WORKING PAPER

HAVE INFLATION AND MONETARY TIGHTENING CHANGED THE GAME? LONG-RUN PERSPECTIVES ON THE INTEREST – GROWTH DIFFERENCE ON PUBLIC DEBT

Freddy Heylen
Marthe Mareels
Christophe Van Langenhove

February 2023
2023/1065

GHENT UNIVERSITY

Department of Economics

Faculty of Economics and Business Administration
Campus Tweekerken, St.-Pietersplein 5, 9000 Ghent - BELGIUM

Have inflation and monetary tightening changed the game? Long-run perspectives on the interest – growth difference on public debt

Freddy Heylen*, Marthe Mareels and Christophe Van Langenhove

Department of Economics, Ghent University

February 2023

Abstract

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 drivers of the interest–growth difference, our approach and contribution are to highlight in particular the impact of real long-run drivers, 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 projections suggest that the major shocks that hit many economies in 2022-2023 have not fundamentally changed the game. Our baseline expectation is that the structural drivers of the interest rate and growth will keep $r - g$ below zero for the next two decades in most European countries that we study. For the US, however, our baseline projection of $r - g$ is positive.

Keywords : public debt, $r - g$, fiscal sustainability, demographic change, inequality

JEL Codes : E43; E62; H63; H68; J11

Declarations of interest : none

* This paper is an updated version of our earlier paper "Should we worry about public debt? An empirical analysis of r – g in OECD countries" (February 2022). Russia's invasion of Ukraine and the induced energy crisis, the explosion of inflation and drastic monetary tightening raised the question of whether our earlier conclusions would still be valid.

We thank Gerdie Everaert, Ewoud Quaghebeur, Selien De Schryder, Gert Peersman and participants at an UGent Macroeconomics Seminar for useful suggestions, comments, and active discussion of an earlier draft of this paper. We are very grateful to Lars Heylen for excellent research assistance.

Corresponding author: Freddy Heylen, Department of Economics, Ghent University, Sint-Pietersplein 6, 9000 Ghent, Belgium. E-mail: Freddy.Heylen@UGent.be.

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. While this difference was positive in the OECD most of the time in 1981-2014, it turned negative in 2015 (Figure 1). 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. Recent OECD data for 2021-2022 confirm that position. In all four country groups in Figure 1, $r-g$ returned to clearly negative territory. For governments, this is of major importance. If structural, a negative $r-g$ allows highly indebted 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.

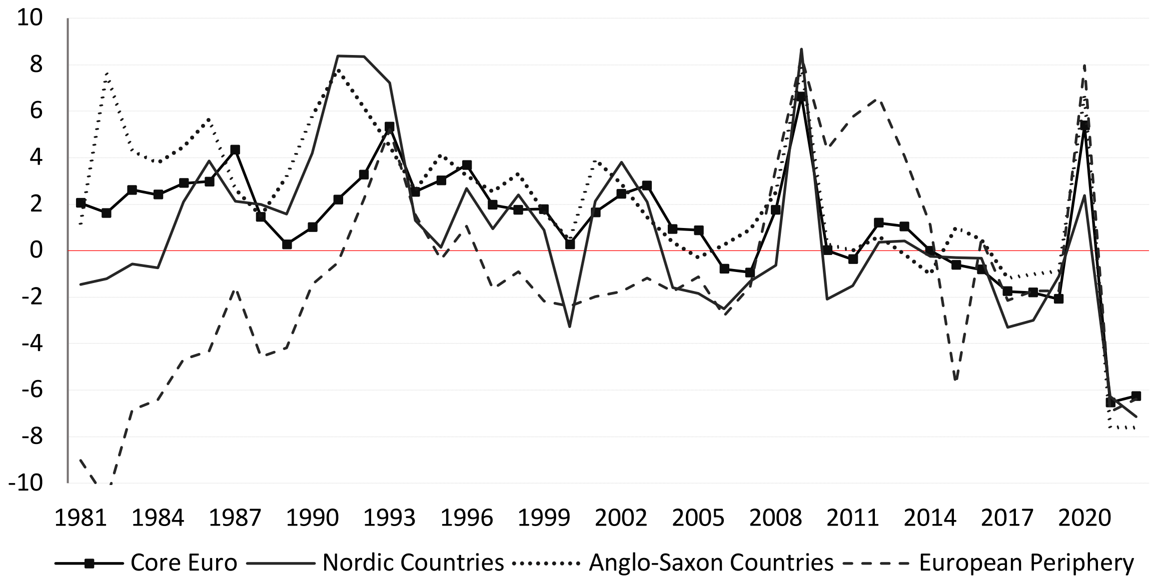
Russia's invasion of Ukraine, however, dramatically changed that picture. It slowed the recovery from the covid-19 recession and sharpened increases in food and energy prices and supply-chain bottlenecks, pushing inflation in many countries to levels not seen since the 1970s. To fight inflation, many central banks aggressively changed course. In addition to (announcing) a reduction of their balance sheets, they raised their policy rates. Both interventions pushed long-term interest rates to the highest level in a decade and further slowed economic growth. If we add to this the negative impact of the new situation on governments' primary balances, for example due to rising expenditures on defence, which may also drive interest rates higher, the obvious question follows whether the years of negative $r-g$ and related fiscal comfort are over.

Given that most of the action is expected 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; Kozlowski et al., 2020; 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. 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

[1] See for example Blanchard (2019) and Blanchard et al. (2021). Assuming a constant primary deficit $\bar{d}$, and given interest and growth rates, it can be shown that the debt ratio will converge to a sustainable finite value equal to $\frac{\bar{d}(1+g)}{(g-r)}$.

Figure 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 Appendix 1. Data for 2022 are based on OECD (2022, *Economic Outlook*, n° 111).

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.

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 since 2022.

Our paper intends to contribute 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) for OECD countries, Escolano et al. (2017), Presbitero and Wiriadinata (2020) 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 drivers of the interest–growth gap, our approach and contribution are to highlight in particular the impact of real long-run drivers, 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 (see e.g. EFB, 2020; 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 public debt 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 drivers 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) and The Economist (2022a), at least when it comes to Europe. The US 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. This finding, however, does not exempt governments from caution in fiscal policies and control of primary deficits. Even if not directly unsustainable, if today's IMF projections of future primary balances persist, public debt ratios would rise to levels above 140% also in European countries such as Belgium, France and Spain.

The remainder of this paper is organized as follows. Section 2 surveys the literature on the drivers 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 advances some policy implications.

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

We first discuss the impact of structural drivers 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 go into the effect of a set of additional variables of a more short-term nature: monetary policy, inflation, and specific crises.

2.1. Long-run drivers

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 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. It depends theoretically on whether θ is greater or smaller than 1. Under log utility, i.e. with 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 center 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.

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

[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.

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] 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), Devriendt and Heylen (2020) 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 net 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. In some of our empirical specifications we will therefore distinguish 'young' and 'old' retirees in percent of total population.

[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 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; Cynamon and Fazzari, 2016; 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 economic growth is subject of more controversy. OECD (2015) reviews the theoretical and empirical literature. In theory, higher inequality may promote growth for example because it fosters incentives to work, invest and undertake risks to benefit from high rewards. 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.

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; Presbitero and Wiriadinata, 2020).

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 confirm this negative effect of public debt on subsequent growth (e.g. Reinhart and Rogoff, 2010; Eberhardt and Presbitero, 2015; Woo and Kumar, 2015; Chudik et al., 2017). Also here, thresholds seem to 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).

Checherita-Westphal and Domingues Semeano (2020) confirm the existence of significant positive effects of public debt on $r - g$. In their base model, a 1 percentage point increase in the public debt ratio pushes $r - g$ almost 4 basis points higher. However, they find no non-linear threshold effect. A 1 percentage point decrease in the primary balance ratio in their study brings about a rise by almost 30 basis points in $r - g$.

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

Even though our paper is mainly focused on real long-run drivers of $r - g$, we will 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 (conventional and unconventional) *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; Hohberger et al., 2019).

Although both the 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 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 1975-95. Escolano et al. (2017) report similar findings.

To capture *business cycle effects*, a standard approach in the literature is to include the output gap. We will follow this approach. Furthermore, crisis or other dummies could be added to account for unique temporary effects related to specific periods in particular countries. For example, in some of their estimated equations for $r - g$, Checherita-Westphal and Domingues Semeano (2020) add dummies to capture the specific effects, if any, of the global financial crisis and the European sovereign debt crisis. They also include a dummy to capture the effect of euro area membership. In our regressions we will also test for such specific effects.

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 different policies or different 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). 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 of all explanatory variables that we consider.

[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.

Table 1. Description of considered explanatory variables

Variable	*Definition*
TFP growth	yearly growth rate of TFP (in %)
working age population growth	yearly growth rate of population aged 15-64 (in %)
employment growth	yearly growth rate of employment (persons, in %)
old age dependency	population 65 and older in % of total population
young age dependency	population aged 0-14 in % of total population
life expectancy	life expectancy at birth at time t-20 (in years)
Gini index	Gini index for disposable income (scale 0-100 with 0 perfect equality)
inflation	yearly change of the GDP deflator (in %)
output gap	(actual output – potential output) / potential output (in %)
short-term interest rate	3-month government T-bill rate (in %)
primary balance	primary balance of general government (in % of GDP)
public debt ratio	gross government debt (in % of GDP)
QE	public sector assets bought by the central bank (flow) in % of outstanding public debt
eurocrisis dummy	1 for euro area countries in years 2010-14
dummies related to other crises	1 in the specific crisis period (e.g. EMS crisis)
euro area membership	1 for euro area members

Note: For a description of data sources, see Appendix 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.[6] This observation justifies the specific error structure that we adopt in Equations (1) and (2).

Unit root tests reveal a great deal of *nonstationarity* in many of the variables in our model. 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 2 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.[7]

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.[8] 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

---

[6] Details are available from the authors upon simple request.

[7] 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 2 the test results imposing a value of 0.05 for α.

