Tax structure and economic growth. A panel data analysis of 20 OECD countries

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Abstract

This paper asks whether tax structure, the relative weight of each tax within a tax system, affects economic growth, using data from twenty OECD countries covering 1970 to 2019. The research framework uses a standard economic growth model, where labour, capital, human capital and technological improvements drive growth. While this model predicts a clear effect of taxation on growth, early empirical research did not find this. In the past twenty years, many studies have arrived at the opposite conclusion: income and corporation taxes would stunt growth, so tax revenue should be shifted from these towards consumption and property taxes. The dataset used combines several sources of information, the main one being OECD data. The estimation approach is dynamic panel data modelling. Some specifications are constrained into a revenue-neutral framework, which allows the evaluation of revenue shifts between taxes while keeping the overall tax burden constant. The main contributions to the literature are extending the timespan of analysis and combining testing for cointegration and cross-sectional dependence. The results show a significant effect of the tax structure on growth rates: A 1% shift in the share of taxation from income or corporation taxes towards property and consumption taxes is correlated to a 0.1%-0.2% increase in growth rates. A shift in the opposite direction shows a negative effect of similar size. Some econometric tests suggest that the relationship could be long-term. These results are similar to the most recent literature, which is unsurprising as they use similar datasets and methodology. Within this framework, it is difficult to differentiate precisely the mechanism through which taxes affect growth or whether their effects are short or long-term. However, this is not a critical issue for policy advice. Some caution is required before inferring policy recommendations because some robustness tests suggest that the results are biased due to cross-sectional dependence, perhaps caused by omitted variables and endogeneity in the specification. An alternative specification, robust by design to cross-sectional dependence, did not yield statistically significant results.

1. Introduction

‘We made it clear in our manifesto that we intended to switch some of the tax burden from taxes on earnings to taxes on spending. This is the only way that we can restore incentives and make worth while to work’

—Sir Geoffrie Howe, Budget speech 1979

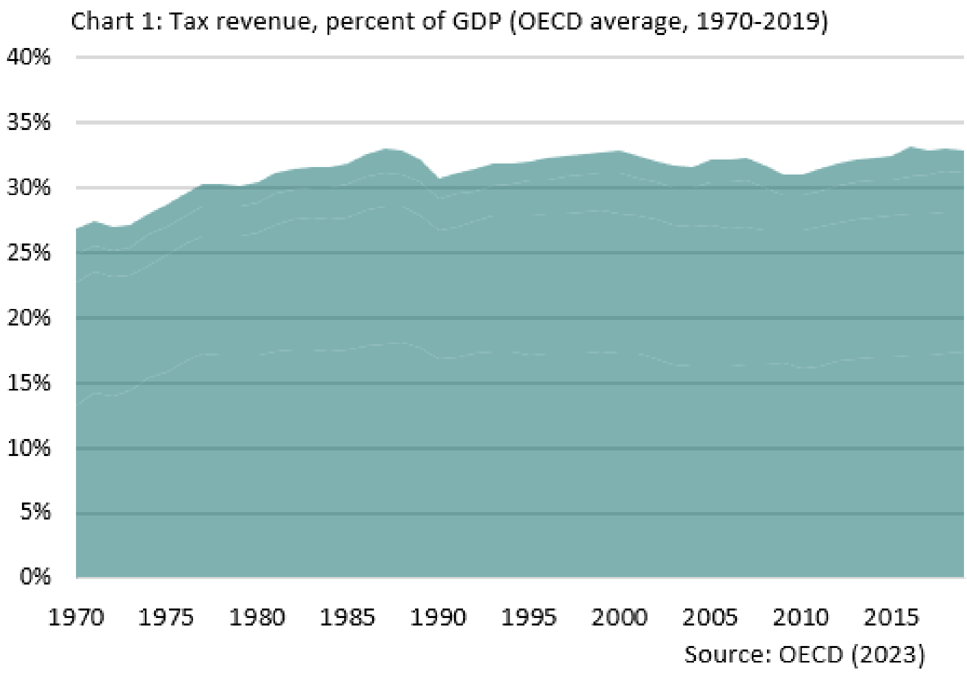
Can the tax structure of a country affect its economic growth rate? During the last few decades, economists and international organisations have thought this may be the case and, following the suggestions of economic theory and a substantial body of applied research, have advised governments to shift from capital and labour taxes to indirect ones to achieve higher economic growth.

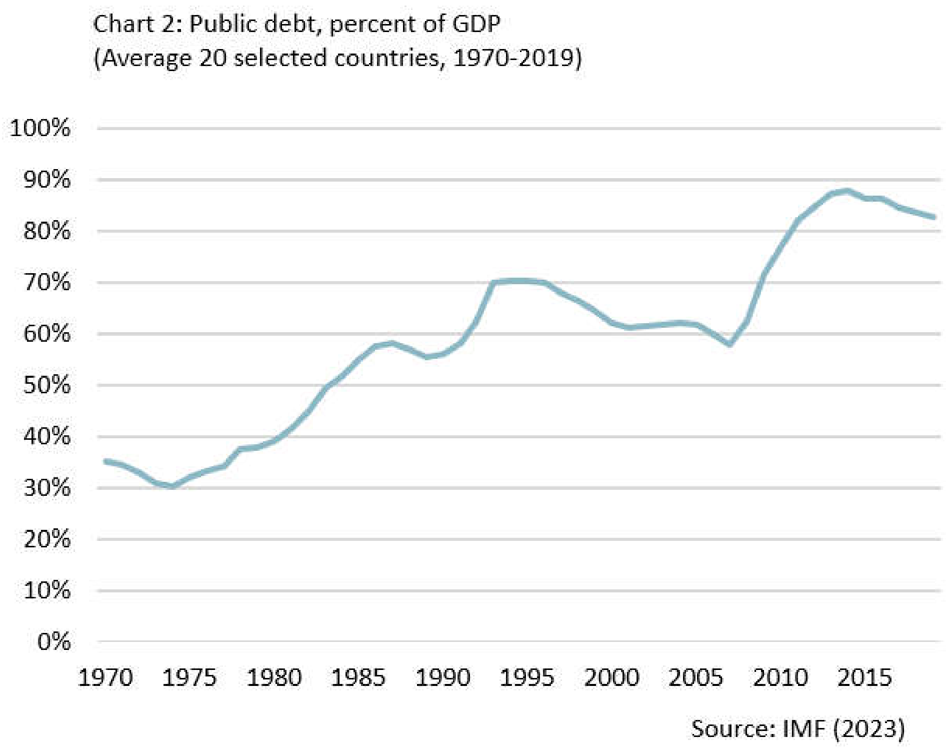
This paper investigates exactly that: tax structures and growth. Its scope is within the framework of economic growth theory. It excludes discussing the effects of taxes on the remote causes of economic growth, like institutions or culture, and the short-term effects of taxes through the demand level or their role in macroeconomic stability. Trade taxes are left out, too, as they are minor sources of government revenue in advanced economies. Moreover, focusing on growth requires ignoring the distributional effects of taxes. What is within the scope of this study is assessing the impact of tax structures on growth through labour, capital, innovation and entrepreneurship in 20 OECD countries[1] from 1970 to 2019.

Most OECD economies have high levels of taxation. It seems unlikely that this high tax burden, close to £1 trillion per year in the UK, could be reduced easily due to the growing demand for public services from ageing populations, the cost of decarbonisation, and the levels of public debt. If high taxes are here to stay, it seems relevant to study if there are tax structures which are growth-enhancing while being aware of others that may be growth-retarding.

Specifically, this paper tries to answer two questions. The first is whether tax structures affect growth and, if so, how. The second is whether shifts from labour and capital taxes to consumption and property ones raise growth rates. The results will be compared to those published in recent papers, which are surveyed in the next section. But first, the next page includes a graphical summary of changes in the tax burden and public debt in OECD countries since 1970. UK-specific charts are included in the Appendix.

[1] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom and the United States.





2. Literature review

2.1 Theory

The original Solow-Swan growth model, developed independently by both in 1956, is a production function with capital and labour as inputs, constant returns to scale, and diminishing returns to capital. The steady-state is a situation where output and capital grow at the same rate, and without technological progress, there is no increase in growth per capita. The introduction of the 'exogenous growth' assumption allows the inputs to become more productive over time through technological improvements.

Endogenous growth models, starting with Romer (1990) and Lucas (1990), allow for sustained growth. The Mankiw et al. (1992) endogenous growth model is an augmented version of the original Solow one as it adds human capital accumulation. Within this model, there is no steady-state output level. Their production function inputs are physical capital (K), human capital (H) and labour (L). The technology level is assumed to be labour-augmenting. A Cobb-Douglas production function which approximates their empirical research is:

$$Y= K^{1/3} H^{1/3} L^{1/3} \qquad (1)$$

It has been discussed (Myles, 2000) that in exogenous models with a steady-state growth rate, fiscal policy can only affect the output level but not the growth rate. In endogenous models like Barro (1990), policy changes can affect both levels and growth. For empirical research, the difference is not essential[2]. Even within the exogenous growth framework, the transition period between two steady-state levels will be indistinguishable from growth rate changes in the medium term.

Within this framework, there are several theoretical ways through which the tax structure can affect economic growth. The role of trade taxes is not discussed, as their size is minimal for the countries and periods selected in this study.

Heer (2009) argues that income tax increases can have diverse effects on labour supply: they will reduce it if the substitution effect consequence of a marginal tax rate hike is higher than the income effect derived by the average rate change.
Capital income taxes reduce the incentive for savings - especially in periods of inflation, as it increases the effective rate of the tax. Mankiw (2009) believes that the worldwide trend towards reduced capital income taxation is consistent with optimal tax theory. Chamley (1986) and Judd (1985) found that the optimal capital tax rate is zero.

Within the endogenous growth framework, a key factor of economic growth is human capital accumulation (Lucas, 1990) which marginal income tax rates can impact, as they reduce the main benefit from education: a higher future income. This negative effect can be increased if unqualified workers' wages are low-taxed, as the opportunity cost of education is directly related to their real wages.

Slemrod and Bakija (2008) explain that marginal income tax rates affect incentives for innovation and entrepreneurship, which improve technology and productivity because they reduce the high but uncertain awards expected from those activities. They also discuss the role of tax subsidies, as subsidising certain activities implies penalising others. They argue that the beneficial tax treatment of investment in housing reduces investment in more productive sectors of the economy.

It is worth noting that, theoretically, some tax categories may not be as distinct as they seem in practice. For example, an income tax which exempts the 'normal' rate of return to capital has a similar effect on incomes as a consumption tax (Adam et al.,2011).

[2] Bernanke and Girkaynak (2001) find that long-run growth is correlated with behavioural variables such as the savings rate, which cannot be explained by exogenously.

2.2 Empirical evidence

Haberger (1964) argued that while the theory predicted clear effects of taxation on growth, the empirically observed effects were minor: taxation could reduce growth rates at most by 0.2%, and only through its impact on savings. Summarising the past century's research, Myles (2000) stated that the empirical evidence was unambiguous: the effect of taxation on growth, if detected at all, was minor.

Deveroux and Love (1994) maintain that capital income, wage, and consumption taxes all reduce growth rates and that capital taxes are the least efficient in raising revenue. Hungerford (2013) finds no evidence in the US post-WWII of a negative effect on growth from tax rates on capital income. Dobbins and Jacob (2016) researched the impact of the 2008 reduction of corporation tax rates on German firms and found that it led to a one-to-one increase in real investment.

