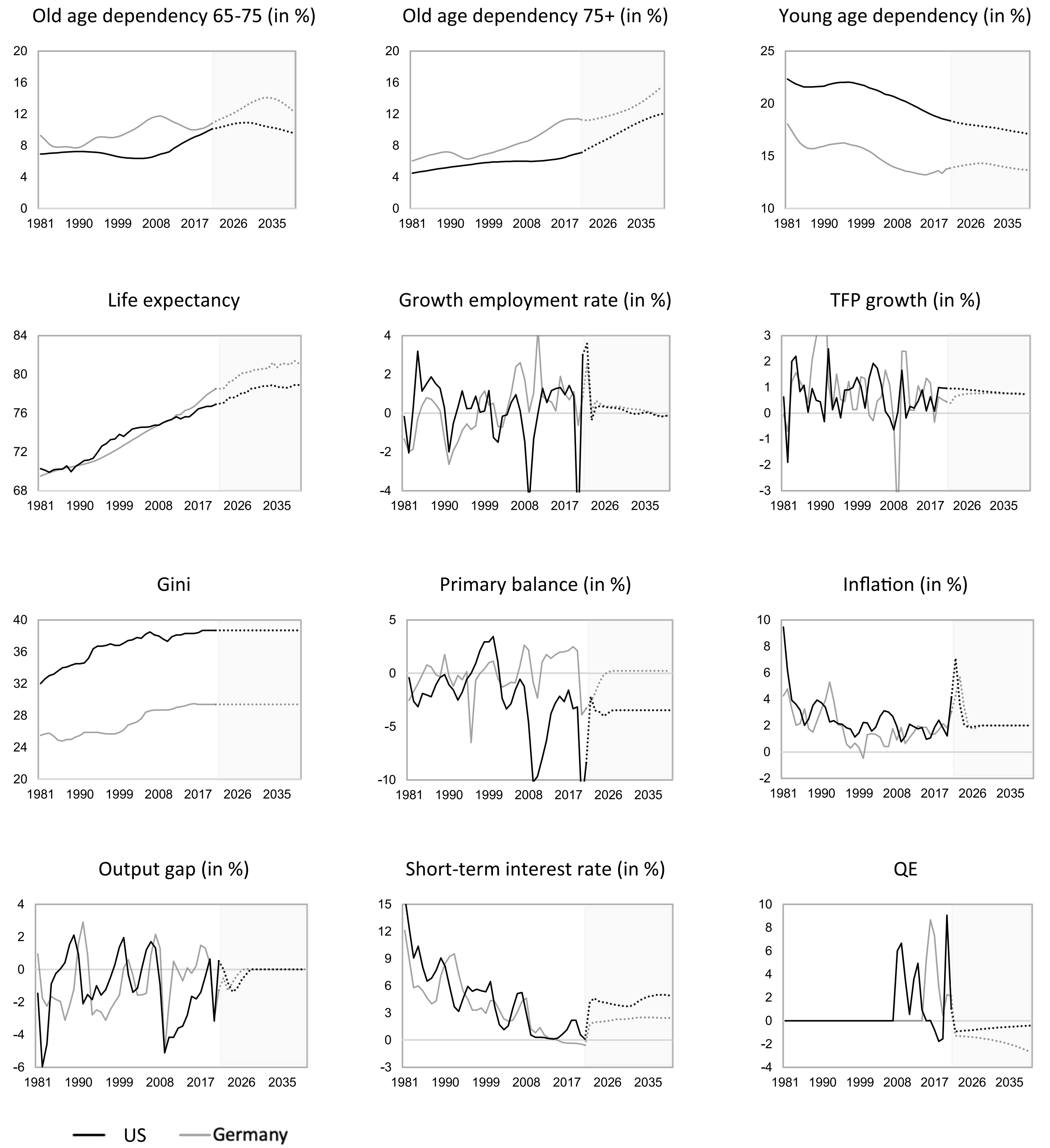

Fig. 2. Historical values and baseline projections concerning the determinants of $r-g$ in the United States and Germany. *Sources and motivation*: see main text. The reported series (full lines) are observations until 2021. From 2022 (dotted lines) they include expectations and projections from the sources described in the main text. In addition to the variables shown here, also the evolution of public debt matters for the behaviour of $r-g$ in the US and Germany. It is determined endogenously by our estimated model. Baseline projections for the other countries are available from the authors upon request.

future short-term interest rates and quantitative tightening. One might conclude that if we err on $r-g$, we will most likely overestimate it.

- The same ambiguity in predictions exists for the Gini coefficient. After decades of rising inequality in most countries, there are arguments leading to an expected further rise as well as arguments indicating a fall of inequality. Often the former arguments emphasize the adverse impact of innovation or demographic change and accelerating automation (e.g. Prettner and Strulik, 2020;

Acemoglu and Restrepo, 2022; Jacobs and Heylen, 2024). The latter arguments highlight the role that policy may play in response to the increased sensitivity to inequality in society during the last decade (see e.g. Blanchard and Rodrik, 2019). In our baseline projections we assume inequality to remain constant.

We collected similar data as for the United States and Germany in Fig. 2 for all countries in our sample. In addition to the variables shown in these figures, every country's $r-g$ depends also on the evolution of its public debt ratio. In our projections the latter will be determined endogenously in the model by applying the debt dynamics equation to the projected $r-g$ and the imposed primary balance.[13]

4.2. Projections of $r-g$

Fig. 3 reports our projections, using the estimation result in column (6) of Table 2. The graphs on the left confront our model's explanation of $r-g$ (full black line) with the data (red dots) in 1981–2018. For all but one country, our empirical model explains at least 80% of the variation in past data. For 11 reported countries, the R^2 is even 0.9 or higher. The full black line in the graphs in the middle depicts for each country our baseline projection for $r-g$ when we assume that the IMF forecast of the primary balance in 2027 applies also to later years. For the United States, Belgium and France, that means persistent deficits higher than 3% of GDP. The other lines show the outcome for $r-g$ when we impose alternative assumptions on its predictors. Two simulations based on alternative assumptions regarding the primary balance are discussed later in this section, two other simulations in the next section. The graphs on the right show the induced corresponding paths for the public debt ratio. We draw three conclusions.

First, we observe a clear difference between North America and most European countries. Whereas our baseline projections show positive interest rate – growth differences in North America, chiefly in the US, $r-g$ is expected to remain in negative territory for the next two decades in most European countries.[14] The main exceptions to this general result are the highly indebted countries in Southern Europe, in particular Italy and Greece.