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

Table 2. 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.

17 countries (including the US, Germany and the UK) nonstationarity cannot be rejected. When we report our regression results and assess their quality in the next section, we will take this 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 will also execute unit root tests on the residuals of our regressions. Meaningful results require stationary residuals.

3.3. Results

Tables 3, 4 and 5 contain our regression results. Table 3 includes the growth rate of total working age population as proxy for the variable n in growth theory. Tables 4 and 5 include the growth rate of employment.

Column (1) in Table 3 shows the results of a straightforward one-way fixed effects estimation, without accounting for the possible impact of unobserved common factors. Column (2) includes the cross-sectional average of $r-g$, but imposes the same coefficient on this variable for all 17 countries. From column (3) on, we allow a different coefficient for each country, and thus a different response to our proxy for the common factor(s). Column (4) leaves room to different effects from the fraction of younger versus the fraction of older retired individuals. The younger group includes all individuals with an age between 65 and 75, the older group all those older than 75. Column (5) allows for different effects of the public debt ratio depending on its level. We impose a threshold at 90%. Alternative estimations with different thresholds never led to econometrically better results. Last, this column also assesses the impact of public asset purchases (QE) by the central bank.

Our findings in the different columns of Table 3 are remarkably robust. We draw six conclusions. *First*, controlling for unobserved common factors slightly improves the R^2 of the regressions, while leaving the estimated coefficients for the observed explanatory

Table 3. Empirical analysis of $r - g$ (17 OECD countries, 1981-2018)[1]

	(1)	(2)	(3)	(4)	(5)
TFP growth	-1.056***	-0.956***	-0.949***	-0.956***	-0.943***
	(0.074)	(0.062)	(0.056)	(0.055)	(0.056)
Working age population growth	0.225	0.176	0.177	0.117	0.226
	(0.287)	(0.358)	(0.347)	(0.351)	(0.326)
Old age dependency	-0.080	0.004	0.040		
	(0.111)	(0.105)	(0.109)		
Old age dependency 65-75				-0.148	-0.124
				(0.123)	(0.121)
Old age dependency 75+				0.427**	0.412*
				(0.178)	(0.202)
Young age dependency	-0.055	0.064	0.104	0.068	0.063
	(0.079)	(0.082)	(0.093)	(0.085)	(0.091)
Life expectancy	-0.407***	-0.274**	-0.322***	-0.481***	-0.428***
	(0.116)	(0.123)	(0.119)	(0.131)	(0.135)
Gini	-0.233**	-0.343***	-0.347***	-0.312***	-0.307**
	(0.103)	(0.111)	(0.099)	(0.106)	(0.107)
Primary balance	-0.169***	-0.137***	-0.134***	-0.148***	-0.158***
	(0.040)	(0.038)	(0.032)	(0.032)	(0.030)
Public debt ratio	0.033***	0.027***	0.028***	0.027***	0.022**
	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)
Public debt ratio x Dummy90+					0.006*
					(0.003)
QE					-0.105**
					(0.043)
Inflation	-1.171***	-1.104***	-1.106***	-1.106***	-1.094***
	(0.055)	(0.054)	(0.053)	(0.049)	(0.050)
Output gap	-0.159***	-0.143***	-0.141***	-0.132***	-0.136***
	(0.041)	(0.038)	(0.041)	(0.040)	(0.038)
Short-term interest rate	0.478***	0.453***	0.431***	0.436***	0.445***
	(0.047)	(0.041)	(0.032)	(0.030)	(0.029)
Cross-sectional average *r-g*		0.270***	CS [2]	CS [2]	CS [2]
		(0.046)			
Observations	643	643	643	643	643
Country fixed effects	yes	yes	yes	yes	yes
Time fixed effects	no	no	no	no	no
R^2	0.83	0.85	0.86	0.86	0.86
R^2 adjusted	0.82	0.84	0.84	0.85	0.85
Cointegration [3]	yes	yes	yes	yes	yes

Notes : 1. Estimated and Driscoll-Kraay (1998) corrected standard errors in brackets. * p<0.1; ** p<0.05; *** p<0.01.
2. CS: the model has been estimated with country-specific coefficients on the cross-sectional average $r - g$.
3. 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.

variables generally unaffected. This conclusion also holds when we allow country-specific coefficients on the common factor in column (3).

Second, for those variables that we have in common with existing studies, our results broadly confirm established findings. We also find that higher primary deficits (lower surpluses) and a higher public debt ratio raise $r - g$. The effects that we find are statistically highly significant, although they are a bit smaller in size than reported by Checherita-Westphal and Domingues Semeano (2020) in their study of $r - g$. They are also a bit smaller than the consensus estimates for the effects of the public debt ratio and the primary balance on r that we reported in Section 2. This is not unexpected, though, since our interest rate r is an average of current and past rates. In line with many studies, we also observe a non-linearity, with the effect of public debt getting stronger above a debt ratio of 90%. From that level on, there may be an adverse effect on the sovereign risk premium in the interest rate or a reinforcement of negative growth effects from high debt. Furthermore, column (5) reveals a significant negative effect of central banks' public asset buying programmes, confirming the observation of Checherita-Westphal and Domingues Semeano (2020).

Third, our results validate the favourable effects of inflation on $r - g$ and public debt dynamics. We observe a negative one-to-one relationship, which is not surprising since a higher growth rate of the GDP deflator feeds through directly in higher nominal GDP growth.[9] Obviously, if monetary authorities respond to higher inflation by raising short-term interest rates, this advantage will get smaller or disappear. Our estimates show a highly significant coefficient of about 0.45 on the short-term interest rate.

Our other conclusions are more innovative. They relate to the real long-run determinants that are at the center of our contribution. *Fourth*, in line with the findings of Lunsford (2017) and Lunsford and West (2019), faster technical progress and TFP growth raise overall economic growth much more than the interest rate, implying a significant decline in $r - g$. *Fifth*, as to the demographic variables, life expectancy is the only one with robust significant effects. In line with expectations that a longer life promotes savings, $r - g$ falls significantly in all five regressions in Table 3. Working age population growth and young age dependency always come out with small and statistically insignificant coefficients. Given the ambiguous theoretical effects of the first, and the lack of consensus in the literature regarding the latter, we should not be surprised about these two results. Given that we control for life expectancy, the absence of a significant (positive) effect on old-age dependency is harder to rationalize, at least at first sight. However, when we allow different effects for younger and older retirees in columns (4) and (5), more robust results arise. These seem to confirm the hypothesis and the findings of e.g. Kankaanranta (2019) that young retirees continue to save whereas it is mainly old retirees who dissave.

Last but not least, we obtain a highly significant negative coefficient on inequality (Gini) in all columns. This observation is fully in line with the hypothesis, and findings in the literature (see Section 2), that a more unequal income distribution raises aggregate savings and reduces the interest rate. If we accept this mechanism, our regressions allow no firm

[9] We tested whether this effect would become smaller over time. Including one, two or five periods lagged inflation, we expected to see a significant positive coefficient on (some of) these lagged terms. However, that was not the case, at least not when we also include the short-term nominal interest rate.

conclusions about the impact of inequality on growth. It can be positive or (mildly) negative. In the $r - g$ literature so far, the effect of inequality has been neglected.[10]

Following Checherita-Westphal and Domingues Semeano (2020), we added several dummy variables to the empirical model to capture the effects of specific crises (the EMS crisis in the early 1990s, the financial crisis in 2007-2008, the 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 noticeable difference for our results, however, when also other variables such as the output gap and the primary balance were included. Therefore, we do not maintain these dummy variables in further regressions.

Table 4 takes column (5) of Table 3 as its starting point, but adds employment growth as an indicator for the variable n in growth theory. This specification, in column (6), explains a notably larger fraction of the variation in $r - g$, as shown by the rise in the R^2. Employment growth obtains a significantly negative effect. Its contribution to economic growth proves stronger than its potential impact on the productivity of capital and the interest rate. Column (7) confirms this result. In that column we replace employment growth and working age population growth by their difference, i.e. the growth rate of the employment rate. Their opposite coefficients, which are not significantly different in absolute value, justify this restriction. The estimated coefficients for the other explanatory variables in column (7) are hardly affected, except for the primary balance and the interaction term testing for a threshold effect on the level of the public debt ratio. The estimated coefficient on the former gets a lot smaller in absolute value.[11] The latter is now both statistically and economically insignificant.

The other two columns in Table 4 test the robustness of the estimation result in (7). Including time fixed effects in column (7b) has no notable impact on the regression, except for QE. Time dummies may pick up its negative effect. In column (8) we account for the possible endogeneity of some explanatory variables and switch to an instrumental variables approach. The observation of cointegration in all regressions, and thus a stationary error term, implies that there can be no correlation of any importance between this error term and the nonstationary explanatory variables. This conclusion does not hold, however, for those variables in Table 2 for which we rejected nonstationarity (a unit root). They are instrumented. Appendix 2 shows the list of instruments and the outcome of the corresponding Wald-tests of their significance in the first-stage regression. The results of the IV regression in column (8) occur highly robust for about all variables. The primary balance and QE keep their negative signs, but the former now also loses its statistical significance. The same happens to the output gap.

Table 5 extends the set of explanatory variables in column (7) with one more determinant. Given the dominant impact of the US 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 US. Columns (9a) and (9b) in Table 5

[10] In Appendix 3 we report the effect of inequality on r and g separately. We obtain two negative effects. The one on r is much stronger and statistically significant. The one on g is weak and insignificant.

[11] Strong correlation (close to 0.55) between employment growth and the primary balance may explain this.