The empirically observed effects of taxes on employment are nuanced too. Prescott (2004) suggests that marginal tax rates on labour and consumption explain why Americans in the 1990s worked 50% more than Europeans. OECD (2011) reports that income tax rates combined with benefits and pension systems affect second-earners' participation levels but not working hours. There is not much evidence that marginal income rates affect workers' mobility. A cross-country analysis from Piketty et al. (2014) shows that cutting top tax rates does not increase economic growth. Madsen et al. (2021) studied the effects of labour taxation on human capital: while personal income taxes reduce investment in tertiary education—as predicted by Lucas (1990)—they increase R&D investment, so their net effect on growth might be positive.

International organisations like the EU and the OECD have published research on fiscal taxation and growth. Barrios and Shaether (2008) recommend shifts from taxes on capital and labour income towards consumption taxes to enhance growth. OECD (2010) prescribes a '*tax and economic growth ranking order'* in which corporate taxes are the most detrimental to growth, followed by personal income taxes and consumption taxes. The less adverse taxes for growth would be property taxes. It is worth noting that OECD countries have recently agreed on a reform of international taxation, including a minimum rate of 15% for multinational enterprises.

The results of a large number of panel data studies on tax structures and growth are summarised in Table 1 (next page). They usually examine advanced economies from the 1970s using macroeconomic tax aggregates. The results of most, but not all, studies have similar recommendations to the OECD 'ranking' discussed. Apart from the inherent problems derived from using aggregated data, a pitfall in recent studies, this one included, is that they do not account for non-linear effects of taxation on growth (Jairnovich & Rebelo, 2016). Also, most papers reviewed do not assess the role of using public deficit as a financing tool, and few discuss cross-sectional dependence. Another problem is publication bias. Alinaghi and Reed (2021) found evidence that journals discriminate against publications which do not show adverse effects of taxes on growth. Gechert and Heimberger (2021) found that by correcting this bias, there is no evidence that corporation taxes affect growth – as most research claims.

Finally, two research directions grounded on macroeconomic simulations are worth mentioning. The first (Pabst, 2022) supports a progressive consumption tax to increase labour supply and savings rates. The second (Komhof et al., 2021) suggests that increasing land value tax rates substantially and reducing capital and labour income taxes accordingly would increase the output level by 15%.

Table 1: Panel-data studies[3]

Source	Comment
Easterly & Rebelo (1993).	No robust links were found between tax variables and growth.
Mendoza el al.(1996)	Tax rates are unlikely to affect growth, but they moderately alter investment.
Engen & Skinner (1996)	Reducing all marginal tax rates by 5% increases the growth rate by 0.2-0.3%.
Kneller et al.(1999) and Bleaney et al.(2001)	Distortionary taxation (income, corporation and property taxes) reduces growth, and non-distortionary taxation (taxes on goods and services) does not.
Wildmalm (2001)	Shifts from income and property taxes to indirect taxes promote growth.
Lee & Gordon (2005)	A 10% reduction in the corporation tax rate raises the growth rate by 1-2%,
Arnold (2008)	A 1% shift in revenue from income and corporation taxes to taxes on property and goods and services increases the growth rate by up to 1%.
Romer & Romer (2010)	Tax increases of 1% of GDP lower real GDP typically by 2.5% in the USA post-WWII.
Gemmell et al.(2011)	Using different estimators than Gemmell et al.(2001), the distortionary and non-distortionary taxes' effects on growth are still present but smaller than before.
Xing (2011)	Shifting tax revenue towards property taxes has a positive effect on growth.
Acosta & Yoo (2012)	Shifts of 1% from income to property taxes increase growth rates by 0.1% and up to 0.25% when shifting towards property taxes in high-income countries.
Bujang et al.(2013)	Evidence of long-term relationship (cointegration) tax structure/growth.
Gemmell et al.(2013)	Marginal income tax rates reduce growth rates, and low corporation tax rates in foreign countries reduce domestic growth.
Arachi et al.(2015)	Shifts from capital and income towards consumption taxation increase growth.
Bakija & Narashimham (2015)	No evidence of a long-term relationship (cointegration) between tax structures and growth rates from a panel of 79 countries.
Stoilova (2016)	Income, import and consumption taxes positively affect growth, while corporation taxes have a negative effect (EU-28 countries).
Arin et al.(2017)	A negative effect of top corporate tax rates on growth. Income taxes are neutral.
Di Sanzo et al.(2017)	Income and consumption taxes hurt growth; property taxes have a positive effect.
McNabb (2018)	Increasing income tax revenue by 1% reduces growth by 0.11%, while shifts towards corporation and property taxes have similar positive effects on growth.
Alinaghi & Reed (2020)	Their meta-analysis suggests that shifting 3.5% of tax revenue from income, corporation, and property taxes to taxes on goods and services increases growth by 0.2%. A shift in the opposite direction reduces growth by 0.2%
Alfo et al.(2022)	A 10% reduction in income or corporation tax rates raises the GDP growth rate by 0.6% and 0.3%, respectively.

[3] Only three studies in Table 1 —Easterly and Rebelo (1993), Mendoza et al. (1996), and Bakija & Narashiman (2015)— did not find a relationship between tax variables and growth.

3. Data and methodology

3.1 Data

A common approach for assessing the effect of taxation on economic growth is to estimate a baseline growth equation, adding to its right-hand side a set of fiscal variables. The baseline equation for this study regresses the growth of GDP p.c. against (the growth of) total hours worked, capital stock, both from Penn World Table (10.1), and the Human Development Index (HDI), produced by the United Nations Development Programme (HDI, 2022). These variables are different to standard regressors used in the literature. Using total hours worked could evidence the effect of labour supply on growth better than employment figures. Capital stock estimates may be less endogenous than investment-to-GDP ratios. Finally, selecting HDI as a proxy for human capital was necessary because of the lack of recent data on average years of schooling[4]. HDI is the geometric mean of expected years of education, life expectancy and gross national income per capita. While the latter indicator is endogenous, HDI is considered an adequate but not perfect measure of human capital.[5]

The fiscal regressors used in the main specification from the OECD Fiscal database (2023) are total tax revenue as a per cent of GDP and four tax categories expressed as shares of the overall tax burden. These can be considered implicit tax rates and account for more than 95% of all tax revenue in the selected countries. They are personal income taxes (IT), including social security contributions and payroll taxes, corporation income taxes (CT), property taxes (TP), and taxes on goods and services (TGS). Some specifications add deficit and non-tax revenues to the specification, as it could be helpful to model them as part of the total fiscal revenue.

Gemmell et al. (2013) discuss the merits of using average tax rates (ATRs) as fiscal variables instead of implicit tax rates. ATRs are the ratios between the revenue from a tax and its tax base as measured in the national accounts (i.e. the ATR on labour is the ratio of the revenue obtained from taxing labour to the total income from labour in an economy). ATRs remove some endogeneity compared to implicit tax rates, as they are unaffected by tax base changes. This study uses McDaniel's (2007) ATRs as another modelling option.

Gemmell et al. (2013) explain that statutory tax rates can reduce the endogeneity further. They are decided by governments instead of being macroeconomic aggregates. This study also shows a regression with marginal IT and CT rates as regressors (from OECD, 2023), as they could affect growth through innovation and entrepreneurship. Using marginal tax rates has its drawbacks, too: they do not account for the effect of rate thresholds and the role of tax reliefs. Also, endogeneity is still present, as governments can change marginal tax rates in response to economic fluctuations.

3.2 Methodology

As discussed in Section 2, labour and capital accumulation drive economic growth in neoclassical growth models, so the tax structure can only affect growth through those production factors. In endogenous growth models like Lucas (1990), fiscal policy directly affects economic growth. Mankiw et al. (1992) augmented Solow model allows for the

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[4] Penn World Table's Human Capital Index is used only in some regressions, as it may be non-stationary.

[5] Ivanova et al.(1999) explain that HDI is better at measuring the current level of development than the future.

estimation of the effect of fiscal variables on growth even when the underlying growth process follows Solow's or Lucas'model.

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t) L(t))^{1-\alpha-\beta} \quad (2)$$

Equation (2) represents a Cobb-Douglas production function with a constant returns-to-scale technology. Output level at time (t) is a function of physical capital (K), human capital (H), and labour (L) —augmented by the technological efficiency level (A). α, β, and 1-α-β are the partial elasticities of each production factor. Within this specification, taxation could affect growth through the factor levels (K, H, and L) or technological efficiency (A) if, for example, they affect innovation or entrepreneurship.

Different ways exist to adapt equation (2) to panel data with a long-time series component. Early research on taxes and growth used specifications which averaged periods of five years or more due to limitations of the modelling available, suited to microeconomic panels with large cross sections and short timespans. Such an approach discards information and data dynamics. Pesaran et al. (1999) introduced the Pooled Mean Group (PMG) estimator suited to dynamic modelling. PMG estimation requires re-parameterising equation (1) into a panel ARDL specification first and then again into an Error Correction model, as shown in equation (3) on the next page.

$$\begin{aligned} \Delta lny_{it} = a_{0i} - \oint_I lny_{it-1} + a_{1i}\, s_{it}^{k} + a_{2i}\, h_{it} - a_{3i}\, n_{it} + \textstyle\sum a_{ji}\, V_{it}^{j} + F_i(t) \\ + b_{1i}\, \Delta lns_{it}^{k} + b_{2i}\Delta lnh_{it} + b_{3i}\Delta lnn_{it} + \textstyle\sum b_{ji}\, \Delta V_{it}^{j} + F_i(t) + \varepsilon_{it} \end{aligned} \quad (3)$$

In equation (2), y is the output per capita, s^k is the growth of capital per working population, h is the growth in human capital (HDI), n is the growth in total hours worked, a_0 denotes country fixed effects, (t) is a function on time, and V is the vector of fiscal variables. The long-term coefficients (a_1, a_2, a_3, a_{ji}) are the main ones discussed in this study. The second line of the equation estimates the short-term coefficients, $\oint$ is the speed of adjustment between short and long-term., and ε the error term. Equation (3) is the main functional form used.

The PMG estimator allows short-term coefficients to differ while imposing a unique long-term coefficient for all cross-sectional units. This feature makes the PMG preferable to other estimators for Panel ARDL. PMG accounts for heterogeneous short-term output responses to tax changes among the selected countries, which may result from diverse industrial or labour regulations. At the same time, the pooled estimation in the long term brings more efficient estimates assuming that output responses to fiscal variables are homogeneous in that long term. This assumption has been assessed and upheld through Hausmann tests (Arnold, 2008; Gemmell et al., 2013) which makes intuitive sense when regressing advanced market economies. This paper reports the results of an alternative estimator (Mean Group estimator) in a robustness test. This estimator reports the mean of the individual cross-sections' coefficients, so the estimation is less efficient than PMG.