Second, our observation of a negative $r-g$ in most European countries is fairly robust to the assumed primary balance. Also when we impose a primary deficit of 3% of GDP in alternative simulations, $r-g$ would remain negative, except in Spain and the UK.[15] We refer to the dotted black lines in Fig. 3. A reason for caution, though, are the consequences for the public debt ratio. The combined impact of a higher primary deficit and its induced increase in $r-g$ is not trivial.[16] This brings us to our third conclusion.

In the introduction to this paper we highlighted that when $r-g$ is negative, public debt is sustainable even with a primary deficit. In times of a high need for public investment and climate mitigation policies, that offers an important opportunity. But it is not without risk. As the dotted lines in the graphs on the right of our Fig. 3 reveal, primary deficits of 3% would imply strongly rising debt ratios. Even if debt would not explode, the higher a country's debt level, the more vulnerable it is to adverse shocks in r or g, or in financial market risk premia. Conversely, if a primary deficit were no longer allowed (the dashed lines), the public debt ratio would decrease year after year in almost all European countries, except Greece and Italy. A balance must thus be struck.

Online Appendix 5 reports the IMF's (October 2022) primary balance projections for all countries included in Fig. 3. It also shows the allowed primary deficit (or required primary surplus) in 2022–2040 that would imply a public debt ratio in 2040 equal to its 2021 level in our simulations. On average across the EU countries that we study, except Greece and Italy, that public debt level was close to 80%. To keep it there by 2040, a primary deficit of 1.4% would be allowed. A stricter debt target would require lower deficits, and vice versa for a softer target. In our concluding Section 5 we briefly touch upon the policy implications of these findings for the fiscal rules discussion in Europe.

4.3. Discussion

Our finding that $r-g$ may remain negative during the next two decades in most European countries that we studied, is important. Two questions remain. How strong is this finding? And how can we explain the striking difference with the United States?

Strength of our main finding. To its support, we repeat that we made several rather conservative assumptions when defining our projections for the driving forces of $r-g$. The imposed future short-term interest rate in particular may be rather high if one considers

[13] The cross-sectional average of $(r-g)$ and $(r-g)_{US}$ are not incorporated in the projections. The former was meant to capture the impact of unobserved common factors in our empirical model. By definition, these are hard to predict. The latter is strongly determined by policy choices in the US, and we prefer not to let our projections for $r-g$ in other countries depend on assumptions for the US primary balance, which may turn out differently in reality. Our reported projections thus show for each country the most likely future path of $(r-g)$ as caused by its domestic predictors. Standardized regression coefficients reveal that these are also by far the most important.

[14] This also holds for Norway, which is not included in Fig. 3. The IMF puts forward for Norway a primary surplus of more than 10% of GDP until 2027. Introducing this into our model, would imply a value for $r-g$ of −3% in that year. Extrapolating the IMF projection for the primary balance into the future, as we do for the other countries, would take $r-g$ to −6.5% in 2040 and imply an increasingly negative public debt ratio.

[15] We report the IMF's primary balance projections for all countries at the bottom of Fig. 3. For Belgium and France this projection already incorporates a primary deficit of (a little more than) 3%.

[16] A comparison of the simulation results shown by the dotted and the dashed black lines in Fig. 3, with the latter assuming a primary balance equal to zero, reveals the importance of the level of the primary deficit. A 3%-points difference may in the longer run imply a difference in $r-g$ of about 1 to 1.5%-points.