Table 4. Empirical analysis of $r - g$ (17 OECD countries, 1981-2018) – part 2 [1]

	(5)	(6)	(7)	(7b)	(8: IV) [5]
TFP growth	-0.943***	-0.929***	-0.927***	-0.929***	-0.847***
	(0.056)	(0.050)	(0.050)	(0.054)	(0.133)
Working age population growth	0.226	0.429*			
	(0.326)	(0.256)			
Employment growth		-0.598***			
		(0.040)			
Growth of the employment rate [2]			-0.592***	-0.541***	-0.711***
			(0.041)	(0.049)	(0.112)
Old age dependency 65-75	-0.124	-0.018	0.003	0.148	-0.108
	(0.121)	(0.102)	(0.113)	(0.102)	(0.157)
Old age dependency 75+	0.412**	0.387**	0.396***	0.341**	0.321**
	(0.202)	(0.151)	(0.146)	(0.140)	(0.142)
Young age dependency	0.063	-0.073	-0.070	-0.042	-0.251*
	(0.091)	(0.056)	(0.056)	(0.059)	(0.158)
Life expectancy	-0.428***	-0.633***	-0.638***	-0.411**	-0.610***
	(0.135)	(0.112)	(0.111)	(0.184)	(0.128)
Gini	-0.307***	-0.247***	-0.247***	-0.183**	-0.283***
	(0.107)	(0.065)	(0.065)	(0.072)	(0.067)
Primary balance	-0.158***	-0.037	-0.043*	-0.055*	-0.016
	(0.030)	(0.025)	(0.025)	(0.030)	(0.044)
Public debt ratio	0.022**	0.031***	0.032***	0.031***	0.014**
	(0.009)	(0.008)	(0.007)	(0.008)	(0.006)
Public debt ratio x Dummy90+	0.006*	-0.00004	0.001	0.001	0.0004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
QE	-0.105**	-0.048*	-0.050**	0.022	-0.010
	(0.043)	(0.025)	(0.025)	(0.041)	(0.025)
Inflation	-1.094***	-1.068***	-1.070***	-1.070***	-1.129***
	(0.050)	(0.042)	(0.041)	(0.045)	(0.162)
Output gap	-0.136***	-0.054**	-0.054**	-0.101***	-0.105
	(0.038)	(0.024)	(0.023)	(0.034)	(0.064)
Short-term interest rate	0.445***	0.393***	0.392***	0.366***	0.402***
	(0.029)	(0.025)	(0.025)	(0.028)	(0.071)
Cross-sectional average $r - g$ [3]	CS	CS	CS	CS	CS
Observations	643	643	643	643	594
Country fixed effects	yes	yes	yes	yes	yes
Time fixed effects	no	no	no	yes	no
R^2	0.86	0.90	0.90	0.87	0.90
R^2 adjusted	0.85	0.89	0.89	0.85	0.89
Cointegration [4]	yes	yes	yes	yes	yes

Notes : 1. Estimated and Driscoll-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. 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.
5. Instrumented variables: TFP growth, growth of the employment rate, output gap, and inflation. See main text and Appendix 2.

Table 5. Empirical analysis of $r - g$ (17 OECD countries, 1981-2018) – part 3 [1]

	(7)	(9a)	(9b)	(10) IV [5]	(11) $r_m - g$
TFP growth	-0.927***	-0.918***	-0.863***	-0.865***	-0.941***
	(0.050)	(0.052)	(0.055)	(0.137)	(0.064)
Growth of the employment rate [2]	-0.592***	-0.585***	-0.515***	-0.747***	-0.607***
	(0.041)	(0.039)	(0.037)	(0.077)	(0.068)
Old age dependency 65-75	0.003	0.015	0.016	0.046	-0.095
	(0.113)	(0.113)	(0.091)	(0.116)	(0.103)
Old age dependency 75+	0.396***	0.380**	0.131	0.378**	0.427***
	(0.146)	(0.150)	(0.150)	(0.162)	(0.145)
Young age dependency	-0.070	-0.073	-0.046	-0.036	0.134**
	(0.056)	(0.055)	(0.075)	(0.111)	(0.068)
Life expectancy	-0.638***	-0.610***	-0.483***	-0.585***	-0.296**
	(0.111)	(0.117)	(0.120)	(0.113)	(0.129)
Gini	-0.247***	-0.233***	-0.209***	-0.272***	-0.015
	(0.065)	(0.068)	(0.040)	(0.078)	(0.069)
Primary balance	-0.043*	-0.041	-0.078**	-0.010	-0.113***
	(0.025)	(0.025)	(0.031)	(0.007)	(0.036)
Public debt ratio	0.032***	0.032***	0.019***	0.010	0.026***
	(0.007)	(0.006)	(0.005)	(0.007)	(0.005)
Public debt ratio x Dummy90+	0.001	0.0005	0.005***	0.003	0.009***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
QE	-0.050**	-0.053**	-0.040**	-0.033*	-0.223***
	(0.025)	(0.027)	(0.020)	(0.017)	(0.053)
Inflation	-1.070***	-1.073***	-0.990***	-1.219***	-0.759***
	(0.041)	(0.041)	(0.039)	(0.137)	(0.043)
Output gap	-0.054**	-0.060**	-0.055**	-0.083	-0.201***
	(0.023)	(0.025)	(0.027)	(0.059)	(0.034)
Short-term interest rate	0.392***	0.384***	0.337***	0.377***	0.572***
	(0.025)	(0.025)	(0.029)	(0.060)	(0.043)
$(r - g)_{US}$		0.062*	CS [6]	CS [6]	CS [7]
		(0.036)			
Cross-sectional average *r-g* [3]	CS	CS	CS	CS	CS [7]
Observations	643	643	643	594	629
Country fixed effects	yes	yes	yes	yes	yes
Time fixed effects	no	no	no	no	no
R^2	0.90	0.90	0.93	0.92	0.91
R^2 adjusted	0.89	0.89	0.92	0.91	0.89
Cointegration [4]	yes	yes	yes	yes	yes

Notes : 1, 2, 3, 4, 5: see Table 4.

6: 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.

7: CS: the model has been estimated with country-specific coefficients on the cross-sectional average of $r_m - g$ and with country-specific coefficients on $r_m - g$ in the US. As relevant 'foreign' $r_m - g$ to explain the US data in the panel, we include the average of $r_m - g$ in Germany, the UK and Canada.

test this hypothesis. In (9a) we impose the same coefficient on all countries, whereas (9b) allows country-specific coefficients. This extension further increases the explanatory power of the regression. The common coefficient in column (9a) is statistically significant at the 10% level. When we allow country-specific coefficients in (9b), these are significant at the 5% level in the majority of countries.[12] The estimated coefficients on all other explanatory variables remain robust. The threshold dummy on the public debt ratio regains statistical significance in (9b). Only 'Old age dependency 75+' loses its statistical significance in that column.

The results of the IV estimation in column (10) are highly similar to those of column (8) in Table 4. The only difference seems to be that 'Young age dependency' is again statistically insignificant, as in about all our earlier regressions. The primary balance, the threshold effect on public debt and the output gap have their expected signs, but in both IV regressions they are statistically insignificant.

Column (11) estimates our model with an alternative dependent variable. Instead of the implicit nominal interest rate r, we use the nominal market rate on 10-year government bonds (r_m) to compute the interest–growth difference. We can again conclude that our earlier findings are highly robust for most variables, both with respect to their estimated sign and their statistical significance. Only the Gini coefficient loses the significance that it had in all regressions reported so far. Furthermore, we observe (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 is stronger. The effect of public asset purchases by the central bank (QE) becomes more negative. Changes in the nominal short-term interest rate feed through stronger in r_m than in r. Last, the effect of inflation is now significantly lower than 1 in absolute value. Appendix 3 includes regressions for r, r_m and g as separate dependent variables.

Our regressions all estimated long-run cointegration relationships. In Appendix 4 we allow different dynamic patterns by including a lagged dependent variable and allowing more time for $r - g$ to respond to changes in demographic variables. This, however, does not affect our main findings. Estimated long-run effects remain largely unchanged.

Looking back at our results in Tables 3 to 5, we can now draw conclusions:

- From growth theory we learn that technical progress and employed population growth are key determinants of both the interest rate and the economic growth rate. Empirically, the effect on g is clearly stronger. Growth promoting policies that target TFP or employment may imply higher r, but their net effect on $r - g$ is clearly and robustly negative.
- Demographic change does affect $r - g$, although not all variables matter. We find no robust significant 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

[12] 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.

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. Whereas young retirees do not seem to save significantly less than people at working age, old retirees do. Only old retirees seem to dissave as predicted by lifecycle theory. Last but not least, all our results show a strong and very significant negative effect on $r-g$ from rising life expectancy. This finding is fully in line with the results of calibrated OLG models studying the effects of demographic change, but it has been neglected by earlier empirical work studying $r-g$.

- We obtain a highly significant negative coefficient on inequality (Gini) in all regressions explaining $r-g$. 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.
- All our regressions confirm that a rise in the public debt ratio implies a higher $r-g$. 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. We learn from our regressions that as soon as we control for employment growth, the primary balance loses a lot of its explanatory power. Public debt above 90% of GDP tends to raise $r-g$ more than below 90%, but this difference is statistically significant in less than half of our regressions.
- Due to its direct effect on nominal GDP growth and its very slow impact on the implicit nominal interest rate, higher inflation has a robust favourable impact 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.

4. Projections

4.1. Underlying assumptions

Having estimated the impact of the long-term drivers of the interest–growth difference, we are now able to make projections for $r-g$ for the next two decades. For these projections we rely on available forecasts from:

- the IMF World Economic Outlook (October 2022)
- the OECD Demography and Population databases (December 2021)
- the World Bank's World Development Indicators (December 2021)
- the OECD's most recent '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, Figures 2a and 2b show the historical values and our adopted projections for the future path of the determinants of $r-g$ in the US, Germany and France. 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 run until 2027. For employment growth, the IMF provides forecasts until 2024. *For later years*, we have 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.[13] Compared to Autumn 2021 when the first central banks turned hawkish, these longer term bond yields capture a significant amount of monetary tightening.[14] 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, it is unlikely that the current situation of accumulated negative supply shocks that have provoked tight monetary policy is 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 that all central banks stop 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 US. For other countries, such as Germany, Sweden, Portugal and Greece, IMF forecasts put forward a slight primary surplus in 2027.