3.3 The budget constraint and estimation process.

Kneller et al. (1999) discuss the importance of specifying the full government budget constraint when assessing the effects of fiscal policy. The budget, including expenditure, revenue, and deficit, is a closed system and adds to zero. They demonstrate that when omitting one of the

fiscal policy variables in the regression, to avoid multicollinearity, that omitted variable is the compensating element of the budget constraint. Arnold (2008), among others, modified this methodology to assess strictly the effect of taxation on growth. The process involves regressing tax categories expressed as shares of the total taxation and controlling for total tax revenue. When the regression omits a tax category, the coefficients for the regressors show the effect on growth of tax revenue increases in the included category, offset by an equivalent reduction of the share of taxation in the omitted one.
This paper uses a similar approach to Arnold (2008) in the main regressions[6] to assess the effect of revenue-neutral tax changes on growth. The dataset selected extends the timespan of previous studies until 2019. The results section shows alternative specifications which regress different fiscal variables, as discussed in section 3.1, while trying to address endogeneity and differentiate the effects of taxes on growth through technology and innovation from possible impacts through the factors of production.

The robustness checks include standard econometric tests, other tests specific to panel datasets with a considerable time-series element, and an assessment of the risk of endogeneity. They conclude with a test on cross-sectional dependence.

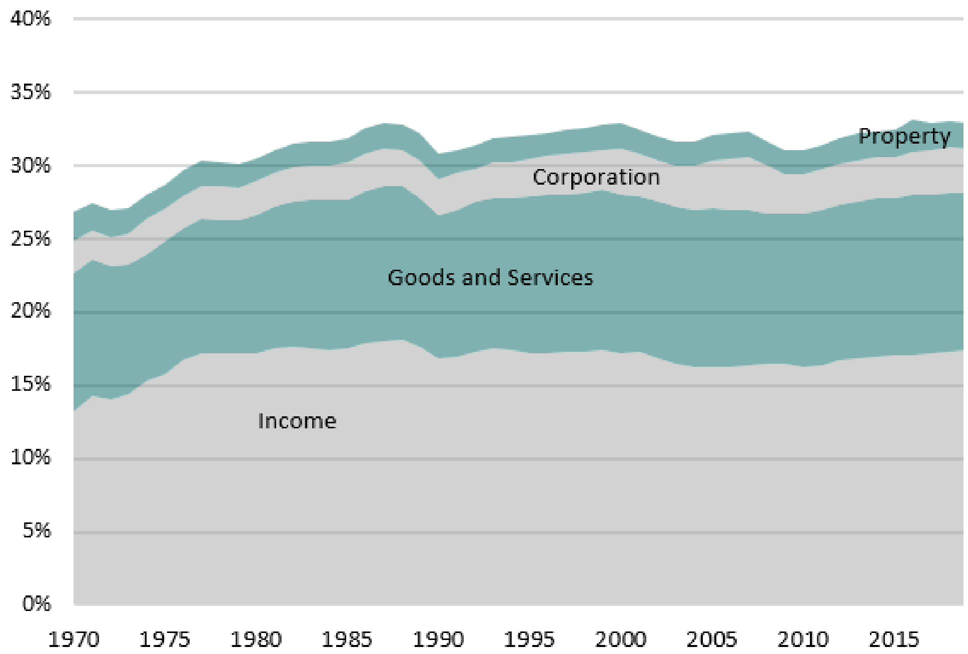
Before the results, the next pages include charts of the fiscal variables and a visual representation of the PMG estimator. Implicit tax rates data is available from 1970 to 2019 for all the countries mentioned in the introduction. Average tax rates data is only available from 1960 to 2002 and excludes Denmark, Greece, Ireland, New Zealand and Norway from the original 20 countries. Marginal tax rates data are restricted too, from 1981 to 2019, and exclude Japan, Norway and Switzerland. A complete set of UK-specific charts is included in the Appendix.

Table 2: Summary of data and methodology.

Type	Description	Source
Dependent variable	GDP p.c.	Penn World Table (10.1)
Baseline regressors	Capital stock, average working hours	Penn World Table (10.1)
Baseline regressor	Human Development Index	United Nations (2022)
Fiscal regressors	Total tax revenue, taxes as a share of total taxation, deficit, non-tax revenue	OECD (2023)
Fiscal regressor	Average tax rates	McDaniel (2007)
Fiscal regressor	Marginal corporation, income tax rates	OECD Tax Statistics (2023)
Model	Panel ARDL	Pesaran et al.(1999)
Estimator	Pooled Mean Group (PMG)	Pesaran et al. (1999)

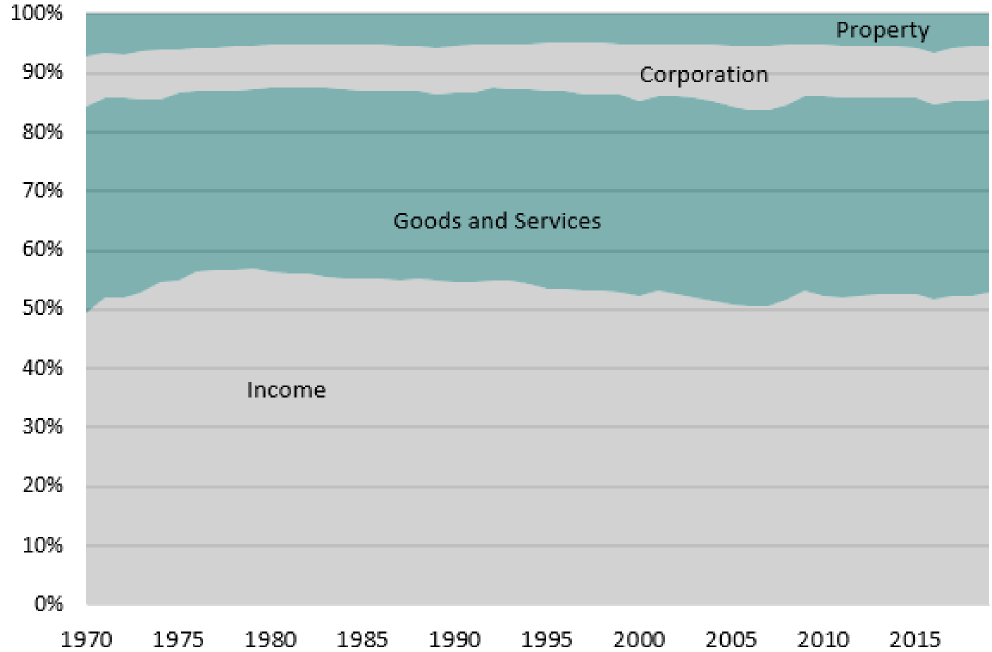
[6] Arnold (2008) omits one tax variable at a time. This approach was plagued by multicollinearity in some regressions, avoided when omitting two fiscal variables in most estimations..

Chart 3: Implicit tax rates, percent of GDP (OECD average, 1970-2019)

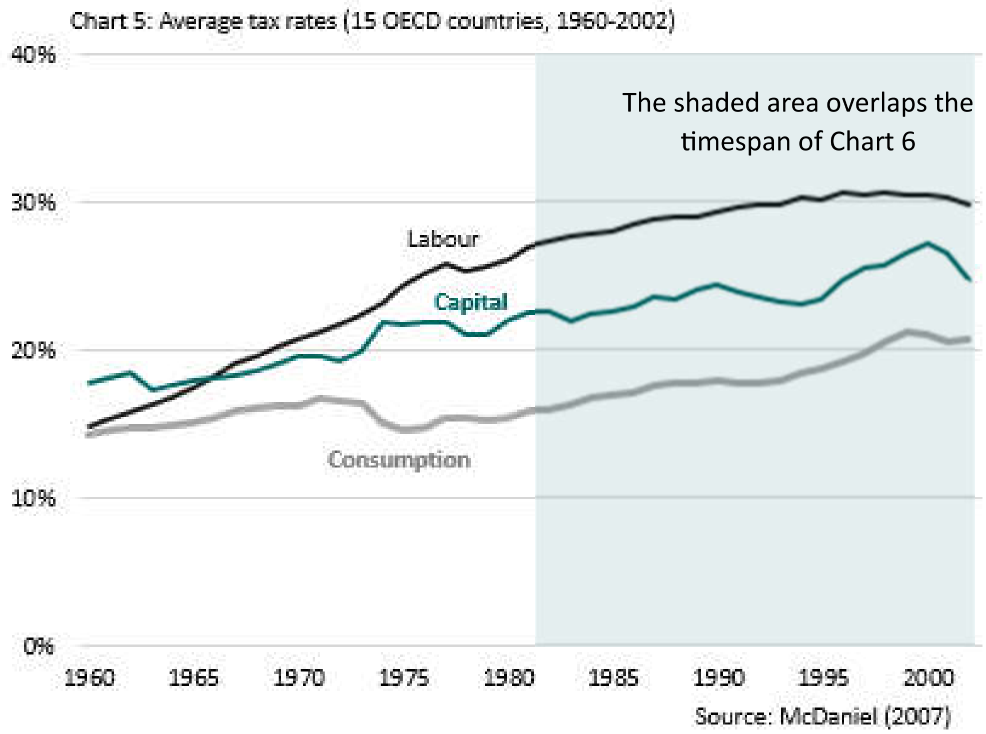


Source: OECD (2023)

Chart 4: Implicit tax rates, percent of total tax revenue (OECD average, 1970-2019)



Source: OECD (2023)



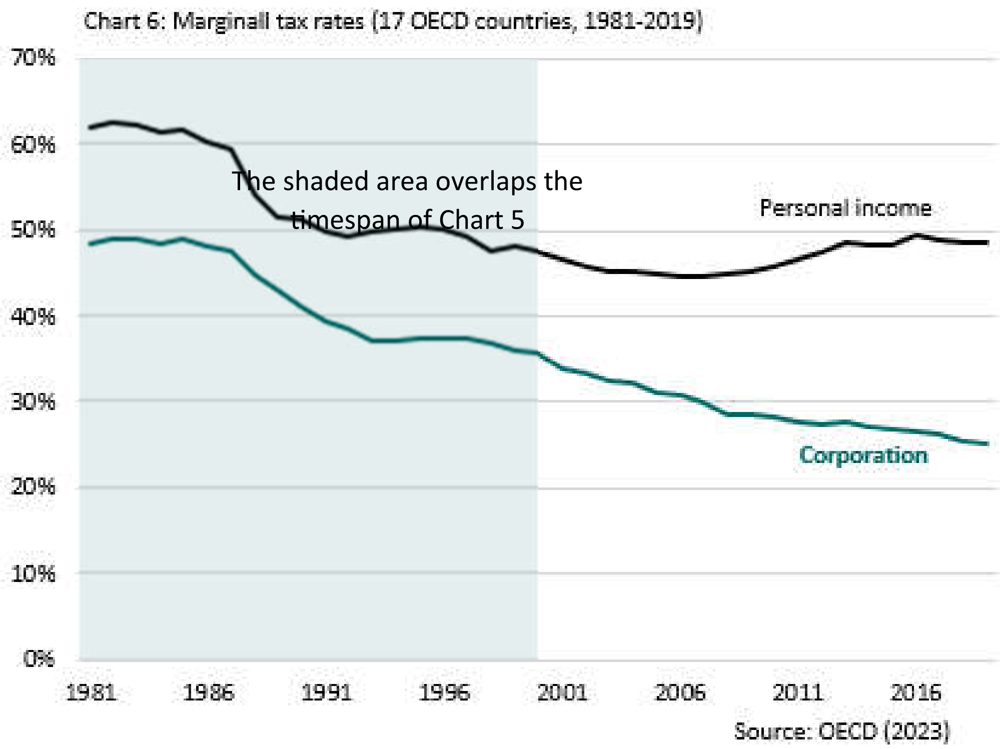
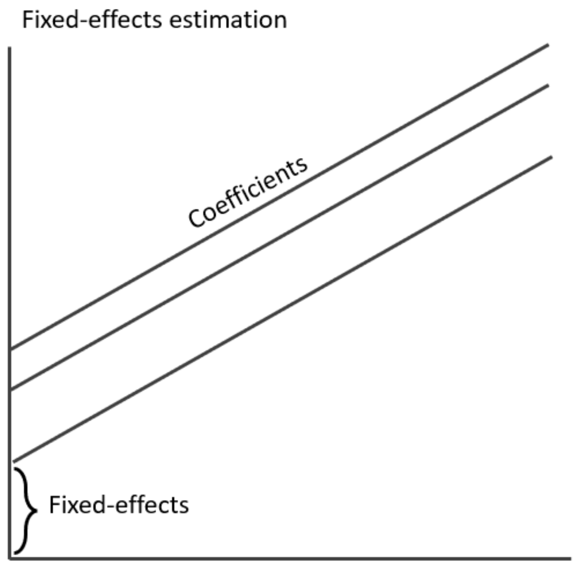
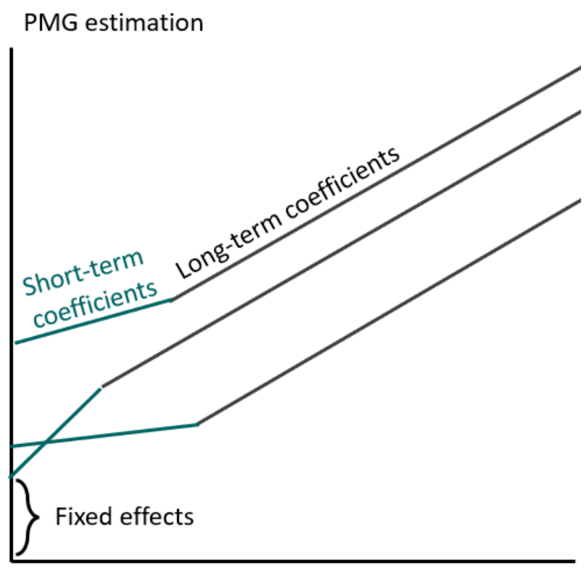