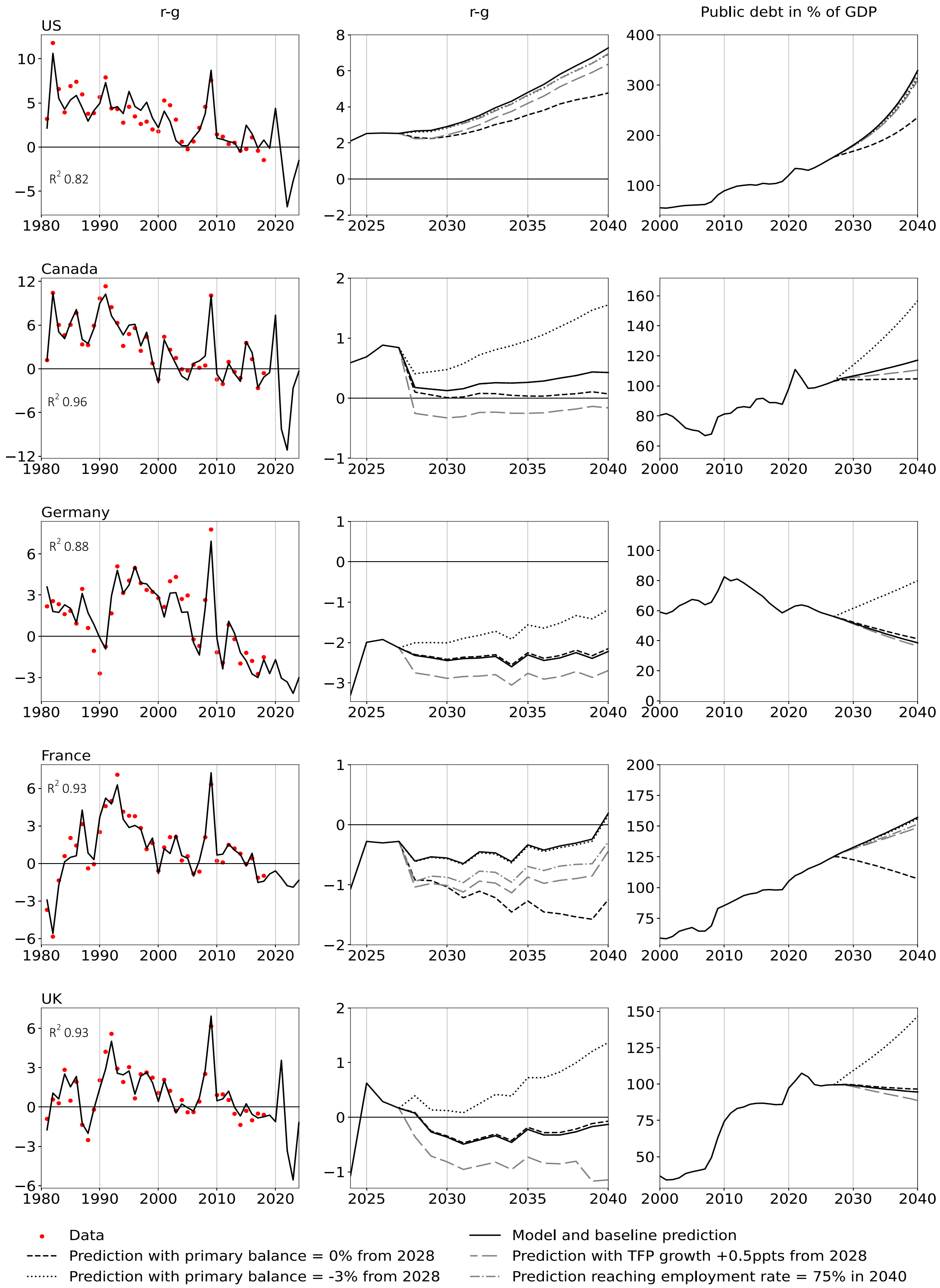

Fig. 3. Projections of $r-g$ and the implied public debt ratio (% of GDP). Note: The IMF's (October 2022) projections for the primary balance in 2027 are −3.5% (US), −0.75% (Canada), 0.2% (Germany), −3.1% (France) and 0.1% (UK), −0.3% (Austria), −3.7% (Belgium), −2.6% (Finland), 1.1% (Ireland), −2.5% (the Netherlands), −0.2% (Denmark), 0.2% (Sweden), 2.0% (Greece), 0.1% (Italy), 0.9% (Portugal) and −2.0% (Spain). The OECD's demographic and 'long-term baseline' economic projections yield employment rates above 75% in 2040 (or even sooner) in all countries except the US, France, Belgium, Greece, Italy and Spain. These countries would achieve employment rates of only 72.7% (US), 69.8% (France), 66% (Belgium), 70% (Greece), 63% (Italy) and 72% (Spain). The last simulation in the figures for these six countries shows the effect on $r-g$ from imposing that the employment rate gradually reaches 75% in 2040 in these countries.

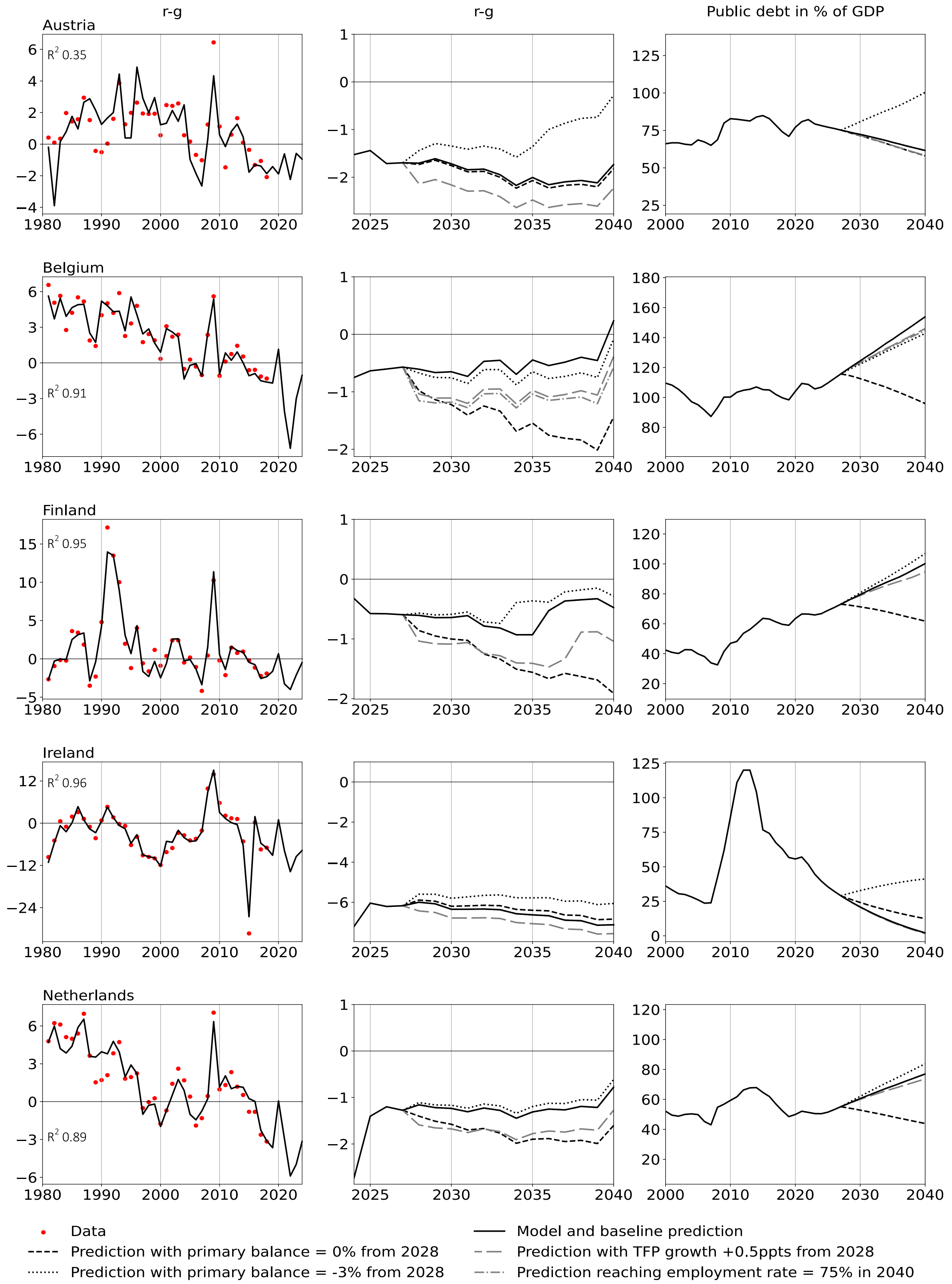

Fig. 3. (*continued*).