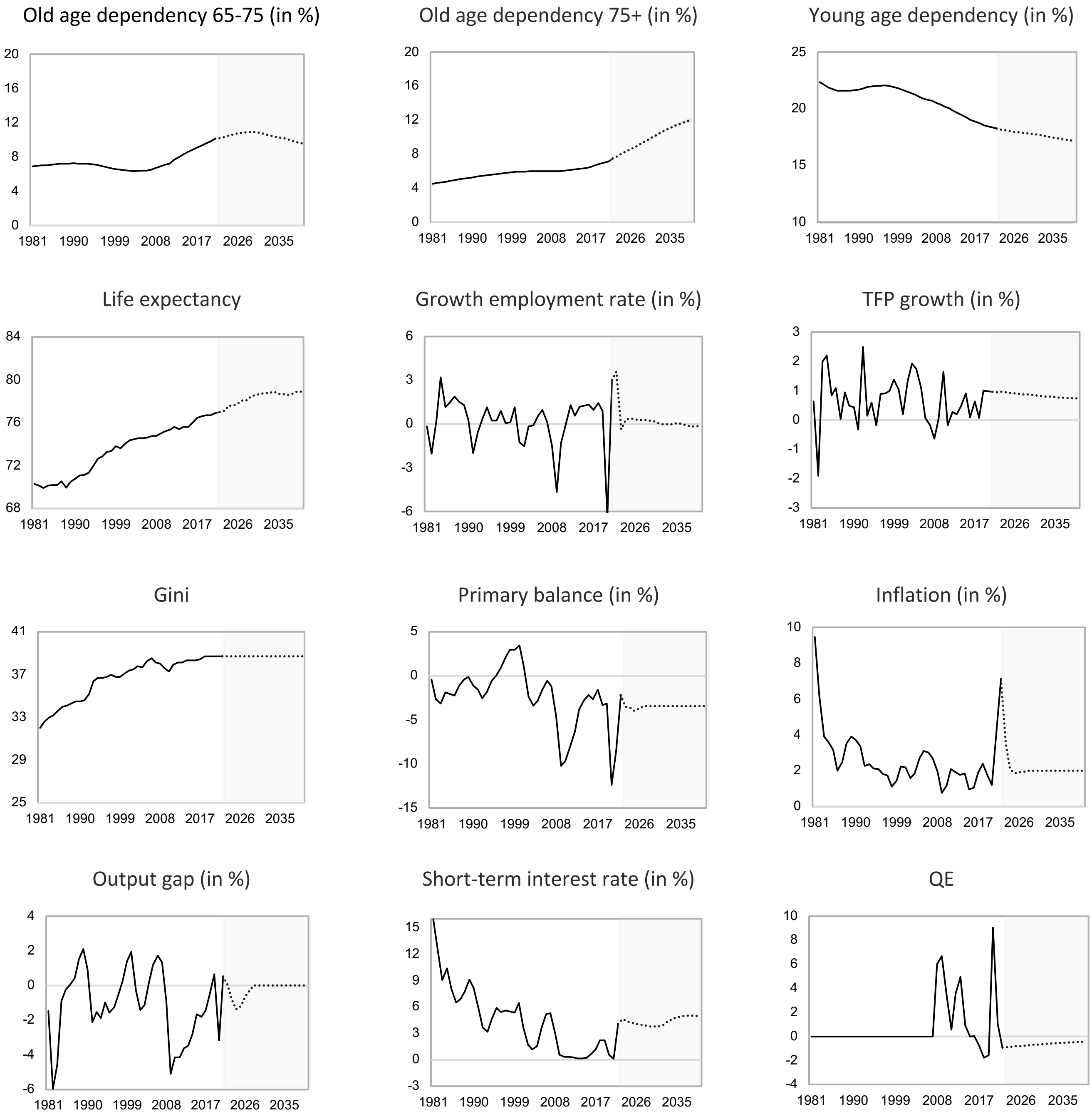
  To see the impact of this choice, as well the impact of changes in the primary balance, we will also introduce alternative assumptions. These impose on all countries either a zero primary balance or a primary deficit of 3% of GDP from 2028.[15]

[13] 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.

[14] Highly similar levels are observed at the time of finishing this paper (mid February 2023).

[15] Taking into account rising costs of ageing, the need for increased investment and other pressures on government spending, it could be argued that we should assume for each country an alternative scenario with

Figure 2a. Historical values and baseline projections concerning the determinants of $r - g$ in the US.

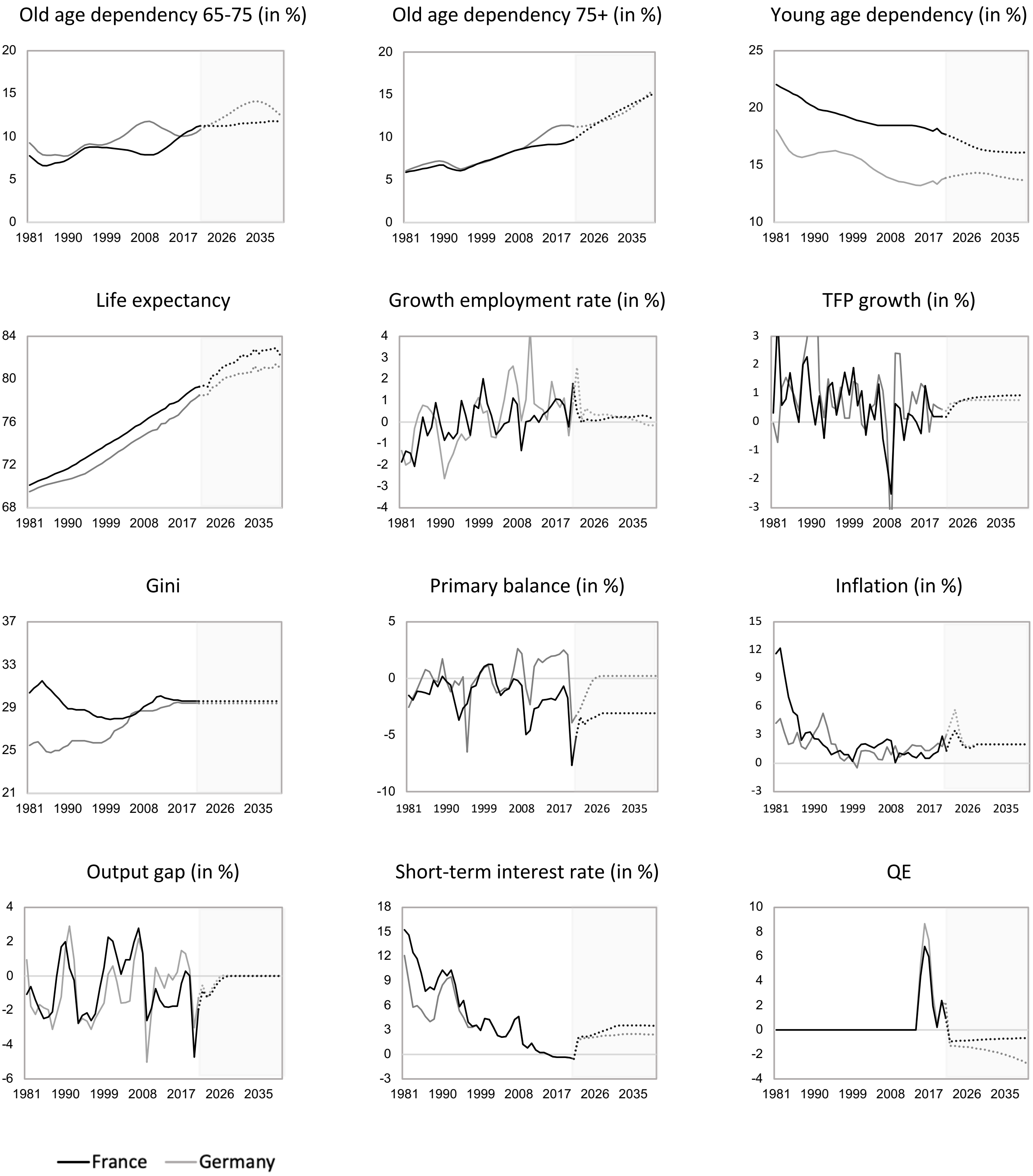


Sources and motivation: see main text. The reported series (full black lines) are observations until 2021. From 2022 (dotted lines) they include expectations and projections from the sources described in the main text. In addition to the variables shown here, also the evolution of public debt matters for the behaviour of $r - g$. It is determined endogenously by our estimated model.

---

primary deficits even above 3%. We have not done that. For one reason, European fiscal rules would not allow persistently higher deficits.

Figure 2b. Historical values and baseline projections concerning the determinants of $r - g$ in Germany and France



Sources and motivation: see main text. The reported series (full black 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 France and Germany. It is determined endogenously by our estimated model.

- The future evolution of the public debt ratio is computed endogenously applying the debt dynamics equation to the produced projections for $r - g$ and the imposed primary balance.

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) and Aiyar et al. (2016) find 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 for example 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) and the Economist (2020), for example, point to firm and household responses to the covid-19 pandemic that accelerate the adoption of new technologies and that may contribute to faster productivity growth. The Economist (2021) emphasizes growing optimism about the potential of new technologies as one explanation for the impressive pace of investment in the aftermath of the covid-19 recession. By contrast, Arriola et al. (2020) highlight possible negative effects of the pandemic on efficiency and TFP following a re-localisation of global value chains. 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 the earlier version in OECD (2018), we observe that the OECD revised its projected TFP growth downward for most countries. Imposing the revised lower growth rates is consistent with the chosen conservative approach in our own projections for future short-term interest rates and quantitative tightening. Recent breakthroughs in artificial intelligence with the emergence of 'generative AI' might, however, make these revised growth rates too pessimistic. If generative models' achievements turn artificial intelligence into a general-purpose technology, their economic impact may be huge (The Economist, 2022b).
- 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 (e.g. Law et al., 2020) or demographic change and accelerating automation (e.g. Prettner and Bloom, 2020; Acemoglu and Restrepo, 2021; Prettner and Strulik, 2021; Jacobs and Heylen, 2021). 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; Clark et al., 2021). In our baseline projections we assume inequality to remain constant for the coming 20 years.