Chart 7: Comparing PMG estimation with Fixed-effects estimation.





4. Results

4.1 Baseline and main specifications

Table 3 shows a growth baseline regression. A 1% increase in capital per worker correlates with a 0.12% increase in GDP p.c. growth rate, while a 1% increase in working hours, with 0.87%. A 1% growth in the HDI correlates with a 0.75% increase in output growth rate. The values are slightly smaller than the ones shown by Arnold (2008) for physical and human capital. The labour force growth coefficient is substantially higher than in Gemmell et al.(2013, table 1), probably due to the use of hours worked as a regressor instead of employment figures.

Table 3: Regression 1, baseline.

Dependent variable: Growth of GDP p.c.	
Labour force growth (hours worked)	**0.87 (0.05)*** **
Human capital growth (HDI)	**0.75 (0.26)*** **
Physical capital growth (stock per employed)	**0.12 (0.02)*** **

*The regression outputs[7] include the long-term coefficients with standard errors in brackets and the significance levels: * at 10%; ** at 5% level; *** at 1%.*

The following regression (Table 4, next page) adds to this baseline the share of four taxes as a per cent of the total tax revenue and the total tax revenue as a control variable in order to achieve revenue neutrality, so increases in the share of tax revenue for the included tax categories are offset by equivalent decreases in the share of the omitted ones. Column 1 shows that an increase in the IT share of 1% offset by a reduction of the share of taxes on goods and services TGS or TP is correlated with a 0.14 decrease in GDP p.c. growth. The CT coefficient is not significant. Column 2 shows how increases in TP and TGS, offset by reductions in CT and IT, are favourable for growth. The coefficients' values are not too dissimilar to Gemmell et al.(2011) and McNabb (2018). Arnold (2008) shows a significant negative effect of CT on growth and substantially higher coefficients. The surprising positive growth effect of the total tax burden is also found in McNabb (2018), while it has a large negative effect in Furceri et al.(2007).

Table 4: Regressions 2(1) and 3(1), implicit tax rates.

Dependent variable: Growth of GDP p.c.	(1)	(2)
Labour force growth	0.90 (0.05)***	0.90 (0.05)***
Human capital growth	0.61 (0.24)**	0.86 (0.24)***
Physical capital growth	0.12 (0.02)***	0.15 (0.06)***
Tax revenue, % of GDP	0.08 (0.04)*	0.12 (0.05)***
IT	—0.14 (0.04)***	
CT	—0.08 (0.06)	
TGS		0.16 (0.07)***
TP		0.17 (0.05)***
Revenue-neutrality achieved by omitting:	TGS, TP	IT, CT

*The regression outputs[8] include the long-term coefficients with standard errors in brackets and the significance levels: * at 10%; ** at 5% level; *** at 1%.*

[7] All PMG regressions also yield coefficients for short-term dynamics, speed of adjustment, a linear trend, and country-specific coefficients. Because they do not affect long-term growth results, these coefficients are excluded from the text, but they are available upon request. The coefficients for speed of adjustment suggest that the output response to fiscal changes is fast: 90% is achieved within a year; Gemmell et al. (2006) discuss this aspect in depth.

[8] All PMG regressions also yield coefficients for short-term dynamics, speed of adjustment, a linear trend, and country-specific coefficients. Because they do not affect long-term growth results, these coefficients are excluded from the text, but they are available upon request. The coefficients for speed of adjustment suggest that the output

Regressions 2 and 3 do not account for non-tax means of financing public expenditure: public debt and non-tax revenues. The following specification adds both variables to the regression, so the total revenue variable now includes all taxes, deficit, and non-tax revenue. Again, the regressions omit different taxes at a time to compensate for changes in the variables regressed to achieve revenue neutrality. The results are close to the previous regression, but now CT has a statistically significant negative effect on growth. Also, column 1 suggests that financing expenditure through deficit and offsetting this with TP and TGS reductions is negative for growth. When IT and CT reductions offset deficit increases, its coefficient is not statistically significant. These coefficients are not dissimilar to the ones shown by Gemmell et al. (2013), noting that they include TP as part of a distortionary taxes group, along with IT and CT, and they add public expenditure to the regression.

Table 5: Regression 4(1) and 5(2), implicit tax rates with deficit.

Dependent variable: Growth of GDP p.c.	(1)	(2)
Labour force growth	**0.67 (0.06)*** **	**0.63 (0.06)*** **
Human capital growth	**0.72 (0.21)*** **	**0.97 (0.22)*** **
Physical capital growth	**0.14 (0.02)*** **	**0.13 (0.02)*** **
Total fiscal revenue, % of GDP	**0.00 (0.03)**	**0.01 (0.04)**
IT	**—0.11 (0.04)*** **	
CT	**—0.15 (0.06)** **	
TGS		**0.11 (0.05)** **
TP		**0.13 (0.08)* **
Government deficit, % of GDP	**—0.13 (0.03)*** **	**—0.01 (0.02)**
Revenue-neutrality achieved by omitting:	TGS, TP	IT, CT

*The regression outputs[9] include the long-term coefficients with standard errors in brackets and the significance levels: * at 10%; ** at 5% level; *** at 1%.*

4.2 Alternative tax measures

Table 6 shows a regression of growth on average tax rates (ATRs). As discussed in section 3.1, using ATRs reduces the specification's endogeneity. However, they cannot be modelled within a revenue-neutral framework. Still, the tax coefficients are like previous estimates: a 1% increase in the ATR on labour correlates with a reduction of GDP growth by 0.16%, and a

response to fiscal changes is fast: 90% is achieved within a year; Gemmell et al. (2006) discuss this aspect in depth.

[9] All PMG regressions also yield coefficients for short-term dynamics, speed of adjustment, a linear trend, and country-specific coefficients. Because they do not affect long-term growth results, these coefficients are excluded from the text, but they are available upon request. The coefficients for speed of adjustment suggest that the output response to fiscal changes is fast: 90% is achieved within a year; Gemmell et al. (2006) discuss this aspect in depth.

similar increase in the ATR on capital correlates with a 0.08% reduction. Consumption taxes have a positive effect on growth, too, even without revenue neutrality. The speed of adjustment to a fiscal change, although not shown, is 20-25% slower than in previous regressions. This could be explained by these variables' lower risk of reverse causality and endogeneity. Note that in this regression, the period analysed is 1960 to 2002 and excludes Denmark, Greece, Ireland, New Zealand and Norway from the original 20 countries, and labour force is measured as growth in employment figures.

Table 6: Regression 6, ATRs.

Dependent variable: Growth of GDP p.c.	
Labour force growth	**0.71 (0.07)*** **
Physical capital growth	**0.28 (0.04)*** **
ATR, labour	**−0.05 (0.02)*** **
ATR, capital	**−0.07 (0.03)** **
ATR, consumption	**0.12 (0.04)*** **

Section 2 discussed how marginal and corporation income tax rates could affect growth. In Table 7, the coefficients for these variables are not significant. Gemmel et al.(2013) found robust evidence that the top rate of income tax has adverse effects on growth, whereas Piketty et al.(2011) did not. This may derive from using different measurements of marginal rates and from the fact that they are crude measurements of taxation, as they do not account for tax reliefs or rate thresholds. This regression excludes Japan, Norway and Switzerland from the original group and the period studied is 1980 to 2019.

Table 7: Regression 7, marginal tax rates.

Dependent variable: Growth of GDP p.c.	
Labour force growth	**0.91 (0.06)*** **
Human capital growth	**0.58 (0.21)*** **
Physical capital growth	**0.06 (0.02)*** **
Marginal income tax	**0.00 (0.01)**
Marginal corporation tax	**0.00 (0.01)**

4.3 Residual growth

Previous models include production factors as regressors. Apart from adding endogeneity to the estimation, this makes it difficult to isolate the effects of fiscal variables on growth indirectly, through labour and capital, from their direct impact through innovation or increased returns to capital derived from entrepreneurship. Gemmell et al.(2013) found a neat way to confirm the fiscal effects on growth outside the factors of production. It consists of regressing the residuals from regression 1, the baseline growth specification (its residuals acting as a 'Solow residual growth' unexplained by the factors of production) against tax regressors. While other factors will affect that residual growth, such regression can be used to attest if the fiscal variables have some explanatory power on that residual growth. Table 8 shows regressions on that 'growth residual' within the revenue-neutrality framework. Comparing their coefficients with previous ones is misleading, as now they should only explain the effect of tax variables on that growth residual, which is part of the overall growth.

Table 8: Regressions 8(1) and 9(2), implicit tax rates.

Dependent variable: Residuals of growth baseline regression	(1)	(2)
Tax revenue, % of GDP	**0.05 (0.04)**	**0.11 (0.04)*** **
IT	**—0.10 (0.03)*** **	
CT	**—0.00 (0.06)**	
TGS		**0.10 (0.04)*** **
TP		**0.17 (0.06)*** **
Revenue-neutrality achieved by omitting:	TGS, TP	IT, CT

Regression 10 assesses IT and CT's effect on productivity (GDP per hour worked), part of that 'growth residual'. There is a negative IT correlation with productivity.