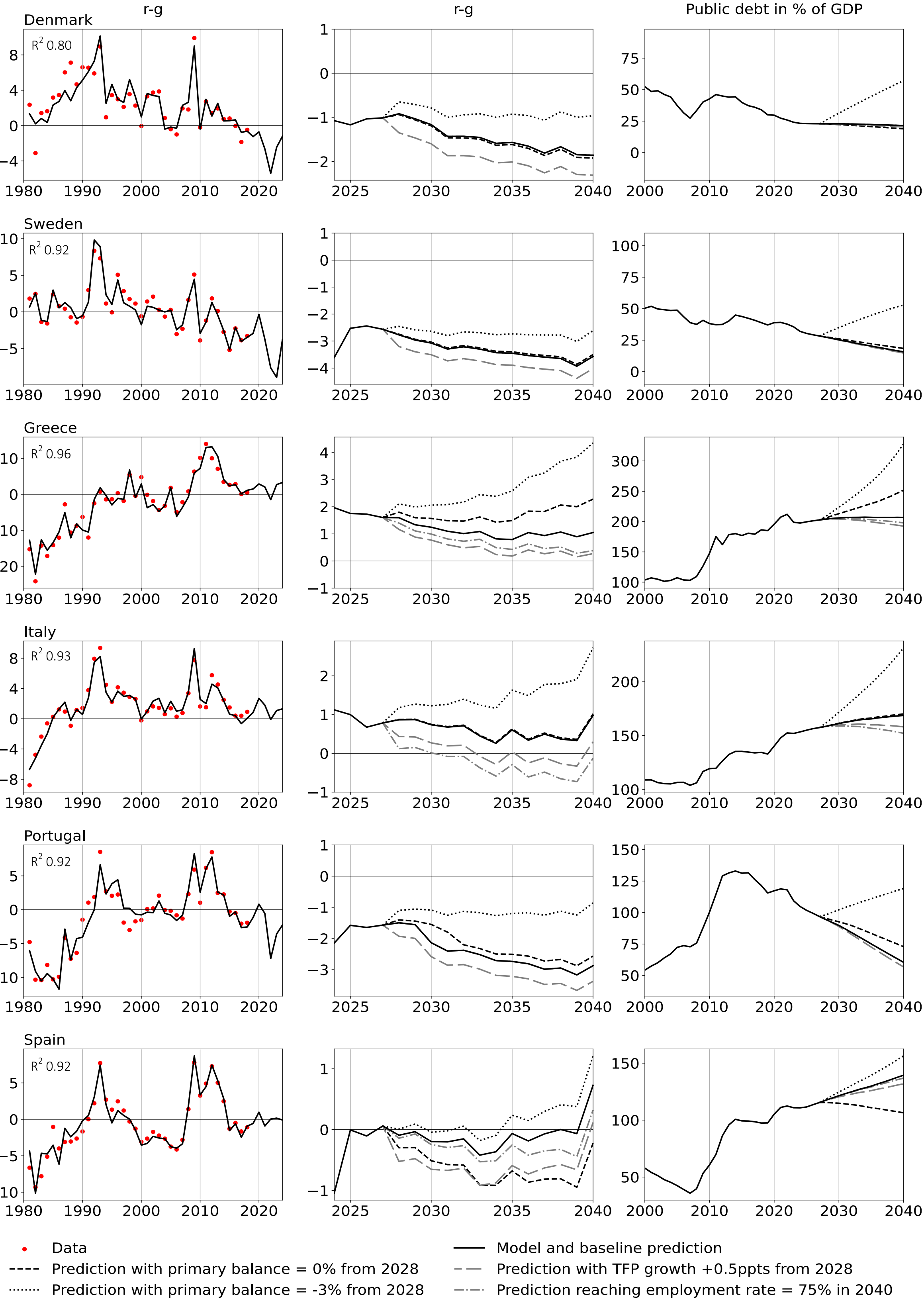

Fig. 3. (*continued*).

that the current situation of tight monetary policy will not last. A 1%-point lower short-term rate is estimated to directly reduce $r-g$ by about 0.4%-points. The induced favourable consequences for the public debt ratio slightly reinforce this effect over time, especially in high debt countries. Given recent developments and breakthroughs in the field of technology, our long-run projections for future TFP growth may be at the lower end. Furthermore, some of the drivers of $r-g$ are directly related to policies. We already highlighted the potential impact of changes in the primary balance. Next to that, policies with respect to innovation, digitalisation and competition, for example, may raise TFP growth. This brings us to the fourth simulation in Fig. 3. A comparison with the baseline reveals that an increase by 0.5%-points in TFP growth implies a reduction in $r-g$ of about the same size. This result follows from our empirical finding that growth responds much more strongly to changes in TFP growth than the interest rate. Last, several countries still have ample room for progress when it comes to employment. Starting from current employment rates among the population of age 15 to 64, and OECD demographic and 'long term' economic projections, we identified the countries with expected employment rates lower than 75% in 2040 (see the notes at the bottom of Fig. 3). Policies achieving 75% could reduce $r-g$ in Belgium, France and Greece by about 0.5%-points, compared to the baseline. In Italy the advantage would even be greater. Indirectly, effective employment policies would also reduce primary expenditures, including pension expenditures when people work longer and retire later.

On the other hand, two factors may imply an increase in $r-g$ relative to the baseline that we reported. One is the need in all countries for massive green and infrastructure investment, which will raise both private and public borrowing. Higher public defence spending in many countries may reinforce the need to borrow. Although these investments may also promote g, their impact on r will probably be stronger. Our alternative projections with a primary deficit of 3% in Fig. 3 may give an indication of the related risk. Even with this (increased) amount of government borrowing in most countries, $r-g$ is expected to remain negative, at least if it can be assumed that rising debt ratios do not trigger strong adjustments of risk premia. (The fact that these investments will reduce climate risk is an advantage in this respect).

The second risk relates to the impact from interest and growth developments in the United States on the other countries. In Fig. 3 we assumed this to be zero. However, given our baseline expectation that $(r-g)_{US}$ will be positive, most other countries will experience some effect, albeit small. Column (5) in Table 2 reveals a relatively small coefficient of 0.06 on $(r-g)_{US}$. Moreover, due to the strong rise in their public debt ratio, US policy makers would most likely be forced to achieve better government balances than presumed in our baseline.

Last but not least, our baseline projection is far from immune to uncertainty. First of all, there is uncertainty in the estimation results in Table 2. Second, all factors behind $r-g$ are subject to shocks, as we frequently observed during the past 40 years that span our empirical analysis. Shocks will occur again in the future, which at worst could change the picture of a negative future $r-g$ in most European countries. However, the probability that this happens, is impossible to determine ex ante. Future shocks are by definition still unknown. To give a somewhat realistic idea of the possible impact of shocks, rather than a purely statistical analysis, we report in online Appendix 6 the results of a set of simulations for three European countries with different debt levels: Denmark, Germany and Belgium. In these simulations we take as our starting point the (most likely) values of the estimated parameters in column (6) of Table 2 and our baseline projections for the demographic variables, inequality, and the two policy variables (QE and the primary balance). For the other variables (TFP growth, employment growth, the output gap, inflation and the short-term interest rate) we allow shocks with realistic characteristics in size, autocorrelation and co-variance. More precisely, we impose the fluctuations in these variables that we observed in the data between 1982 and 2018.