Similar data as for the US, France and Germany in Figures 2a and 2b are collected 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 this will be determined endogenously by the model.[16]

[16] 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

4.2. Projections of $r - g$

Figure 3 reports our projections, using the estimation result in column (9b) of Table 5. 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 out of 16 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 US, 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 driving forces. 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, domestic forces are expected to keep $r - g$ into negative territory for the next two decades in most European countries.[17] The main exceptions to this general result are the highly indebted countries in Southern Europe, in particular Italy and Greece.

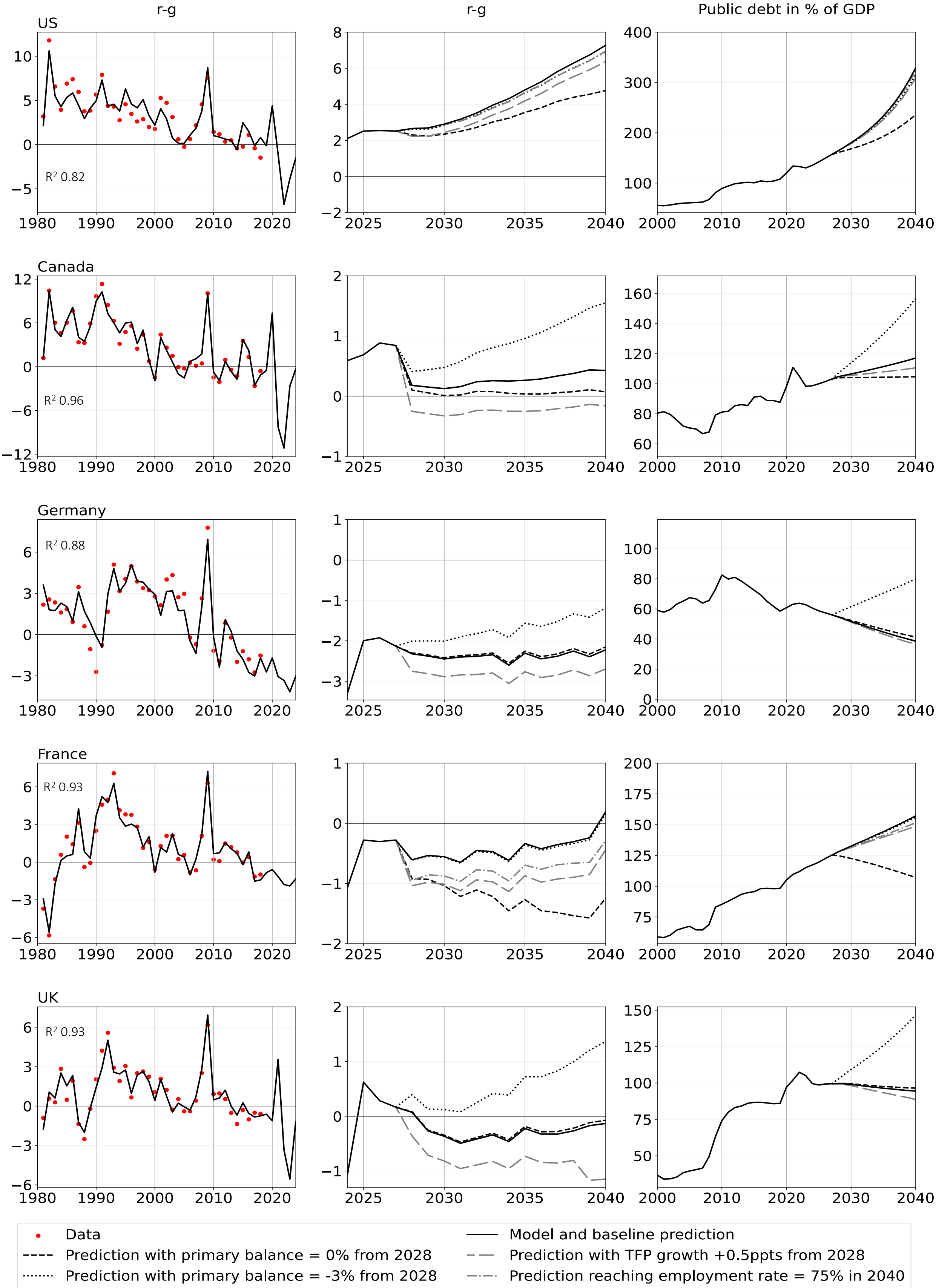
Second, the European countries enjoy (or would enjoy) this negative $r - g$ even with fiscal primary deficits up to 3% of GDP. Our baseline projections for Belgium, Finland, France and the Netherlands already take into account deficits of that size, or almost that size. If we impose a primary deficit of 3% in alternative simulations for the other European countries, $r - g$ remains negative, except in Spain and the UK. We refer to the dotted black lines in Figure 3. Comparing the simulation results shown by the dotted and the interrupted black lines 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.

Third, given the former results, we can conclude that in most European countries public debt is most likely sustainable even with a primary deficit. The level to which the debt ratio would eventually converge may, however, be much higher than today. Our baseline simulation in the graphs on the right reveals a rapid further increase of the public debt ratio in France, Belgium, Finland, Greece and the Netherlands. Similar primary deficits of 3% in the other European countries would also there imply rising debt ratios. Conversely, if we impose a zero primary balance, the public debt ratio would decrease in almost all European countries, but not in the US, Greece and Italy. For these countries to stabilize their public debt ratio, primary surpluses are required. Table 6 summarizes the IMF's (October 2022) primary balance projections for all countries included in Figure 3, as well as the required

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 drivers. Standardized coefficients reveal that these are also by far the most important.

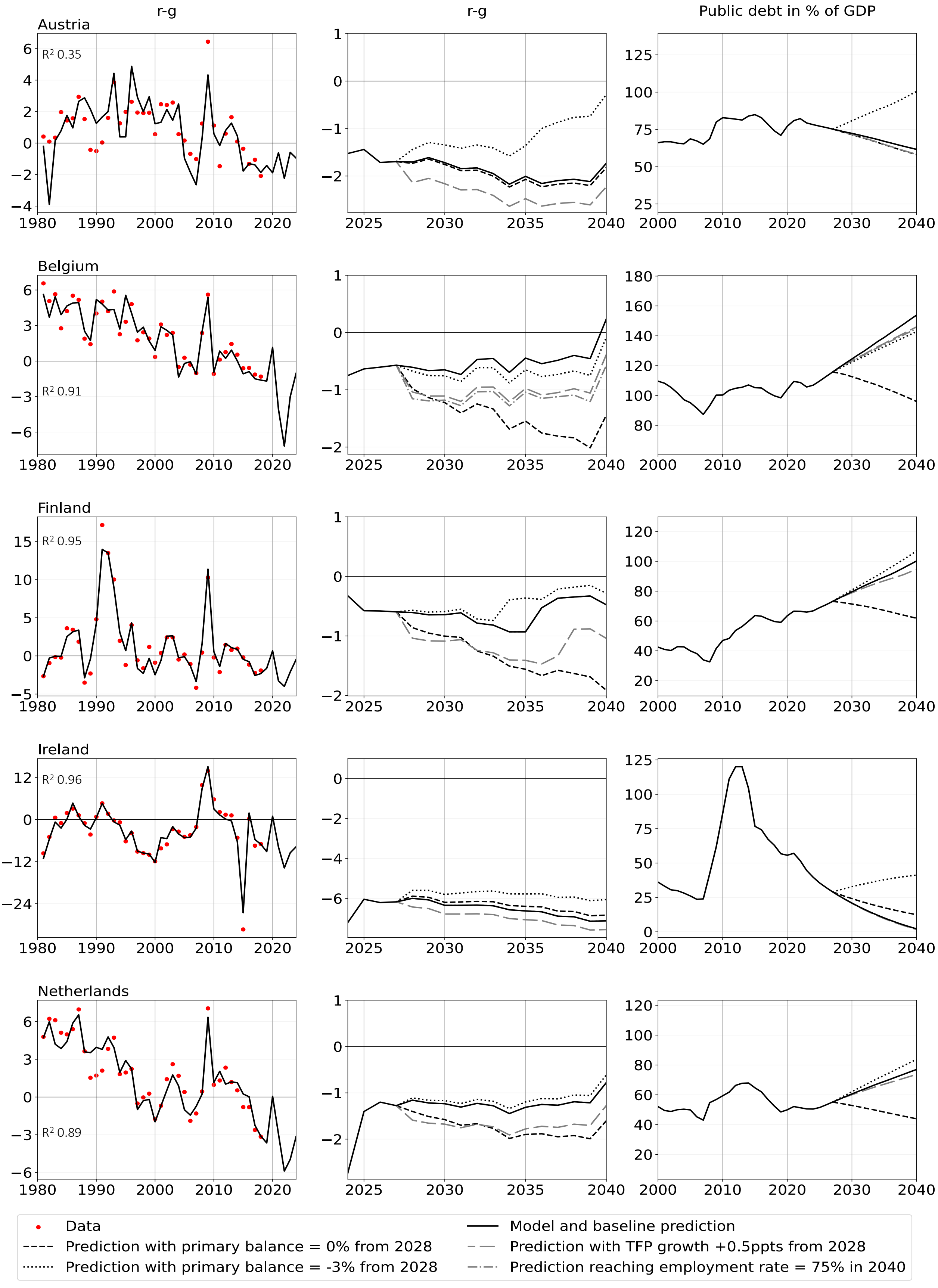
[17] This also holds for Norway, which is not included in Figure 3. The IMF puts forward for Norway a primary surplus of more than 10% of GDP until 2027. Introducing this into our model, would imply a value for $r - g$ of −3% in that year. The public debt ratio would become negative. Extrapolating the 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. However, since this scenario would also imply an increasingly negative public debt ratio, it is hard to take seriously.