Table 9: Regression 10, implicit tax rates.

Dependent variable: GDP per hour worked	
Labour force growth	**—0.08 (0.06)*** **
Human capital growth	**0.58 (0.04)*** **
Physical capital growth	**0.18 (0.02)*** **
Tax revenue, % of GDP	**0.06 (0.04)**
IT	**—-0.15 (0.04)*** **
CT	**—0.06 (0.06)**
Revenue-neutrality achieved by omitting:	TGS, TP

4.4 Growth through the factors of production

Assessing the effect of taxes on production factors may give some insights into how they affect growth indirectly through them. Table 8 shows regressions on factors against the ATRs on labour and capital. While there is a clear risk of omitted variable bias, the regression follows the spirit of Pesaran (2017))[10]. While the effect of the labour tax on labour is small, the effect of the average taxes on capital is surprisingly large. While the 'residual growth' regression did not find significance for the coefficient of capital taxation, the large coefficient shown below could reflect the effect of capital ATRs on growth through investment and signal the potential endogeneity of previous estimations. Notably, regressing average working hours, within the revenue-neutrality framework, yielded no significant tax coefficients. This is consistent with empirical evidence (OECD, 2011) of income taxes affecting participation levels via the incorporation of second earners rather than through its effects on hours worked.

[10] This applied paper claims explanatory power from coefficients yielded by some models where public debt is the only regressor. Pesaran, the creator of the PMG estimator (Pesaran, 1999), seems untroubled about bias, perhaps because such a regression reduces endogeneity, and the specification includes fixed effects.

Table 10: Regressions 11(1), 12(2), and 13(3), ATRs.

	Dependent Variables		
Independent variables	(1) Labour force	(2) Human capital	(3) Physical capital
ATR, labour	—0.08 (0.03)**	0.00 (0.00)	
ATR, capital		0.02 (0.00)	—0.40 (0.09)***

A different way to assess the indirect effect of taxes on growth through the production factors is by excluding them from the regression and comparing their coefficients with those from a regression which includes them. While this again increases the risk of omitted variable bias, it decreases the risk of endogeneity. Table 12 shows this comparison: the coefficient for the effect of ATRs on capital has doubled, while the one for ATR on labour is similar. The consumption tax coefficient is no longer significant.

Table 11: Regressions 6(1) and 14(2) omitting production factors.

Dependent variable: Growth of GDP p.c.	(1)	(2)
Labour force growth	0.74 (0.07)***	
Human capital growth	1.27 (0.41)***	
Physical capital growth	0.26 (0.04)***	
ATR labour	—0.16 (0.04)***	—0.15 (0.04)***
ATR capital	—0.08 (0.04)*	—0.15 (0.05)***
ATR consumption	0.08 (0.05)*	0.07 (0.04)

Summarising the results and assessing the mechanism through which taxes affect growth is difficult. If average taxes on labour affect labour growth in regression 11, why are its coefficients unchanged after omitting labour as a regressor? Human capital reacts positively (with a very small coefficient) to higher ATRs on capital but not negatively to ATRs on labour, which contradicts Lucas (1990). Perhaps raising the costs of capital marginally increases labour training as capital tax raises renders labour relatively cheaper. In any case, the human capital variable used for this specification may be non-stationary at first-difference, which will bias panel ARDL estimation. Regression 2 suggests no impact of CT on growth. In contrast, regression 4 shows a negative effect when adding deficit as a regressor, which may be explained by the combined effect of the tax and the crowding-out effect of deficit on investment. This negative effect of CT in regression 4 is not confirmed by the 'growth residual' regression using ATRs. Moreover, the growth residual regression should yield higher tax coefficients than when estimating their effect on overall growth, as the residual growth is part of it.

A possible explanation for these inconsistencies is that the regressions report biased coefficients due to endogeneity and omitted variables. The conceptual difference between implicit tax rates and ATRs may confound things further. The robustness checks section discusses these issues in depth.

Table 12: Summary of results	Implicit tax rates, regressions 4,5				ATRs, regressions 7,10		
Growth variables/Tax variables	IT	CT	TGS	TP	Labour	Capital	Consumption
Growth of GDP p.c.	—	—	+	+	—	—	+
Residual growth/productivity	—	?	+	+	—	—	+
Labour force growth					—		
Human capital growth					?	+	
Physical capital growth						—	

5. Robustness checks

5.1 Standard tests

Several specifications regress shares of total tax revenue which implies potential collinearity, as together they add up to 1. The revenue-neutrality framework reduces this risk in some regressions, as they omit fiscal variables. The low correlation between variables shown in Table 13 reduces the multicollinearity risk even further.

Table 13: Correlation coefficients, non-fiscal variables.

	Growth of GDP p.c.	Labour force growth	Human capital growth	Physical capital growth
Growth of GDP p.c.	**1.00**			
Labour force growth	**0.40**	**1.00**		
Human capital growth	**0.24**	**0.05**	**1.00**	
Physical capital growth	**0.06**	**—0.26**	**0.08**	**1.00**

Chart 5 shows the Jarque-Bera test results and a histogram of the residuals for regression 2. The test rejects the null hypothesis that they are normally distributed, suggesting an omitted variable, as expected in growth regressions. Recent literature (Knief & Forstmeier, 2021) consider that violating the normality assumption has limited risks for estimation,

Chart 8: Residuals of regression 2, histogram and Jarque-Bera test.

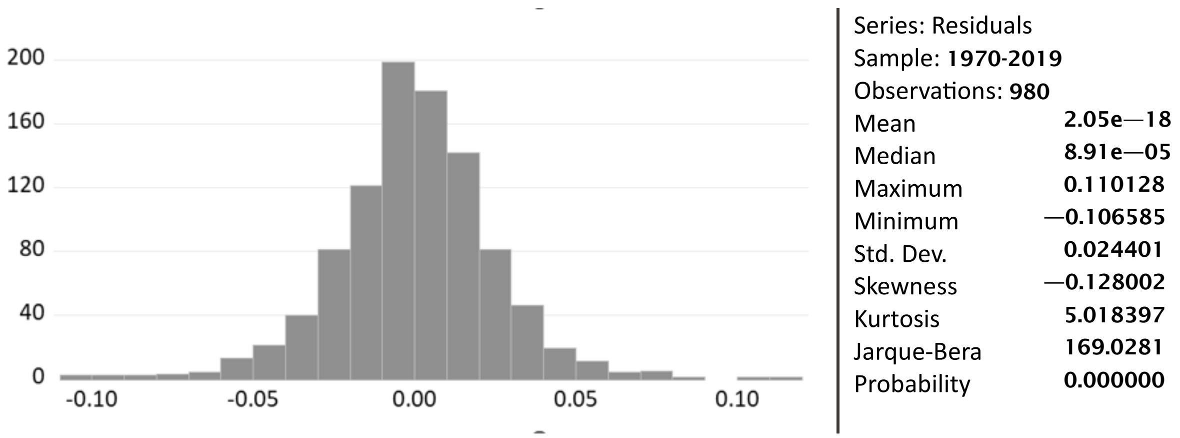


Table 14 shows the results of the Im, Pesharan and Shim (IPS) and Augmented Dickey-Fuller (ADF) tests, with mixed evidence of stationarity in the residuals for regression 2, indicating that the regression could be spurious (Woolridge, 2008). If they were stationary, this would imply that the residuals are homoscedastic, as expected from a dataset with a strong time-series component. In both tests, the null hypothesis is the existence of a unit root.

Table 14: Residuals of regression 2, further tests.

Null hypothesis: unit-root and no-autocorrelation	Statistic	Prob.
IPS[11]	—2.77	0.00
ADF	50.10	0.11
Ljung-Box Q	28.46	0.00
Ljung-Box Q regression 16	19.53	0.08

Table 14 also shows the results of the Ljung–Box Q test for autocorrelation. The null hypothesis is no-autocorrelation, which cannot be rejected up to the 12^{th} lag[12]. Table 15 compares the original specification with a two-lagged one which does not show signs of autocorrelation up to the 12^{th} lag. It is worth noting that the Schwarz-Bayesian information criterion (SIC) used in these regressions - following Pesaran et al. (2009)– selects one-lagged specifications. Regression 16 also confirms the stability of the specification with different lag structures, as Arnold (2008) reported.

[11] IPS was selected for the residuals because is a panel unit root test. Several lag lengths were tried, and the reported result tested 12. The test suggested non-stationarity with a very large number of lags. ADF lag selection follows Schwert's (1989) recommendation of 10 lags for a 50-year timespan.

[12] An informal rule for Ljung-Box Q lag selection is to divide the number of years by four or five.

Table 15: Regression 2(1) compared to the two-lagged regression 16(2).

Dependent variable: Growth of GDP p.c.	(1)	(2)
Labour force growth	**0.90 (0.05)*** **	**0.89 (0.07)*** **
Human capital growth	**0.61 (0.24)** **	**0.69 (0.25)*** **
Physical capital growth	**0.12 (0.02)*** **	**0.11 (0.03)*** **
Tax revenue, % of GDP	**0.08 (0.04)* **	**0.12 (0.04)*** **
IT	**—0.14 (0.04)*** **	**—0.12 (0.04)*** **
CT	**—0.08 (0.06)**	**—0.05 (0.06)**
Revenue-neutrality achieved by omitting:	TGS, TP	

Another robustness test used in the literature consists of comparing regressions with the same variables but different timespans. Table 12 compares regression 2 with another, which restricts the years analysed to 1975-2010 (regression 17) and shows asymmetrical changes in the magnitude of the coefficients, but their signs remain unchanged.

Table 16: Regression 2(1) and regression 17(2).

Dependent variable: Growth of GDP p.c.	(1)	(2)
Labour force growth	**0.90 (0.05)*** **	**0.90 (0.06)*** **
Human capital growth	**0.61 (0.24)** **	**0.61 (0.24)** **
Physical capital growth	**0.12 (0.02)*** **	**0.14 (0.00)*** **
Tax revenue, % of GDP	**0.08 (0.04)*** **	**0.18 (0.05)*** **
IT	**—0.12 (0.04)*** **	**—0.09 (0.05)*** **
CT	**—0.08 (0.06)**	**—0.13 (0.07)* **
Revenue-neutrality achieved by omitting:	TGS, TP	TGS, TP

Two further tests are shown in Table 17: Regression 18 omits two of the smallest countries in the sample[13], and regression 19 adds inflation as a regressor. Column 1 shows the outputs for the original regression 4. The changes after reducing the country selection are negligible. However, adding inflation reduces the coefficients of IT and CT, brings a significant negative coefficient for total revenue, and the coefficient for deficit loses significance. Similar results were reported with and without a linear time trend.

[13] Ireland and Norway are omitted. Apart from being two of the smallest countries in the sample, they have some fiscal singularities. Ireland has had the lowest CT rates in the sample during the last two decades, and Norway has the highest non-tax public revenues due to oil exports.

Table 17: Regression 2(1) compared to regression 18(2) omitting two countries and 19(2) adding inflation.