For each country we observe that if the shocks of the past happened again, this would in the majority of scenarios raise $r-g$. A comparison of the median scenario with our baseline suggests an increase of about 0.5 to 1 percentage point. Nevertheless, in Germany the implied $r-g$ would remain negative in about 90% of the 'shock scenarios'. In Denmark that would be in about 70% of the scenarios. Belgium is in the most vulnerable situation, with $r-g$ remaining negative in only about 50% of the scenarios. We conclude that if the adverse shocks of the previous decades happened again (or worse), $r-g$ could return to positive values also in Europe, even under a demographic context that is favourable to a low $r-g$. However, considering the rather conservative assumptions underlying our baseline, the probability that this happens remains fairly low.

Difference United States – Europe. When we look at the underlying determinants of $r-g$ in the US and Germany, three main differences stand out. Concentrating on the US, these are the higher initial public debt ratio, the worse primary balance, and the lower (and less steep) life expectancy (see also Fig. 2). A fourth factor is the endogenous amplifying mutual influence between (adverse) developments in $r-g$ and the public debt ratio. Imposing Germany's debt level on the US in 2024, everything else equal, would imply a reduction of $r-g$ in the US of 4.8%-points by 2040. Imposing Germany's primary balances from 2025 would reduce $r-g$ in the US by 3.4%-points by 2040. Last, imposing Germany's life expectancy from 2025 would imply a reduction of $r-g$ in the US of 2.4%-points by 2040. Imposing the entire German demographic structure and evolution would reduce the decline to a little more than 1%-point.

5. Conclusions and policy implications

The sustainability of public debt and optimal fiscal governance depend crucially on the difference between the implicit nominal interest rate on outstanding debt and the growth rate of nominal GDP. This paper studies the factors behind this difference empirically in a panel of 17 OECD countries in 1981–2018. In line with existing literature, we include fiscal, monetary and financial predictors of $r-g$. We also control for the impact of unobserved common factors and for the influence of changes in $r-g$ in the United States on the other countries. Our paper distinguishes itself from existing empirical literature by its focus on the real long-run determinants of $r-g$ such as technical progress, employment growth, life expectancy and other components of demographic change, and income inequality.

We find robust results for the influence of determinants about which existing evidence was mixed or lacking. More precisely, we observe robust negative effects on $r-g$ from faster technical progress, higher employment growth, rising life expectancy and rising inequality. A rising proportion of old retirees (75+) in the population implies an increase in $r-g$ in most of our regressions.

As to other factors, we confirm a number of established findings. We observe a significant increase of $r-g$ when the ratio of public debt to GDP rises, or when the central bank raises the short-term interest rate. Furthermore, we find that asset purchases by the central bank and higher inflation induce a significantly lower $r-g$ in almost all our regressions. Last, we observe a robust negative influence from the government's primary balance and a positive threshold effect from higher public debt when debt exceeds 90% of GDP, but these results are not always statistically significant.

The second part of the paper shows our projections for $r-g$ until 2040. Even if these projections are far from immune to uncertainty, our results suggest that $r-g$ will most likely remain negative for the next two decades in most European countries that we study. Italy and Greece are notable exceptions. Tight monetary policy, rising market interest rates and other shocks induced by Russia's invasion of Ukraine have clearly disturbed the picture in 2022–2023 and possibly longer, but according to our results they have not fundamentally changed the game. Once the fight against inflation is won, we project that this disturbance will disappear. The message from structural determinants related to demography, technical progress, employment, and/or inequality, may thus for many countries still be one of low interest rates and a negative $r-g$. In that spirit, our results offer support to the basic position taken recently by for example Blanchard (2023) and The Economist (2022a), at least when it comes to Europe. The United States are a major exception to our main findings. For this country our baseline projection of $r-g$ until 2040 is positive. Currently projected fiscal policies may put the United States on an explosive debt path.

Our results have important implications for policy and fiscal governance in Europe. If $r-g$ remains negative, the debt-carrying capability of governments in many countries is structurally higher now than in the 1990s when the European Union established its fiscal rules in the Maastricht Treaty. The recent debate on these fiscal rules has not, however, led to a revision of the 3% overall public deficit norm and the 60% public debt target. Although understandable from a political Treaty-related point of view, it may be regretted from an economic point of view.[17] In times of a great need for public investment and a greening of the economy, a higher debt-carrying capacity offers a unique opportunity. For example, the 'optimal' policy package of the IMF (2023b) to achieve net zero emissions also implies a limited increase of the debt-to-GDP ratio of 10 to 15 percentage points by 2050 in representative advanced economies. The required changes in the primary balance to bring public debt from currently on average about 80% of GDP in the European countries in our study (disregarding Greece and Italy) to 60% would make the achievement of net zero much harder.

Concurrently, our findings do not eliminate reasons for caution, though. Not only for the United States and Italy, but also for countries such as France and Belgium, today's expectations of the future primary deficit would imply debt ratios above 150% by 2040. Moreover, besides climate mitigation and adaptation also rising costs related to ageing and to defence put pressure on all countries' public budgets. Last, the higher the debt level, the more vulnerable the fiscal situation will be to future adverse shocks that may push the interest rate above the growth rate. In our analysis we have accounted for endogenous interest rate changes due to standard crowding out effects, but for possible changes in the risk premium that are much harder to model. Policy makers are therefore not exempted from the task to strongly monitor their expenditures, balances and debt. Nor from the task to develop policies in the area of TFP and employment that we found influential in reducing the interest-growth difference.

CRediT authorship contribution statement

Freddy Heylen: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Marthe Mareels:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Christophe Van Langenhove:** Data curation, Formal analysis, Investigation, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[17] Also authors from the European Stability Mechanism advocated a revision of the public debt target from 60% to 100% of GDP (ESM, 2021).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jimonfin.2024.103093.

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Appendix 1: Data description and sources

Gross government debt in percent of GDP

Source: OECD Economic Outlook No. 109 (series GGFLMQ). Data before 1995 has been obtained by extrapolation with data from EU Commission (AMECO, series UDGGL) and IMF (WEO and Historical Public Debt database). Data for the USA have been taken from FRED.

Gross general government interest payments

Source: OECD Economic Outlook No. 109 (series GGINTP and GDP). Missing data for Germany, Greece and Ireland have been obtained by extrapolation with data from the World Bank.

Implicit nominal interest rate r

Computed for year t as gross government interest payments in year t divided by government debt in year t-1, i.e. r(t) = GGITNP(t)/(GGFLMQ(t-1)*GDP(t-1))

Gross domestic product, nominal value, growth

Source: OECD Economic Outlook No. 109 (series GDP_ANNPCT)

Output gap in percent of potential GDP

Source: OECD Economic Outlook No. 109 (series GAP). Missing data for Germany, Greece and Ireland, and data for the years before 1985, have been obtained by extrapolation from IMF (WEO) data.