Figure 3. Projections of $r - g$ and the implied public debt ratio (% of GDP)



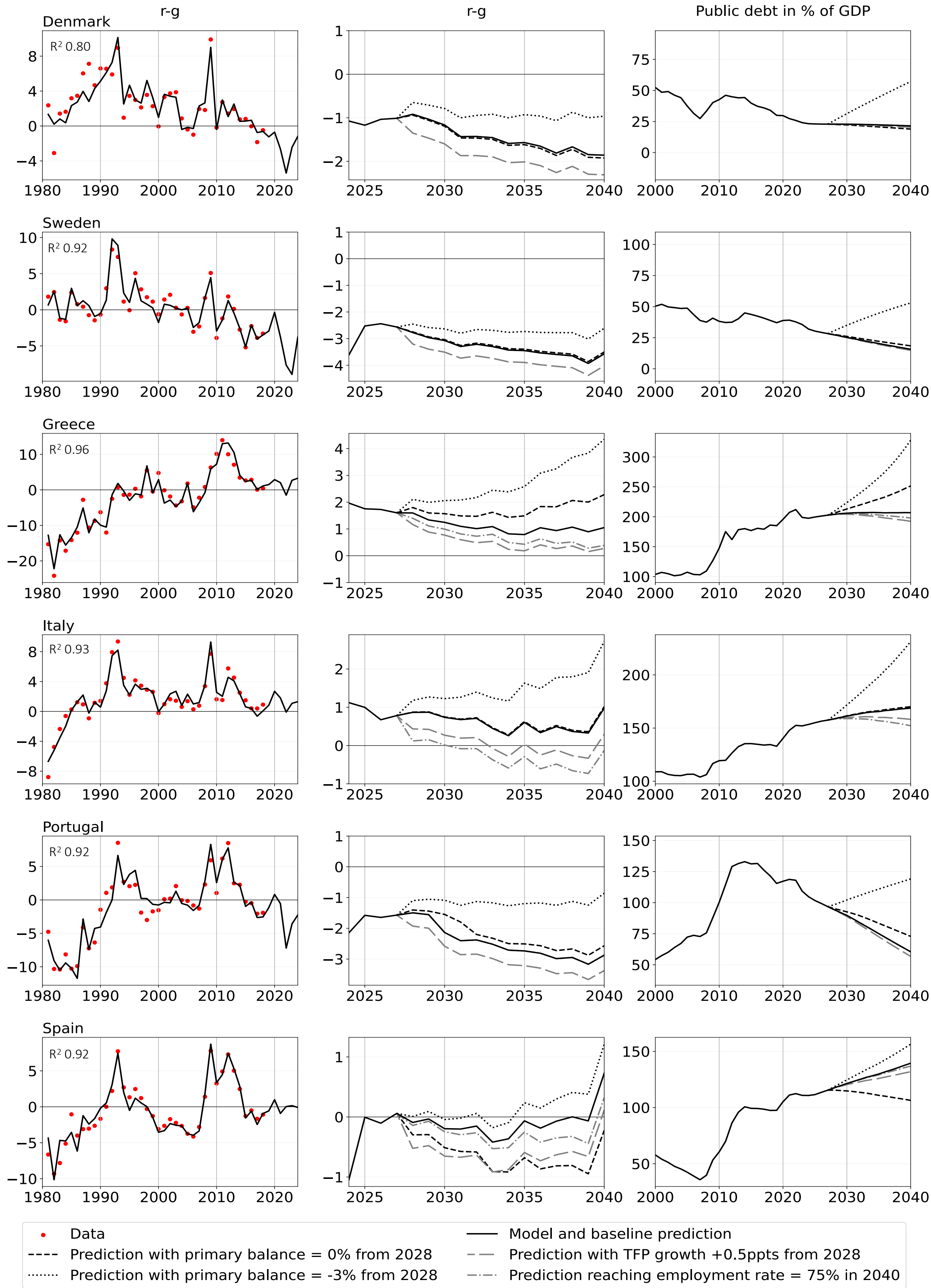
<u>Note</u>: The IMF's (October 2022) projections for the primary balance in 2027 are -3.5% (US), -0.75% (Canada), 0.2% (Germany), -3.1% (France) and 0.1% (UK). The OECD's demographic and 'long-term baseline' economic projections yield employment rates above 75% in 2040 (or even sooner) in Canada, Germany and the UK. France would achieve an employment rate of only 69.8%, the US of 72.7%. The last simulation in the figures for the US and France shows the effect on $r - g$ from imposing that the employment rate gradually reaches 75% in 2040 in these two countries.

Figure 3. Projections of $r-g$ and the implied public debt ratio (% of GDP) – continued



Note: The IMF's (October 2022) projections for the primary balance in 2027 are -0.3% (Austria), -3.7% (Belgium), -2.6% (Finland), 1.1% (Ireland) and -2.5% (the Netherlands). The OECD's demographic and 'long-term baseline' economic projections yield employment rates above 75% in 2040 (or even sooner) in all countries in this Figure, except Belgium. That country would achieve an employment rate of only 66%. The last simulation in the figure for Belgium shows the effect on $r-g$ from imposing that the employment rate gradually reaches 75% in 2040.

Figure 3. Projections of $r - g$ and the implied public debt ratio (% of GDP) – continued



Note: The IMF's (October 2022) projections for the primary balance in 2027 are -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 in this Figure, except Greece, Italy and Spain. These countries would achieve an employment rate of only 70%, 63% and 72% respectively. The last simulation in the figure for these three countries shows the effect on $r - g$ from imposing that the employment rate gradually reaches 75% in 2040.

primary surplus or the allowed primary deficit in 2022-2040 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 6. 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.

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 US?

Strength of our main finding. To its support, we repeat that we made several rather conservative assumptions when defining the projections for the driving forces of $r-g$. The imposed future short-term interest rate in particular may be rather high if one considers 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. 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, digitalization and competition, for example, may raise TFP growth. This brings us to the fourth simulation in Figure 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 Figure 3). Policies achieving 75% could directly 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, one factor may imply an increase in $r - g$ relative to the baseline that we reported. In Figure 3 we assumed zero impact from interest and growth developments in the US on the other countries. However, given our baseline expectation that $(r - g)_{US}$ will be positive, most other countries will experience some effect, albeit small. Our estimation result (9a) in Table 5 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 will 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. Shocks occur, as we frequently observed during the past 40 years that span our empirical analysis. They 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. The number and the characteristics of future shocks are by definition still unknown. To give some idea, we report in Appendix 5 the results of a set of simulations for four European countries: Germany, France, Belgium and Denmark. In these simulations 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 a total of 25 simulations for each country and allows the calculation of a confidence band. For Germany, France and Belgium, more than 80% of the projected values for $r - g$ are within a band of 4 percentage points. In Denmark that is 5 percentage points. It gives us at least some indication of the uncertainty around the reported baseline.

Difference US – Europe. When we look at the underlying determinants of $r - g$ in the US and for example 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. 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 imply a reduction of $r - g$ in the US of 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 whole German demographic structure and evolution would reduce this gain to a little more than 1%-point.

5. Conclusions

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 drivers of this difference econometrically in a panel of 17 OECD countries in 1981-2018. In line with existing literature, we include fiscal, monetary and financial determinants 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 drivers 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 effect 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 $r - g$. By contrast, an increase in the fraction of children or the fraction of young retirees (age 65 – 75) at the expense of the fraction of people at working age, has no significant effect on $r - g$.

As to other determinants, we confirm a number of established findings. So we also 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 imply a significantly lower $r - g$ in almost all our regressions. Last, we do observe a negative effect from the government's primary balance and a positive threshold effect from higher public debt when debt exceeds 90% of GDP, but these effects are often statistically insignificant.

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 countries of the European Union 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 drivers 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 US 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 US on an explosive debt path.

Our results have important implications for future policy and fiscal governance in Europe. *First*, a negative $r - g$ enables governments to run a primary deficit without debt necessarily rising in percent of GDP. With a high primary deficit, the public debt ratio will rise, but eventually converge to a constant equilibrium level. In times of a great need for public investment and a greening of the economy, this offers a unique opportunity. Considering the current and expected interest–growth difference, the capacity of governments to carry debt is substantially higher today than in the past. *Second*, all this does not eliminate, however, reasons for caution when interpreting our results. Not only for the US and Italy, but also for countries such as France, Spain and Belgium, today's expectations of the future primary deficit are (much) higher than consistent with a constant or declining public debt ratio. Moreover, in all countries rising costs related to ageing (see e.g. OECD, 2021) and climate adaptation will make it harder to achieve the allowed primary deficit, or the required primary surplus. Higher primary deficits may not imply an explosive public debt. But the higher the equilibrium debt level, the more vulnerable the fiscal situation will be to future bad 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 not for possible changes in the risk premium that are much harder to model. A structurally negative $r - g$ creates important opportunities and makes life easier for fiscal policy makers. However, it does not exempt them 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.

References

Acemoglu, D., & Restrepo, P. (2021). Tasks, automation, and the rise in US wage inequality. *NBER Working Paper,* No. 28920, National Bureau of Economic Research.

Aiyar, S., Ebeke, C., & Shao, X. (2016). The impact of workforce aging on European productivity. *IMF Working Paper*, No WP/16/238.

Aksoy, Y., Basso, H. S., Smith, R. P., & Grasl, T. (2019). Demographic structure and macroeconomic trends. *American Economic Journal: Macroeconomics*, *11*(1), 193–222.

Andrade, P., Gali, J., Le Bihan, H. & Matheron, J. (2021). Should the ECB adjust its strategy in the face of a lower r*?, *Journal of Economic Dynamics and Control, 132*, https://doi.org/10.1016/j.jedc.2021.104207.