Dependent variable: Growth of GDP p.c.	(1)	(2)	(3)
Labour force growth	0.67 (0.06)***	0.70 (0.06)***	0.49 (0.02)***
Human capital growth	0.72 (0.21)***	0.72 (0.21)***	1.15 (0.21)***
Physical capital growth	0.14 (0.02)***	0.15 (0.03)***	0.09 (0.02)***
Inflation (Consumer Price Index)			−0.02 (0.02)
Total fiscal revenue, % of GDP	0.00 (0.03)	0.02 (0.04)	−0.09 (0.03)***
IT	−0.11 (0.04)***	−0.12 (0.04)***	−0.05 (0.03)*
CT	−0.15 (0.06)***	−0.17 (0.07)**	−0.10 (0.05)**
Government deficit, % of GDP	−0.13 (0.03)***	−0.15(0.04)***	−0.04 (0.03)
Revenue-neutrality achieved by omitting:	TGS, TP	TGS, TP	TGS, TP

5.2 Time-series tests[14]

Panel ARDL estimation requires stationary at levels I(0) or at first-difference, I(1) for all the variables. The ADF test (Table 18) indicates that this is true for taxes expressed as shares of tax revenue. ATRs fail the test. However, IPS testing suggested that they might be I(1) or I(2), depending on the lag selection. Surprisingly, the growth rate is I(1) using the ADF test, while the IPS test reports I(0) with some lag lengths.

Table 18: ADF test.

	Level		First-difference	
Null hypothesis: unit-root	Statistic	Prob.	Statistic	Prob.
Growth of GDP p.c.	50.72	0.12	−5.68	0.00
IT	45.25	0.26	93.53	0.00
CT	32.42	0.19	58.35	0.03
TGS	41.41	0.41	73.03	0.00
TP	36.51	0.62	64.33	0.01
ATR, labour	32.42	0.35	20.98	0.89
ATR, consumption	17.13	0.97	33.85	0.88
ATR, capital	25.39	0.71	38.14	0.15

Most of the surveyed literature reports output growth as I(0) and fiscal variables as I(1). Jones (1995) argued that non-stationary variables could not explain stationary ones like GDP growth unless *'by some astonishing coincidence all of the movements in variables that can have permanent effects on growth rates have been offsetting'*. Gemmel et al.(2011) argue that this paradox can be explained because fiscal policy is volatile and because *'growth-enhancing and growth-retarding fiscal changes often occur simultaneously.'* For Bajika & Narashiman (2015), though, this issue negates the possibility of taxation changing the long-term growth rate: at most, tax policy can affect only the output level, However, it can be argued that, as discussed in section 3.1, a slow change towards a higher output level will look similar to a growth rate change.

[14] Due to their length, some test results are not shown. They are available upon request.

Another consequence of the claimed growth rate's stationarity is that it cannot be cointegrated. This would reaffirm the idea of no long-term relationship between tax variables and growth rates and that the regression results may be either spurious or the consequence of unobserved factors which affect growth and taxation, which would be at odds with the stationary behaviour of regression 2 residuals in the ADF test. Cointegration implies at least one causal relationship between variables, understood as Granger-causality, which is helpful for forecasting but does not mean true causality.

As the ADF test suggests that growth may be I(1) in the period studied, it makes sense to test for cointegration. Table 19 shows the first four indicators reported in pairwise cointegration tests between growth and taxes. The Pedroni tests include seven indicators which, overall, strongly suggest cointegration. Cointegration implies a solid long-term relationship and assumes that both variables are I(1). This result should be taken with caution due to the mixed result of the stationarity test. Also, after rigorous testing, Bajika & Narashiman (2015) could not find cointegration between the variables.

Table 19: Pedroni cointegration test (3 lags following Pedroni, 1997).

Null hypothesis: No-cointegration	v-Statistic(p)	Rho-Statistic(p)	PP-Statistic(p)	ADF-Statistic(p)
Growth—IT	**9.03 (0.00)**	**—27.96 (0.00)**	**—20.15 (0.00)**	**—8.36 (0.00)**
Growth—CT	**1.96 (0.02)**	**—21.67 (0.01)**	**—22.47 (0.00)**	**—9.27 (0.00)**
Growth—TGS	**0.04 (0.48)**	**—22.67 (0.00)**	**—21.85 (0.00)**	**—8.54 (0.00)**

5.3 Endogeneity and reverse causality

Endogeneity and reverse causality are essential concerns in growth research. It is easy to imagine a situation where consumption-driven growth increases consumption tax revenues or where a recession prompts governments to change tax rates. This can be addressed using instrumental variables. Due to the scarcity of valid instruments for tax variables, lags of the suspected endogenous regressors are commonly used. However, lagged tax variables can still suffer from endogeneity brought in by expectations as, for example, a government may reduce taxes to address forecasted low growth.

This study tries to reduce endogeneity through the modelling approach, using average tax rates in some regressions and omitting production factors in others. The specification selected (ARDL) yields unbiased long-run coefficients even in the presence of reverse causality and endogeneity (Pesaran et al.,1999) if the regressors are I(1), are not cointegrated among themselves (but uniquely cointegrated with the dependent variable), have sufficient lags, and are weakly exogenous. ADF tests show that tax variables are I(1). Table 19 and further Johansen-Fisher tests indicate that the specification upholds the cointegration conditions, and the recommended SIC selects the lag structure. Weak exogeneity has not been tested, however, Gemmell et al. (2015) found that their tax variables were weakly exogenous for most countries used in their study, which assesses a similar sample of countries and timespan than this one.[15]

[15] Gemmell et al. (2015) weak exogeneity test, which follows Calderon et al. (2015) requires estimating hundreds of models.

5.4 Cross-sectional dependence

Panel ARDL assumes that errors are cross-sectionally independent, which may not be true when unobserved economic factors or common shocks affect different cross-sections in the model. This could be an issue for the countries selected, as they are interdependent, so their economic cycles are synchronised, and tax changes in a country can affect neighbours. If this is ignored, the biases introduced in regressions are large.

The Pesaran CD test (Pesaran, 2017) results for regression 2 rejected the null hypothesis of no cross-sectional dependence (18.94 statistic, prob. 0.00). Chudik et al.(2015) explain how augmenting the ARDL specification with cross-sectional averages of the variables and a sufficient number of lags (three for forty years timespans) eliminates cross-sectional dependence bias. This modelling approach (CS-ARDL) did not find statistical significance for the tax variables, as shown in Table 18, perhaps because such a specification, which adds extra coefficients and lags for each variable, substantially reduces the degrees of freedom per group. The effect is compounded because the specification is estimated with the less efficient Mean Group estimator.

Table 20: Regression 20, CS-ARDL re-estimation of regression 2.

Dependent variable: GDP per hour worked	
Labour force growth	**0.45 (0.22)***
Human capital growth	**0.76 (0.91)**
Physical capital growth	**0.08 (0.25)**
Tax revenue, % of GDP	—**0.11 (0.22)**
IT	—**0.18 (0.22)**
CT	—**0.06 (0.06)**
Revenue-neutrality achieved by omitting:	TGS, TP

Chudik et al.(2017) found cross-sectional dependence while researching the effects of public debt on growth. Accounting for it changed some results: Their CS-ARDL estimation reported no evidence of a universally applicable threshold effect at 60% debt/GDP. A previous estimation, not accounting for cross-sectional dependence, however, did report a threshold effect. The fact that they sampled a large number of countries may be the reason for finding robust results using CS-ARDL. While the results of the cointegration tests add strength to this report's findings, the effects of inflation in the estimation and the evidence of cross-sectional dependence, not resolved through alternative modelling, demand a sceptical conclusion section.

6. Conclusion

This paper aimed to assess whether a relationship exists between tax structures and economic growth and evaluate the effects on growth rates from shifting revenue between taxes. The results of the robustness checks forbid giving a definite answer to these questions.

Before the robustness testing, most regressions show modest, but not negligible, positive effects on growth from shifting the burden of tax from personal income and corporation taxes to taxes on consumption and property. A 'Growth-friendly' 1% shift in the tax burden is estimated to raise growth rates by 0.1%-0.2%, partly through labour and capital and partly through higher productivity or returns to investment. Human capital affects growth, but no evidence has been found that the tax structure affects it. Whether taxation changes growth rates or shifts output levels is unclear but not a critical problem.

The specification seems robust to endogeneity, and growth is perhaps cointegrated with tax variables. However, cross-sectional dependence and the sensitivity of the results to standard growth regressors like inflation can indicate biased coefficients, probably derived from unresolved endogeneity and omitted variables. As the coefficients are small, the bias could be enough to change their true signs, invalidating policy recommendations based on these results. This is compounded because non-linear effects of tax changes have not been modelled.

Techniques that overcome cross-sectional dependence in dynamic panel data are fairly recent findings in the literature, so future theoretical developments may help to improve macroeconomic-based tax research. Alternatively, perhaps microeconomic research at the firm or individual level can give more solid answers on taxation and growth. There is also literature on the non-distortionary nature of taxation on unearned income or rent-seeking activities, which could be empirically tested. In any case, this research does not prove that tax structures do not affect growth. And even if they did, this would not need to be necessarily bad news: policy-makers could use tax policy for objectives like equity without worrying too much about its effect on growth.

To conclude, it is worth mentioning that coincidentally with this paper, VAT has celebrated its 50th birthday. In that time, it has collected three trillion pounds, which may or may not be a motive for celebration. Also, this dissertation has been financed through the Apprenticeship Levy —in essence, a tax relief for human capital investment.

References

Acosta-Ormaechea, S., and Yo, J. (2012). *Tax composition and growth: a broad cross-country perspective*. IMF WP/12/257. International Monetary Fund.

Adam, S., Besley, T., Blundell, R. (2011). *Tax by design*: *The Mirrlees Review*. Oxford: Oxford University Press.

Alinaghi N., Reed W.R. (2018). *Meta-analysis and publication bias: How well does the FAT-PET-PEESE procedure work?* Research Synthesis Methods, vol. 9(2), pp. 285–311.

Alfo, M., Carbonari, F., Trovato, G. (2021). *On the effects of taxation and growth: an assessment.* Macroeconomic Dynamics (2022), 1-30.

Arachi, G., V. Bucci, and A. Casarico, (2015). *Tax structure and macroeconomic performance*. International Tax and Public Finance 22, 635-662.

Arnold, J. (2008). *Do tax structures affect aggregate economic growth? Empirical evidence from a panel of OECD countries*. OECD Economics Department Working Papers, p. 643.

Arnold, J., Brys B., C. Heady, Johansson, A., Schwellnus, C. and Vartia, L. (2011). *Tax policy for economic recovery and growth*. Economic Journal 121(550), F59–F80.

Bakija, J., Narasimhan, T. (2015). *Effects of the Level and Structure of Taxes on Long-Run Economic Growth: What Can We Learn from Panel Time-Series Techniques?* Available online at: https://www.ntanet.org /wpcontent/uploads/proceedings/2015/049-bakija-narasimhan-effects-level-structure-taxes-long.pdf

Barrios, S., Schaechter, A. (2008). *The quality of public finances and economic growth.* Economic Papers 337. European Commission.

Barro, R. (1990). *Government spending in a simple model of endogenous growth*. Journal of Political Economy 98(5, Part 2), pp. 103–125.

Bernanke, B.S., Gürkaynak, R. S. (2002). *Is Growth Exogenous? Taking Mankiw, Romer and Weil Seriously.* NBER Macroeconomics Annual 2001, MIT Press, Massachusetts, 2002, pp. 11-17.