Primary balance as a percentage of GDP

Source: OECD Economic Outlook No. 109 (series NLGXQ). Missing data for Germany, Greece and Ireland have been obtained by extrapolation with data from IMF (Public Finances in Modern History).

Inflation (*GDP market prices, deflator, growth)*

Source: OECD Economic Outlook No. 109 (series PGDP_ANNPCT). Missing data for Germany and Greece have been obtained by extrapolation with data from IMF (WEO). The data for the year 1991 for Germany has been taken from ECB.

Short-term interest rate

Source: OECD Economic Outlook No. 109 (series IRS). Missing data for Germany, Greece, Ireland and Sweden in the 1980s and early 1990s has been obtained by extrapolation with data from EU Commission (AMECO).

The Gini Index, disposable income

Source: Solt, F. (2020). Measuring income inequality across countries and over time: The Standardized World Income Inequality Database. *Social Science Quarterly*, *101*, 1183-1199 (SWIID Version 9.1., series gini_disp).

Life expectancy at birth in years

Source: The World Bank (series SP.DYN.LE00.IN, downloaded April 2021)

Growth of TFP at constant national prices

Source : Penn World Tables 10.0 (series rtfpna)

Working age population growth (growth of population aged 15-64)

Source: The World Bank (series SP.POP.1564.TO, downloaded April 2021)

Employment growth

Source: OECD Economic outlook No. 109 (series ET_ANNPCT). Missing data for Germany, Greece and Ireland are extrapolated with data taken from Penn World Tables (series emp).

Growth of the employment rate

Computed as the difference between employment growth and working age population growth

Population of ages 65 and above, percent of total population

Source: The World Bank (series SP.POP.65UP.TO.ZS, downloaded April 2021)

Population of ages 0-14, percent of total population

Source: The World Bank (series SP.POP.0014.TO.ZS, downloaded April 2021)

QE: Quantitative easing

Computed as public sector assets bought by the central bank in year t (flow) as a percentage of outstanding public debt in t.

Source: Databases of the central banks of the countries in our sample.

Appendix 2: Time series properties of the data, panel unit root tests

We ran country-specific ADF tests, the p-values of which we then used in an intersection test for panel unit roots as proposed by Hanck (2013). The test is robust to general patterns of cross-sectional dependence and yet straightforward to implement. Table A1 summarizes our results. We report both the number of countries (out of 17) in our sample for which the ADF test rejects the null hypothesis of nonstationarity at the 5% significance level, and the conclusion of the Hanck panel unit root test.[1]

As to the explanatory variables in our model, the Hanck test cannot reject nonstationary for three demographic variables, the fiscal variables, inequality (Gini), and the short-term nominal interest rate.[2] By contrast, nonstationarity is strongly rejected for TFP growth, employment growth, inflation and the output gap. More caution seems needed in the interpretation of the results for $r - g$ and working age population growth. For these two variables the Hanck test rejects the unit root for the panel, despite that for at least 11 out of 17 countries (including the US, Germany and the UK) nonstationarity cannot be rejected. When we report our regression results and assess their quality, we take that observation into account. Since the null of a unit root cannot be rejected for $r - g$ in so many countries, nor in several explanatory variables, we also execute unit root tests on the residuals of our regressions. Meaningful results require stationary residuals.

Table A1. Unit root tests (1981-2018)

	Number of countries with p-value below 5% in the ADF test[1]	Hanck panel unit root test. Reject unit root?
$r - g$	6	yes
TFP growth	12	yes
Working age population growth	2	yes
Employment growth	12	yes
Old age dependency	0	no
Young age dependency	2	no
Life expectancy	0	no
Gini	2	no
Primary balance	5	no
Public debt ratio	1	no
Inflation	11	yes
Output gap	13	yes
Short-term interest rate	0	no

Note: 1. ADF test with drift. The number of lags has been determined using the AIC and may differ by country. The alternative BIC did not yield different results.

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[1] To determine the optimal number of lags for the ADF test we use the Akaike Information Criterion (AIC). The procedure of the Hanck panel test for a particular variable is as follows: we retrieve the p-values of the ADF test for all the cross-sections and arrange them in ascending order (= from most to least significant). Next, we compare $p_{(j)}$ with the critical point $j \cdot \alpha/n$ for each j with n denoting the number of series in the panel. The null hypothesis is rejected at level α if and only if $p_{(j)} \leq j \cdot \alpha/n$ for some $j \in \mathbb{N}_n$. In our sample $n = 17$. We report in Table A1 the test results imposing a value of 0.05 for α.

[2] For the first differences of all these variables nonstationarity is rejected.

Appendix 3: Instrumental variables

For the four endogenous explanatory variables in equation (1), which are vulnerable to possible correlation with the error term in the regressions, we suggest the instruments displayed in Table A2. We then conduct a regression of each of these four endogenous variables on all exogenous variables from equation (1) and the entire list of proposed instruments. This so-called first stage regression is subsequently used to execute Wald tests of instrument significance, with outcomes presented in Table A3. All Wald tests yield F-statistics that exceed Staiger and Stock's (1997) rule of thumb value of 10.

Table A2. List of possible instruments for the endogenous variables.

Variable	***Suggested instruments***
TFP growth	TFP growth (t-2) TFP growth (t-3) Output gap (t-2) Output gap (t-3) Dummy Ireland 2015 [1] Dummy Ireland 2016
Growth of the employment rate	Growth of the employment rate (t-2) Growth of the employment rate (t-3) Labor tax rate (t) [2] Labor tax rate (t-1) Oil price (t) [3] Oil price (t-1)
Inflation	Inflation (t-2) Inflation (t-3) Short-term interest rate (t-2)
Output gap	Output gap from advanced economies (t) Output gap from advanced economies (t-1)

Notes: 1.The two dummies capture hard to explain extreme movements in TFP growth in Ireland in 2015 (+17%) and 2016 (-7%) in the Penn World Tables 10.0.
2. The labor tax rate was calculated as (compensation rate/wage rate) – 1.
3. The oil price refers to the USD price per barrel of spot brent oil.
Data sources for these instruments: OECD Economic Outlook No. 109 (series WSST, WRT, WPBRENT).

Table A3. Wald tests of instrument significance.

Regression	***F-statistic Wald test***
Regression (4)	
TFP growth	20.3
Growth of the employment rate	19.8
Inflation	14.4
Output gap	36.0
Regression (6)	
TFP growth	16.2
Growth of the employment rate	19.1
Inflation	12.2
Output gap	33.6

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Appendix 4A: Complementary regressions – robustness tests [1]

Column (4b) extends (4) with time fixed effects. Column (4c) and column (6b) follow from estimating (4) and (6) using instrumental variables as defined in Appendix 3.
In Column (7) we added a lagged dependent variable to our baseline regression in (6).