Arriola et al. (2020), Efficiency and risks in global value chains in the context of COVID-19. *OECD Economics Department Working Papers*, No. 1637.

Attanasio, O., Bonfatti, A., Kitao, S., & Weber, G. (2016). Global demographic trends. In: Pigott, J. & Woodland A. (Eds.). *Handbook of the Economics of Population Aging*, North-Holland, vol. 1A, 179–235.

Barro, R. J., & Sala-I-Martin, X. I. (2004). *Economic Growth*, MIT Press, 2nd edition.

Berg, A., Ostry, J. D., Tsangarides, C. G., & Yakhshilikov, Y. (2018). Redistribution, inequality, and growth: new evidence. *Journal of Economic Growth*, *23*, 259–305.

Blanchard, O. (2019). Public debt and low interest rates. *American Economic Review*, *109*(4), 1197–1229.

Blanchard, O. (2023). *Fiscal Policy under Low Interest Rates*, MIT Press.

Blanchard, O., Leandro, A., & Zettelmeyer, J. (2021). Redesigning EU fiscal rules: from rules to standards. *Economic Policy*, *36*(106), 195–236.

Blanchard, O., & Rodrik, D. (2021). *Combating Inequality: Rethinking Government's Role*, MIT Press.

Boeckx, J., Dossche, M., & Peersman, G. (2017). Effectiveness and transmission of the ECB's balance sheet policies. *International Journal of Central Banking*, *13*(1), 297–333.

Carroll, C. (1998). Why Do the Rich Save So Much? *NBER Working Paper,* No. 6549, National Bureau of Economic Research.

Carvalho, C., Ferrero, A., & Nechio, F. (2016). Demographics and real interest rates: Inspecting the mechanism. *European Economic Review*, *88*, 208–226.

Cass, D. (1965). Optimum growth in an aggregative model of capital accumulation. *Review of Economic Studies, 32,* 233-240.

Checherita-Westphal, C., & Domingues Semeano, J. (2020). Interest rate-growth differentials on government debt: An empirical investigation for the euro area. *ECB Working Paper*, No 2486

Chudik, A., Mohaddes, K., Pesaran, M. H., & Raissi, M. (2017). Is there a debt-threshold effect on output growth? *Review of Economics and Statistics*, *99*(1), 135–150.

Clark, A. E., d'Ambrosio, C., & Lepinteur, A. (2021). The fall in income inequality during COVID-19 in four European countries. *Journal of Economic Inequality*, *19*, 489-507.

Cynamon, B. Z., & Fazzari, S. M. (2016). Inequality, the Great Recession and slow recovery. *Cambridge Journal of Economics*, *40*(2), 373–399.

Devriendt, W., & Heylen, F. (2020). Macroeconomic and distributional effects of demographic change in an open economy—the case of Belgium. *Journal of Demographic Economics*, *86*(1), 87–124.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics*, *80*(4), 549–560.

Dynan, K., Skinner, J., & Zeldes, S. (2004). Do the rich save more? *Journal of Political Economy*, *112*(2), 397–444.

Eberhardt, M., & Presbitero, A. F. (2015). Public debt and growth: Heterogeneity and non-linearity. *Journal of International Economics*, *97*(1), 45–58.

EFB (2020). *Annual Report 2020*, European Fiscal Board.

Eggertsson, G. B., Mehrotra, N. R., & Robbins, J. A. (2019). A model of secular stagnation: Theory and quantitative evaluation. *American Economic Journal: Macroeconomics*, *11*(1), 1–48.
Escolano, J., Shabunina, A., & Woo, J. (2017). The puzzle of persistently negative interest-rate-growth differentials: Financial repression or income catch-up? *Fiscal Studies*, *38*(2), 179–217.
ESM (2021) EU fiscal rules: reform considerations. *Discussion Paper Series,* No. 17, European Stability Mechanism.
Farhi, E., & Gourio, F. (2018). Accounting for macro-finance trends: Market power, intangibles, and risk premia. *NBER Working Paper*, No 25282, National Bureau of Economic Research.
Feyrer, J. (2007). Demographics and productivity. *The Review of Economics and Statistics*, *89*(1), 100-109.
Gagnon, E., Johannsen, B. K., & López-Salido, D. (2021). Understanding the new normal: The role of demographics. *IMF Economic Review*, *69*, 357–390.
Hamilton, J. D., Harris, E. S., Hatzius, J., & West, K. D. (2016). The equilibrium real funds rate: Past, present, and future. *IMF Economic Review*, *64*(4), 660–707.
Hanck, C. (2013). An intersection test for panel unit roots. *Econometric Reviews*, *32*(2), 183–203.
Heijdra, B. J. (2017). *Foundations of Modern Macroeconomics,* Oxford University Press, 2nd edition.
Hesse, H., Hofmann, B., & Weber, J. M. (2018). The macroeconomic effects of asset purchases revisited. *Journal of Macroeconomics*, *58*, 115-138.
Hohberger, S., Priftis, R., & Vogel, L. (2019). The macroeconomic effects of quantitative easing in the euro area: Evidence from an estimated DSGE model. *Journal of Economic Dynamics and Control*, *108*, https://doi.org/10.1016/j.jedc.2019.103756.
Holston, K., Laubach, T. & Williams, J.C. (2017). Measuring the natural rate of interest: International trends and determinants. *Journal of International Economics*, *108*, 559-575.
IMF (2021). Strengthening the credibility of public finances. *Fiscal Monitor*, chapter 2.
Jacobs, A., & Heylen, F. (2021). Demographic change, secular stagnation and inequality: automation as a blessing? *Working Paper,* Department of Economics, Ghent University, No 2021/1030.
Jappelli, T. (1999). The age-wealth profile and the life-cycle hypothesis: A cohort analysis with a time series of cross-sections of Italian households. *Review of Income and Wealth*, *45*(1), 57–75.
Jordà, S., Knoll, K, Kuvshinov, D., Schularick, M., & Taylor, A. M. (2019). The rate of return on everything, 1870-2015. *The Quarterly Journal of Economics*, *134*(3), 1225–1298.
Kankaanranta, P. (2019). A cohort-analysis of age-wealth profile in Finland. *Aboa Centre for Economics Discussion paper*, No 130.
Koopmans, T. C. (1965). On the concept of optimal economic growth. In: *The Econometric Approach to Development Planning*, North-Holland.
Kozlowski, J., Veldkamp, L., & Venkateswaran, V. (2020). Scarring body and mind: the long-term belief-scarring effects of COVID-19. *NBER Working Paper*, No 27439, National Bureau of Economic Research.
Krueger, D., & Ludwig, A. (2007). On the consequences of demographic change for rates of returns to capital, and the distribution of wealth and welfare. *Journal of Monetary Economics*, *54*(1), 49–87.
Law, S. H., Naseem, N.A.M., Lau, W. T., & Trinugroho, I. (2020). Can innovation improve income inequality? Evidence from panel data. *Economic Systems*, *44*(4), https://doi.org/10.1016/j.ecosys.2020.100815.
Li, H., Zhang, J., & Zhang, J. (2007). Effects of longevity and dependency rates on saving and growth: Evidence from a panel of cross countries. *Journal of Development Economics*, *84*(1), 138–154.
Lorenzoni, G., & Werning, I. (2019). Slow moving debt crises. *American Economic Review*, *109*(9), 3229–3263.
Lunsford, K. G. (2017). Productivity Growth and Real Interest Rates in the Long Run. *Economic Commentary,* Federal Reserve Bank of Cleveland, 1–6.
Lunsford, K. G. & West, K. (2019). Some evidence on secular drivers of US safe real rates. *American Economic Journal: Macroeconomics*, *11*(4), 113–139.

Mankiw, N. G. (2022). Government debt and capital accumulation in an era of low interest rates. *Brookings Papers on Economic Activity,* Spring, 219-231.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, *107*(2), 407–437.

Marchiori, L., Pierrard, O., & Sneessens, H. R. (2017). The EU-US unemployment puzzle revisited: Institutions, demography, and capital flows. *Journal of Demographic Economics*, *83*(3), 259–305.

Mauro, P., & Zhou, J. (2021). r-g<0: Can we sleep more soundly? *IMF Economic Review*, *69*(1), 197–229.

McKinsey Global Institute (2021). Will productivity and growth return after the COVID-19 crisis? McKinsey, March.

Mokyr, J. (2014). Secular stagnation? Not in your life. In: Teugels, C. & Baldwin, R. (Eds.). *Secular Stagnation: Facts, Causes and Cures,* A VoxEU.org Book, CEPR Press, 83-89.

OECD (2015). The impact of income inequality on economic growth. *In it Together: Why Less Inequality Benefits All*, Chapter 2, 59-100.

OECD (2018). The long view: Scenarios for the world economy to 2060. *OECD Economic Policy Paper*, No 22.

OECD (2021). The long game: Fiscal outlooks to 2060 underline the need for structural reform. *OECD Economic Policy Paper*, No 29.

Paniagua, J., Sapena, J., & Tamarit, C. (2017). Sovereign debt spreads in EMU: The time-varying role of fundamentals and market distrust. *Journal of Financial Stability, 33*, 187–206.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *Cambridge Working Papers in Economics*, No 0435, University of Cambridge.

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica*, *74*(4), 967–1012.

Presbitero, A., & Wiriadinata, U. (2020). Public debt and r - g at risk. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3710776

Prettner, K. & Bloom D. E. (2020). *Automation and its Macroeconomic Consequences: Theory, Evidence and Social Impacts*, Elsevier, Academic Press.

Prettner, K. & Strulik, H. (2020). Innovation, automation, and inequality: Policy challenges in the race against the machine. *Journal of Monetary Economics*, *116*, 249-265.

Rachel, L., & Smith, T. D. (2017). Are low real interest rates here to stay? *International Journal of Central Banking*, *13*, 1–43.

Rachel, L., & Summers, L. (2019). On falling neutral real rates, fiscal policy, and the risk of secular stagnation. *Brookings Papers on Economic Activity*. Spring, 1–54.