Bleaney, M. F., N. Gemmell & R. Kneller (2001). *Testing the endogenous growth model: Public expenditure, taxation, and growth over the long run.* Canadian Journal of Economics 34(1), 36–57.
Bujang, I., Hakim, T. A., and Ahmad, I. (2013). *Tax structure and economic indicators in developing and high-income OECD countries: a panel cointegration analysis*. Procedia Econ. Finance 7, 164–173. doi: 10.1016/S2212-5671(13)00231-1
Calderón C, Moral-Benito E, Servén L. (2011). *Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach.* Policy Research Working Paper Series 5682. World Bank.
Chamley, C. (1986). *Optimal taxation of capital income in general equilibrium with infinite lives.* Econometrica, 54,
Chudik, A. and Pesaran, M. H. (2015). *Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors*. Journal of Econometrics 188(2), 393–420.
Chudik, A., Mohaddes, Pesaran, M. H. and Raissi, M. (2017). *Is There a Debt-Threshold Effect on Output Growth?* The Review of Economics and Statistics 2017; 99 (1): 135–150.
Devereux, M.B. and Love, D. (1994). *The Effects of Factor Income Taxation in a Two-Sector Model of Endogenous Growth*. Canadian Journal of Economics, 27, 509-536
Dobbins, L., & Jacob, M. (2016). *Do corporate tax cuts increase investments?* Accounting and Business Research, 46:7, pp. 731–759.
Easterly W, Rebelo S. (1993). *Fiscal policy and economic growth*. Journal of Monetary Economics 32(3): 417–458.
Engen, E. M. and Skinner, J.S. (1996). *Taxation and economic growth.* NBER working paper no.5826.
Feenstra, R.C., Inklaar, R.,Timmer, M.P. (2015). *The Next Generation of the Penn World Table*. American Economic Review, 105(10), 3150–3182.
Furceri, D., Karras, G. (2007). *Tax changes and economic growth: Empirical evidence for a panel of OECD countries*, available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.360.2497&rep=rep1&type=pdf*.
Fuller, W. A. (1976). *Introduction to Statistical Time Series*. New York: John Wiley and Sons.
Gechert, S., and Heimberger, P. (2022). *Do corporate tax cuts boost economic growth?* European Economic Review, Elsevier, vol. 147(C).
Gemmell, N., Kneller, R., and Sanz, I. (2006). *Fiscal Policy Impacts on Growth in the OECD: Are They Long-or Short-Term?* UK: University of Nottingham.
Gemmell, N., Kneller, R. and Sanz, I. (2011). *The timing and persistence of fiscal policy impacts on growth: Evidence from OECD countries*. Economic Journal 121(550), F33–F58.
Gemmell, N., Kneller, R. and Sanz, I (2013). *The growth effects of tax rates in the OECD.* Canadian Journal of Economics 47(4), 1217–1255.
Gemmell, N., Kneller, R. and Sanz, I (2015). *Does the Composition of Government Expenditure Matter for Long-Run GDP Levels?* Oxford Bulletin of Economics and Statistics, 78, 6 (2016) 0505-9049.
Heer, B. (2019). *Public Economics*. Springer Texts in Business and Economics, Springer, number 978-3-030-00989-2, June.
Harberger, A. C., (1964). *Taxation, Resource Allocation and Welfare, in The Role of Direct and Indirect Taxes in the Federal Revenue System*. NBER and the Brookings Institution eds., Princeton Univ.Press, NJ.
Hobbes, T. (1662). *On the citizen.* 1998 Edition by Silverthorne, M. and Tuck, R. Cambridge (UK) Cambridge University Press.
Hugenford, T. L. (2023). *Corporate tax rates and economic growth since 1947*. Economic Policy Institute. Available at: https://www.epi.org/publication/ib364-corporate-tax-rates-and-economic-growth/
Im, K. S., Pesaran, M. H., and Shin, Y. (2003). *Testing for unit roots in heterogeneous panels.* Journal of Econometrics 115, 53-74.
IMF (2023), *Public Finances in Modern History.* Available at //www.imf.org/external/datamapper/datasets/FPP
Ivanova, I., Arcelus, F. J., and Srinivasan, G. (1999). *An Assessment of the Measurement Properties of the Human Development Index.* Social Indicators Research: An International and Interdisciplinary Journal for Quality-of-Life Measurement, Springer, vol. 46(2).
Jaimovich, N. and Rebelo, S. (2017). *Nonlinear effects of taxation on growth*. Journal of Political Economy 125(1), 265–291.
Jarque, Carlos M., Bera, Anil K. (1980). *Efficient tests for normality, homoscedasticity and serial independence of regression residuals*. Economics Letters. 6 (3): 255–259.
Johansen, S., (1992). *Cointegration in partial systems and the efficiency of single-equation analysis*. Journal of Econometrics, Vol. 52, pp. 389–402.
Jones, C. I. (1995). *Time Series Tests of Endogenous Growth Models.* Quarterly Journal of Economics. Vol. 110, No. 2.
Judd, K. L. (1985). *Redistributive taxation in a simple perfect-foresight model*. Journal of Public Economics, pp. 28, 59–83.
Kneller, R., Bleaney, M. F. and Gemmell, N. (1999). *Fiscal policy and growth: Evidence from OECD countries*. Journal of Public Economics 74(2), 171–190.
Knief, U., Forstmeier, W. (2021). *Violating the normality assumption may be the lesser of two evils.* Behav Res 53, 2576–2590. https://doi.org/10.3758/s13428-021-01587-5
Kumhof, M., Tideman, N., Hudson, M., and Goodhart, C. (2021). *Post-Corona Balanced-Budget Super-Stimulus: The Case for Shifting Taxes onto Land*. CEPR Discussion Paper No. 16652.
Lee, Y. and Gordon, R. (2005). *Tax structure and economic growth.* Journal of Public Economics 89(5-6).
Lucas, R. E. (1990). *Supply-side economics: An analytical review*. Oxford Economic Papers 42(2), 293–316.
Ljung, G. M., Box, G.E.P.(1978). *On a Measure of a Lack of Fit in Time Serie Models*. Biometrika. 65 (2): 297–303.
McDaniel, C. (2007). *Average Tax Rates on Consumption, Investment, Labor and Capital in the OECD: 1950–2003*. Manuscript, Arizona State University, 2007.
McNabb, K. (2018). *Tax Structures and Economic Growth: New Evidence from the Government Revenue Dataset.* J. Int. Dev., 30: pp. 173– 205. doi 10.1002/jid.3345.
Madsen, J. B., Minniti, A., Venturini, F. (2021). *The long-run investment effect of taxation in OECD Countries.* NIESR Discussion Paper, No. 527.
Mankiw, N. G., David, R. D. and Weil, D.N. (1992). *A contribution to the empirics of economic growth.* Quarterly Journal of Economics 107(2), 407–437.
Mankiw, G. Weinzierl, N., and Ferris, D. (2009). *Optimal taxation in theory and practice*. Journal of Economic Perspectives 23(4): 147-174.

Mendoza, E. G., Milesi-Ferretti, G. M. and Asea, P. (1997). *On the ineffectiveness of tax policy in altering long-run growth: Harberger's super neutrality conjecture.* Journal of Public Economics 66(1), 99–126.

Myles, G. D. (2000). *Taxation and economic growth*. Fiscal Studies, Vol. 21, pp. 141–168.

OECD (2023) Fiscal database. Paris: OECD.

OECD (2010). *Tax Policy Reform and Economic Growth.* OECD Tax Policy Studies, No. 20, OECD Publishing, Paris

OECD (2023), *Tax revenue.* doi: 10.1787/d98b8cf5-en

Pabst, A. (2022). *Fairer Taxation? The Case For and Against More Progressive Consumption Taxes in the UK.* National Institute of Economic and Social Research. United Kingdom

Pedroni, P. (2004). *Panel cointegration; asymptotic and finite sample properties of pooled time series tests, with an application to the PPP hypothesis*. Econometric Theory 20, 575–625.

Peren Arin, K., Braunfels, E., and Doppelhofer, F. (2017). *Revisiting the Growth Effects of Fiscal Policy: A Bayesian Model Averaging Approach*. CAMA Working Paper 68/2017.

Pesaran, M. H. and Smith, R. P. (1995). *Estimating long-run relationships from dynamic heterogeneous panels.Journal of Econometrics*. Vol. 68, pp. 79–113.

Pesaran, M. H. (1997). *The role of economic theory in modelling the long run*. Economic Journal, Vol. 107.

Pesaran, M. H., Shin, Y. and Smith, R. P. (1999). *Pooled mean group estimation of dynamic heterogeneous panels*. Journal of the American Statistical Association, Vol. 94.

Pesaran, M. H. (2007). *A simple panel unit root test in the presence of cross-section dependence*. Journal of Applied Econometrics, Vol. 22, pp. 265–312.

Phillips, P. C. B. and Sul, D. (2007). *Some empirics on economic growth under heterogeneous technology.* Journal of Macroeconomics 29(3), 455–469.

Piketty, T., Saez, E. and Stantcheva, S. (2014). *Optimal taxation of top labour incomes: A tale of three elasticities.* American Economic Journal: Economic Policy 6(1).

Prescott, E. C. (2004). *Why do Americans work so much more than Europeans?* Federal Reserve Bank of Minneapolis Quarterly Review, pp. 28, 2–13.

Rebelo, S. (1991). *Long-Run policy analysis and long-run growth. Journal* of Political Economy 99(3), 500–521.

Romer, P. M. (1990). *Endogenous Technological Change.* Journal of Political Economy 98, S71–S102

Romer, C. and Romer, D. (2010). *The macroeconomic effects of tax changes: Estimates based on a new measure of fiscal shocks.* American Economic Review 100(3).

Sanzo, S., Bella, M., and Graziano, G. (2017). *Tax Structure and Economic Growth: A Panel Cointegrated VAR Analysis.* Italian Economic Journal, vol. 3(2), pages 239-253, July.

Schwarz, G. E. (1978). *Estimating the dimension of a model.* Annals of Statistics, 6 (2): 461–464,

Schwert, G. (1989). *Testing for unit roots: A Monte Carlo investigation*. Journal of Business and Economic Statistics 7: pp. 147–59

Slemrod, J., and Bakija, J. M. (1996). *Taxing ourselves: A citizen's guide to the great debate over tax reform.* Cambridge, Mass., MIT Press.

Solow, R. M. (1956). *A contribution to the theory of economic growth*. Quarterly Journal of Economics 70(1).

Stoilova, D. (2017). *Tax structure and economic growth: Evidence from the European Union.* Available at www.cya.unam.mx/index.php/cy

United Nations Development Programme, Human Development Report. (2021-22). *Human Development Index.* Retrieved from https://hdr.undp.org/content/human-development-report-2021-22

Swan T. (1956). *Economic growth and capital accumulation*. Economic Record 32(2): 334–361.

Widmalm, F. (2001). *Tax structure and growth: Are some taxes better than others?* Public Choice 107(3/4), 199–219.

Wooldridge, J. M. (2009). *Introductory Econometrics: A Modern Approach*. 4th ed., international student ed. [Mason (OH)]: South-Western, Cengage Learning,

Xing, J. (2011). *Does tax structure affect economic growth? Empirical evidence from OECD countries*. Working Paper 11/20. Oxford University Centre for Business Taxation.