	(4)	(4b)	(4c) IV [6]	(6)	(6b) IV [6]	(7)
One period lagged r-g						0.098***
						(0.025)
TFP growth	-0.927***	-0.929***	-0.937***	-0.863***	-0.965***	-0.923***
	(0.050)	(0.054)	(0.055)	(0.055)	(0.062)	(0.060)
Growth of the employment rate [2]	-0.592***	-0.541***	-0.711***	-0.515***	-0.740***	-0.441***
	(0.041)	(0.049)	(0.113)	(0.037)	(0.078)	(0.039)
Old age dependency 65-75	0.003	0.148	-0.020	0.016	0.064	0.028
	(0.113)	(0.102)	(0.132)	(0.091)	(0.110)	(0.079)
Old age dependency 75+	0.396***	0.341**	0.319**	0.131	0.306*	0.098
	(0.146)	(0.140)	(0.133)	(0.150)	(0.168)	(0.132)
Young age dependency	-0.070	-0.042	-0.083	-0.046	-0.027	0.056
	(0.056)	(0.059)	(0.118)	(0.075)	(0.100)	(0.070)
Life expectancy	-0.638***	-0.411**	-0.584***	-0.483***	-0.642***	-0.375***
	(0.111)	(0.184)	(0.118)	(0.120)	(0.109)	(0.129)
Gini	-0.247***	-0.183**	-0.187***	-0.209***	-0.152***	-0.168***
	(0.065)	(0.072)	(0.057)	(0.040)	(0.049)	(0.033)
Primary balance	-0.043*	-0.055*	-0.016	-0.078**	-0.024	-0.066*
	(0.025)	(0.030)	(0.041)	(0.031)	(0.036)	(0.034)
Public debt ratio	0.032***	0.031***	0.016***	0.019***	0.012**	0.011**
	(0.007)	(0.008)	(0.006)	(0.005)	(0.006)	(0.006)
Public debt ratio x Dummy90+	0.001	0.001	0.001	0.005***	0.002	0.005***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)
QE	-0.050**	0.022	-0.028	-0.040**	-0.052***	-0.016
	(0.025)	(0.041)	(0.019)	(0.020)	(0.018)	(0.016)
Inflation	-1.070***	-1.070***	-1.163***	-0.990***	-1.079***	-0.944***
	(0.041)	(0.045)	(0.144)	(0.039)	(0.101)	(0.041)
Output gap	-0.054**	-0.101***	-0.095	-0.055**	-0.137***	-0.046
	(0.023)	(0.034)	(0.060)	(0.027)	(0.050)	(0.029)
Short-term interest rate	0.392***	0.366***	0.423***	0.337***	0.322***	0.333***
	(0.025)	(0.028)	(0.060)	(0.029)	(0.052)	(0.028)
Cross-sectional average *r-g* [3]	CS	CS	CS	CS	CS	CS
$(r-g)_{US}$ [4]				CS	CS	CS
Observations	643	643	556	643	556	628
Country fixed effects	yes	yes	yes	yes	yes	yes
Time fixed effects	no	yes	no	no	no	no
R^2	0.90	0.87	0.91	0.93	0.93	0.93
R^2 adjusted	0.89	0.85	0.90	0.92	0.92	0.92
Cointegration [5]	yes	yes	yes	yes	yes	yes

Notes : 1, 2, 3, 4, 5: see Table 2 in the main text.
6: Instrumented variables: TFP growth, growth of the employment rate, output gap, and inflation. See main text and Appendix 3.

Appendix 4B: Complementary regressions – robustness tests [1]

Instead of the implicit nominal interest rate r, we use in column (7) the nominal market rate on 10-year government bonds (r_m) to compute the interest–growth difference. Columns (8) – (10) report regression results for the separate components of the interest–growth difference.

	(6) $r - g$	(7) $r_m - g$	(8) r	(9) r_m	(10) g
TFP growth	-0.863***	-0.941***	0.023	0.037	0.971***
	(0.055)	(0.064)	(0.020)	(0.024)	(0.042)
Growth of the employment rate [2]	-0.515***	-0.607***	0.004	-0.026	0.575***
	(0.037)	(0.068)	(0.021)	(0.053)	(0.025)
Old age dependency 65-75	0.016	-0.095	-0.104***	-0.242***	-0.170**
	(0.091)	(0.103)	(0.039)	(0.083)	(0.066)
Old age dependency +75	0.131	0.427***	-0.303**	-0.048	-0.248***
	(0.150)	(0.145)	(0.131)	(0.111)	(0.082)
Young age dependency	-0.046	0.134**	-0.002	0.015	-0.114*
	(0.075)	(0.068)	(0.040)	(0.079)	(0.063)
Life expectancy	-0.483***	-0.296**	-0.220**	-0.045	-0.030
	(0.120)	(0.129)	(0.106)	(0.109)	(0.072)
Gini	-0.209***	-0.015	-0.138**	-0.063	-0.010
	(0.040)	(0.069)	(0.053)	(0.058)	(0.046)
Primary balance	-0.078**	-0.113***	-0.003	-0.036	0.052**
	(0.031)	(0.036)	(0.015)	(0.022)	(0.022)
Public debt ratio	0.019***	0.026***	0.007	0.014***	-0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
Public debt ratio x dummy	0.005***	0.009***	0.001	0.007***	-0.007***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
QE	-0.040**	-0.223***	0.001	-0.125***	0.083***
	(0.020)	(0.053)	(0.010)	(0.032)	(0.019)
Inflation	-0.990***	-0.759***	0.031	0.120***	1.023***
	(0.039)	(0.043)	(0.025)	(0.033)	(0.028)
Output gap	-0.055**	-0.201***	-0.002	-0.115***	0.094***
	(0.027)	(0.034)	(0.025)	(0.032)	(0.020)
Short-term interest rate	0.337***	0.572***	0.134***	0.451***	-0.046***
	(0.029)	(0.043)	(0.027)	(0.054)	(0.013)
Cross-sectional average r-g [3]	CS	CS	CS	CS	CS
$(r-g)_{US}$ [4]	CS	CS	CS	CS	CS
Observations	643	629	643	629	643
Country fixed effects	yes	yes	yes	yes	yes
R^2 adjusted	0.92	0.89	0.95	0.96	0.98
Cointegration [5]	yes	yes	yes	yes	yes

Notes : 1, 2, 3, 4, 5: see Table 2 in the main text. There are no time fixed effects included.