Ramsey, F. P. (1928). A mathematical theory of saving. *The Economic Journal*, *38*(152), 543–559.

Reinhart, C. M., & Rogoff, K. S. (2010). Growth in a time of debt. *American Economic Review*, *100*(2), 573–578.

Shiller, R. J., Campbell, J. Y. & Schoenholtz, K. L. (1983). Forward rates and future policy: Interpreting the term structure of interest rates. *Brookings Papers on Economic Activity*, 173-223.

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.).

The Economist (2020). The pandemic could give way to an era of rapid productivity growth, *The Economist*, 8 December.

The Economist (2021). The urge to plurge, *The Economist*, 5 February.

The Economist (2022a). Elderly populations mean more government spending. They also mean low interest rates, *The Economist*, 5 October.

The Economist (2022b). Huge "foundation models" are turbo-charging AI progress Generative AI, *The Economist*, 11 June.

Turner, D., & Spinelli, F. (2011). Explaining the interest rate-growth differential underlying government debt dynamics. *OECD Economics Department Working Papers*, No 919.

Woo, J., & Kumar, M. S. (2015). Public debt and growth. *Economica*, *82*(328), 705–739.

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 (2020), 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: 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 7. 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 8. All Wald tests yield F-statistics that exceed Staiger and Stock's (1997) rule of thumb value of 10.

Table 7. 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)
Growth of the employment rate	Growth of the employment rate (t-2) Growth of the employment rate (t-3) Labor tax rate (t) [1] Labor tax rate (t-1) Oil price (t) [2] Oil price (t-1)
Inflation	Inflation (t-2) Inflation (t-3) Short-term interest rate (t-1) Short-term interest rate (t-2)
Output gap	Output gap from advanced economies (t) Output gap from advanced economies (t-1)

Notes: 1. The labor tax rate was calculated as (compensation rate/wage rate) – 1.
2. 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 8. Wald tests of instrument significance.

Regression	*F-statistic Wald test*
Regression (7d)	
TFP growth	13,52
Growth of the employment rate	21,19
Inflation	29,18
Output gap	33,96
Regression (9d)	
TFP growth	13,02
Growth of the employment rate	20,44
Inflation	23,69
Output gap	29,66

References

Staiger, D. & Stock, J.H. (1997). Instrumental variables regression with weak instruments. *Econometrica*, *65*, 557-586.

Appendix 3: Empirical analysis of r, r_m and g as single dependent variables (17 OECD countries, 1981-2018) [1]

	r	r_m	g
TFP growth	0.023	0.037	0.971***
	(0.020)	(0.024)	(0.042)
Growth of the employment rate	0.004	-0.026	0.575***
	(0.020)	(0.053)	(0.025)
Old age dependency 65-75	-0.104**	-0.242***	-0.170**
	(0.039)	(0.083)	(0.066)
Old age dependency 75+	-0.303**	-0.048	-0.248***
	(0.131)	(0.111)	(0.082)
Young age dependency	-0.002	0.015	-0.114*
	(0.040)	(0.079)	(0.063)
Life expectancy	-0.220**	-0.045	-0.030
	(0.106)	(0.109)	(0.072)
Gini	-0.138***	-0.063	-0.010
	(0.053)	(0.058)	(0.054)
Primary balance	-0.003	-0.036	0.052**
	(0.015)	(0.022)	(0.022)
Public debt ratio	0.007	0.014***	-0.002
	(0.005)	(0.005)	(0.004)
Public debt ratio x Dummy90+	0.001	0.007***	-0.007***
	(0.001)	(0.002)	(0.001)
QE	0.001	-0.125***	0.083***
	(0.010)	(0.032)	(0.019)
Inflation	0.031	0.120***	1.023***
	(0.025)	(0.033)	(0.028)
Output gap	-0.002	-0.115***	0.094***
	(0.025)	(0.032)	(0.020)
Short-term interest rate	0.134***	0.451***	-0.046***
	(0.027)	(0.054)	(0.013)
$(r, g, r_m)_{US}$ [2]	CS	CS	CS
Cross-sectional average [2]	CS	CS	CS
Observations	643	643	643
Country fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No
R^2	0.95	0.96	0.98
R^2 adjusted	0.95	0.95	0.97
Cointegration	yes	yes	yes

Notes: 1. Estimated and Driscoll-Kraay (1998) corrected standard errors in brackets. * p<0.1; ** p<0.05; *** p<0.01.
2. CS: the model has been estimated with country-specific coefficients on the cross-sectional average of r, r_m and g and with country-specific coefficients on r, r_m and g in the US. As relevant 'foreign' variables to explain the US data in the panel, we include the average of r, r_m and g respectively in Germany, the UK and Canada.

Appendix 4: Regression results allowing dynamic effects in Equation (9b)

The regressions in the table on the next page extend column (9b) of Table 5. We add a one-period lagged term of the dependent variable in column (9c), and five- or ten-period lagged terms of the demographic indicators[18], the Gini coefficient, and the public debt ratio in columns (9d) and (9e). Everything else is the same.

As can be seen, allowing more dynamics in the response of $r-g$ to these variables does not change our main findings. In column (9c) the lagged dependent $r-g$ obtains a highly significant positive coefficient, but this is close to zero, suggesting a very low degree of persistence. Adding lagged $r-g$ has no notable effect on the estimation results for the other variables. Only QE loses its statistical significance. In columns (9d) and (9e), the coefficients and statistical significance of the contemporaneous demographic, inequality and public debt related variables are hardly affected when we add their five- or ten-periods lagged counterpart. Adding up the estimated coefficients for the contemporaneous and lagged terms of old age dependency (65-75 and 75+)[19], we always obtain a positive result close to 0.1 or 0.2. For young age dependency the outcome is always close to -0.05. For the Gini coefficient it is always close to -0.2, and for the public debt ratio close to 0.015. Also in columns (9d) and (9e) there is no notable effect on the results for the other explanatory variables.

In additional regressions we also added lagged terms of inflation. We only obtained very small and statistically highly insignificant coefficients for these lagged terms.

[18] Except life expectancy. In all our regressions in this paper, included data for life expectancy in a particular year t relate to World Bank data for 'life expectancy at birth in year $t-20$' (see Table 1). This will capture the perspectives of young people in year t better than life expectancy at birth in t.

[19] Considering both fractions of old-age dependents together, is justified when 10-period lags are involved. Separate effects of both fractions will be harder to distinguish: the fraction of people older than 75 at time t will be highly correlated to the fraction of 65-75 years old people at $t-10$.

	(9b)	(9c)	(9d)	(9e)
TFP growth	-0.863***	-0.885***	-0.867***	-0.867***
	(0.055)	(0.066)	(0.059)	(0.061)
Growth of the employment rate	-0.515***	-0.474***	-0.517***	-0.525***
	(0.037)	(0.040)	(0.042)	(0.043)
Old age dependency 65-75	0.016	0.013	-0.081	0.016
	(0.091)	(0.079)	(0.109)	(0.088)
Old age dependency 65-75 (t-5)			0.216*	
			(0.111)	
Old age dependency 65-75 (t-10)				0.392**
				(0.167)
Old age dependency 75+	0.131	0.125	-0.101	-0.243
	(0.150)	(0.138)	(0.148)	(0.229)
Old age dependency 75+ (t-5)			0.203	
			(0.143)	
Old age dependency 75+ (t-10)				0.041
				(0.108)
Young age dependency	-0.046	-0.012	-0.159	-0.117
	(0.075)	(0.088)	(0.104)	(0.101)
Young age dependency (t-5)			0.109*	
			(0.057)	
Young age dependency (t-10)				0.075
				(0.060)
Life expectancy (at birth, t-20)	-0.483***	-0.386***	-0.420***	-0.352***
	(0.120)	(0.130)	(0.135)	(0.144)
Gini	-0.209***	-0.214***	-0.186***	-0.194***
	(0.040)	(0.049)	(0.050)	(0.046)
Gini (t-5)			-0.038	
			(0.030)	
Gini (t-10)				-0.013
				(0.029)
Primary balance	-0.078**	-0.059*	-0.067*	-0.065**
	(0.031)	(0.033)	(0.037)	(0.033)
Public debt ratio	0.019***	0.015**	0.026***	0.023***
	(0.005)	(0.006)	(0.007)	(0.005)
Public debt ratio (t-5)			-0.006	
			(0.005)	
Public debt ratio (t-10)				-0.007*
				(0.004)
Public debt ratio x Dummy90+	0.005***	0.005***	0.005***	0.006***
	(0.002)	(0.001)	(0.002)	(0.002)
QE	-0.040**	-0.024	-0.041**	-0.046**
	(0.020)	(0.017)	(0.019)	(0.022)
Inflation	-0.990***	-0.965***	-0.999 ***	-0.996***
	(0.039)	(0.041)	(0.039)	(0.042)
Output gap	-0.055**	-0.055**	-0.035	-0.057**
	(0.027)	(0.027)	(0.033)	(0.026)
Short-term interest rate	0.337***	0.347***	0.347***	0.329***
	(0.029)	(0.033)	(0.034)	(0.031)
One period lagged $r-g$		0.076***		
		(0.027)		
$(r-g)_{US}$	CS	CS	CS	CS
Cross-sectional average $r-g$	CS	CS	CS	CS
Observations	643	641	628	613
Country fixed effects	yes	Yes	yes	yes
Time fixed effects	no	no	no	no
R^2 adjusted	0.92	0.92	0.92	0.92

Appendix 5: 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 a few countries with an institutional and monetary context that is not too far away from today's context (e.g. EU membership, fixed exchange rate): Germany, France, 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 $r - g$ around the median. For Germany, France and Belgium one might conclude that if the shocks of the past happened again, the implied variation in $r - g$ would remain within a range of 4 percentage points with a probability of 80%. In Denmark that would be a range of 5 percentage points.

Figure A5. Variation in $r - g$ projections if the shocks of the past happened again in the future.