Appendix 4C: Complementary regressions – robustness tests [1]

In this appendix we introduce two alternative indicators for the fiscal situation: the gap between the primary balance and its required level to stabilize the debt ratio, indicated as 'fiscal effort', and the long-term sovereign debt rating. Equations (12) and (14) include the latter variable. They are estimated over 1990-2018 due to a lack of data for the 1980s.

	$r-g$			$r_m - g$	
	(6)	(11)	(12)	(13)	(14)
TFP growth	-0.863***	-0.795***	-0.938***	-0.840***	-0.955***
	(0.055)	(0.044)	(0.065)	(0.049)	(0.101)
Growth of the employment rate [2]	-0.515***	-0.403***	-0.528***	-0.460***	-0.620***
	(0.037)	(0.044)	(0.054)	(0.056)	(0.051)
Old age dependency 65-75	0.016	0.018	0.135	-0.126	-0.058
	(0.091)	(0.095)	(0.156)	(0.104)	(0.144)
Old age dependency 75+	0.131	0.073	0.115	0.434***	0.263
	(0.150)	(0.141)	(0.184)	(0.145)	(0.186)
Young age dependency	-0.046	-0.011	0.110	0.138**	-0.134
	(0.075)	(0.072)	(0.106)	(0.068)	(0.121)
Life expectancy	-0.483***	-0.419***	-0.965***	-0.272**	-1.185***
	(0.120)	(0.113)	(0.149)	(0.113)	(0.173)
Gini	-0.209***	-0.145***	-0.077	0.034	0.048
	(0.040)	(0.042)	(0.096)	(0.063)	(0.123)
Primary balance	-0.078**		-0.111**		-0.139**
	(0.031)		(0.043)		(0.054)
Fiscal effort		-0.132***		-0.186***	
		(0.025)		(0.026)	
Public debt ratio	0.019***	0.014***	0.011*	0.020***	0.005
	(0.005)	(0.004)	(0.006)	(0.005)	(0.011)
Public debt ratio x Dummy90+	0.005***	0.006***		0.009***	
	(0.002)	(0.001)		(0.002)	
QE	-0.040**	-0.026	-0.024	-0.202***	-0.149***
	(0.020)	(0.020)	(0.026)	(0.052)	(0.043)
Inflation	-0.990***	-0.916***	-0.840***	-0.658***	-0.736***
	(0.039)	(0.041)	(0.040)	(0.050)	(0.077)
Output gap	-0.055**	-0.026	-0.024	-0.163***	0.054
	(0.027)	(0.025)	(0.040)	(0.034)	(0.073)
Short-term interest rate	0.337***	0.320***		0.532***	
	(0.029)	(0.027)		(0.041)	
Sovereign debt rating			-0.185***		-0.689***
			(0.048)		(0.103)
Cross-sectional average *r-g* [3]	CS	CS	CS	CS	CS
$(r-g)_{US}$ [4]	CS	CS	CS	CS	CS
Observations	643	628	493	615	488
Country fixed effects	yes	yes	yes	yes	yes
R^2 adjusted	0.92	0.93	0.90	0.91	0.89
Cointegration [5]	yes	yes	yes	yes	yes

Notes : 1, 2, 3, 4, 5: see Table 2 in the main text. There are no time fixed effects included.

Appendix 5: Projected and required primary balances for public debt stability

Table A4 below summarizes the IMF's (October 2022) primary balance projections for all countries included in Figure 3 in the main text. Furthermore, it shows the required primary surplus or the allowed primary deficit in 2022-2040 according to our model to generate a public debt ratio in 2040 equal to its 2021 level. Lower targeted debt ratios would require higher primary balances, and vice versa.

Table A4. Projected and required primary balances for public debt stability (at the 2021 level)

	Projected primary balance 2027 (IMF)	Required/allowed primary balance (2022-2040) to obtain a public debt ratio in 2040 equal to its 2021 level			Projected primary balance 2027 (IMF)	Required/allowed primary balance (2022-2040) to obtain a public debt ratio in 2040 equal to its 2021 level	
		Public debt 2021 (model prediction)	Required/allowed primary balance			Public debt 2021 (model prediction)	Required/allowed primary balance
US	-3.5%	136%	1.4%	Ireland	1.1%	56%	-3.2%
Canada	-0.7%	109%	-0.7%	Netherlands	-2.5%	52%	-1.1%
Germany	0.2%	64%	-1.5%	Denmark	-0.2%	27%	-0.4%
France	-3.1%	109%	-1.4%	Sweden	0.2%	39%	-1.3%
UK	0.1%	102%	-0.4%	Greece	2.0%	212%	1.8%
Austria	-0.3%	82%	-1.4%	Italy	0.1%	148%	0.6%
Belgium	-3.7%	109%	-1.8%	Portugal	0.9%	118%	-1.7%
Finland	-2.6%	66%	-0.9%	Spain	-2,0%	113%	-0.9%

Note: All data in percent of GDP.

Appendix 6: A measure of uncertainty in future $r - g$ projections

In this appendix we show the variation in our future projections for $r - g$ if the 'shocks' of the past occurred again in the future. Practically, we ran 25 simulations for three European countries with a different public debt level but an institutional and monetary context that is not too far away from today's context (e.g. EU membership, fixed exchange rate): Germany, Belgium and Denmark. In each simulation we take as given our baseline projections for the demographic variables, inequality, and the two policy variables (QE and the primary balance). For the other variables (TFP growth, employment growth, the output gap, inflation, and the short-term interest rate) we allow shocks with realistic characteristics in size, autocorrelation and co-variance. More precisely, we simulate our model for 2028-2040 while subsequently imposing for the 'shock variables' their observed data in 1982-1994 (first simulation), 1983-1995 (second simulation), 1984-1996 (third simulation), and so on. The last simulation uses the observed data for the 'shock variables' in 2006-2018. This gives us 25 simulations for each country. The figures below reveal for each year from 2028 to 2040 the distribution of the projected values for $r - g$. For each country we conclude that if the shocks of the past happened again, this would in the majority of scenarios raise $r - g$. A comparison of the median (50^{th} percentile) scenario with our baseline suggests an increase of about 1 percentage point in Germany and Denmark and of about 0.5 percentage point in Belgium. Nevertheless, in Germany the implied $r - g$ would remain negative in about 90% of the 'shock scenarios'. In Denmark that would be in about 70% and in Belgium in about 50% of the scenarios.

Figure A1. Variation in $r - g$ projections if the shocks of the past happened again in the future.