Appendix: UK data

Chart 9: Tax revenue, percent of GDP (UK, 1970-2019)

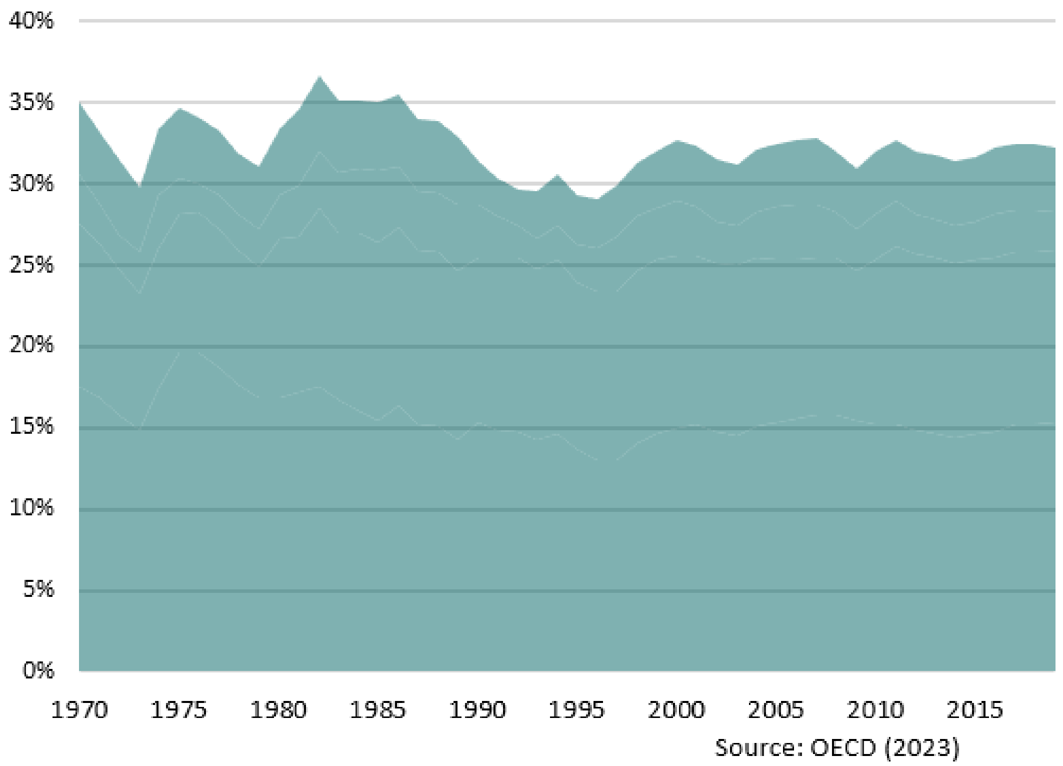


Chart 10: Public debt, percent of GDP (UK, 1970-2019)

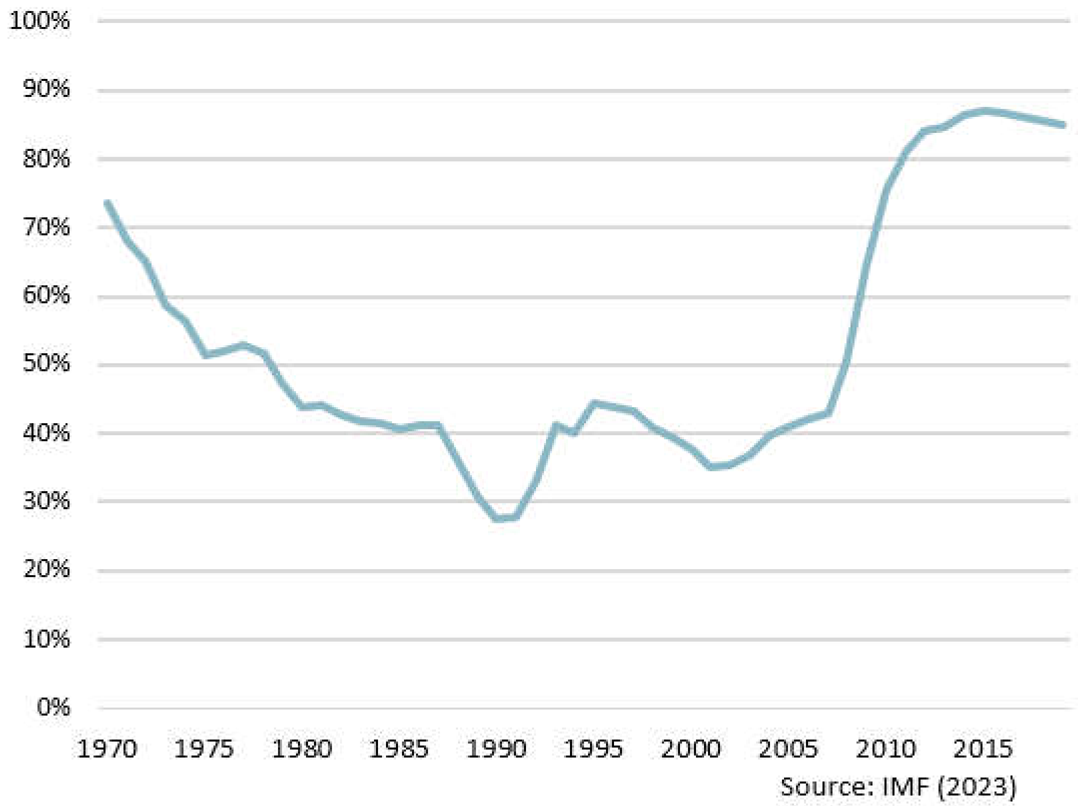


Chart 11: Implicit tax rates, percent of GDP (UK, 1970-2019)

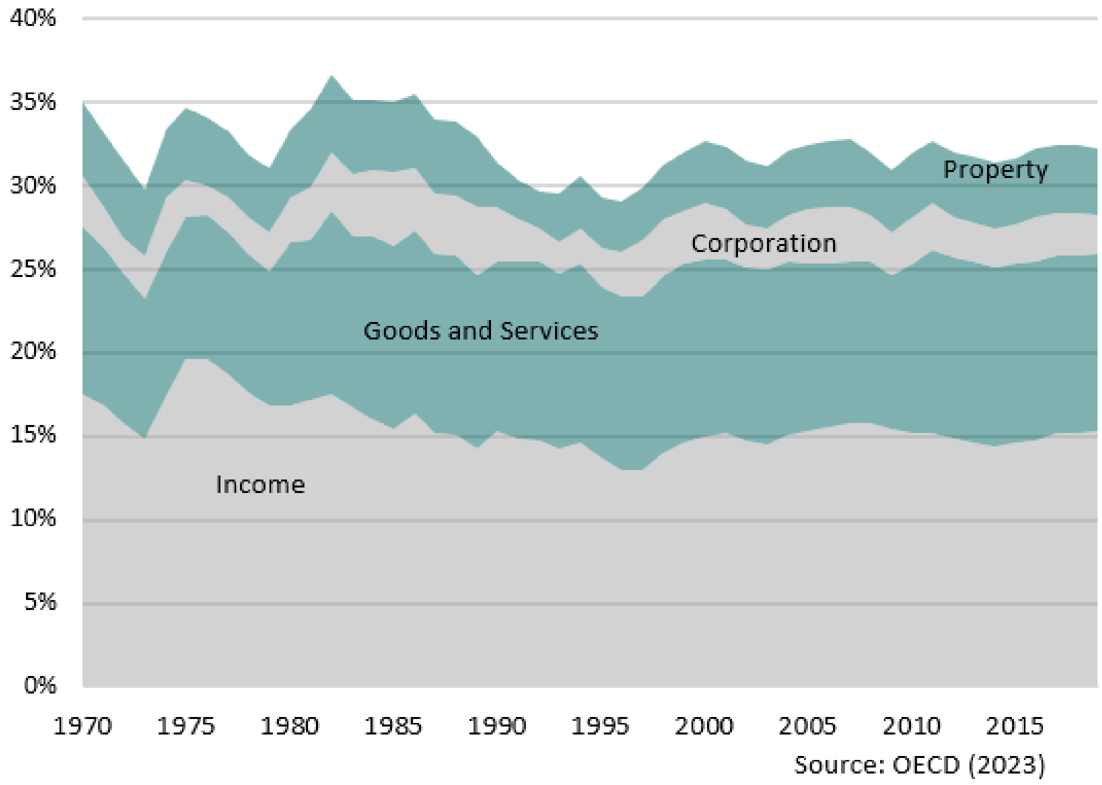
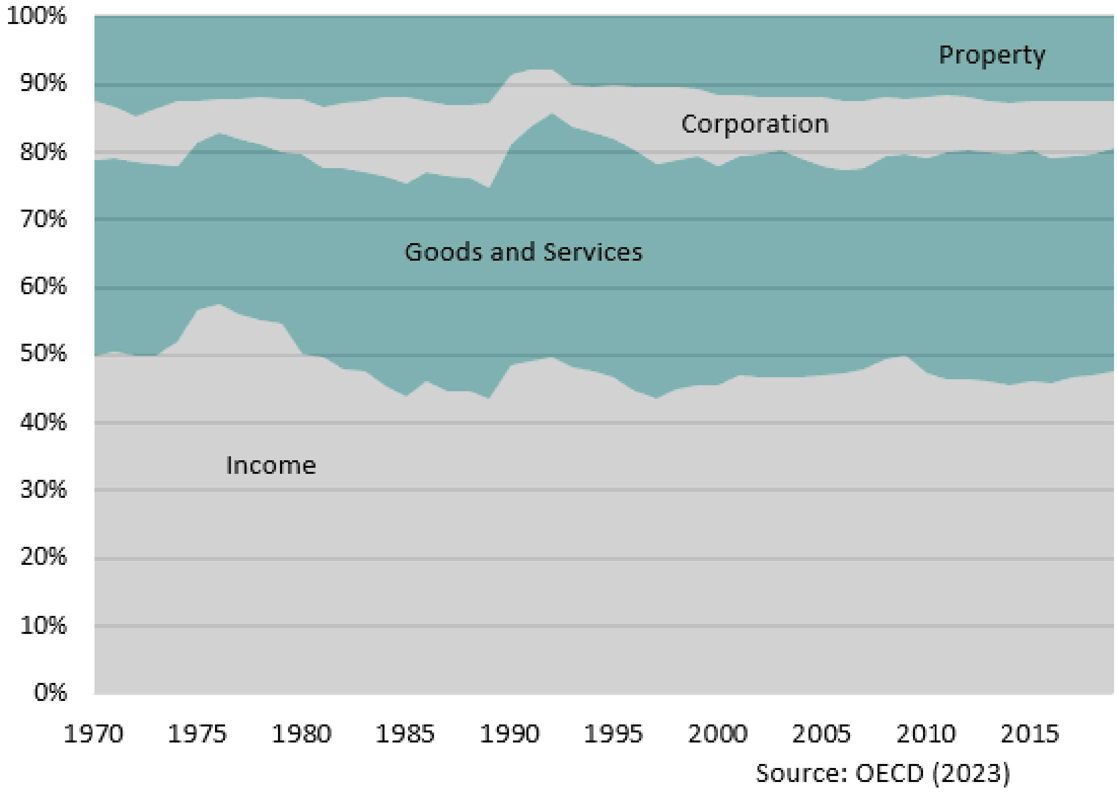


Chart 12: Implicit tax rates, percent of total tax revenue (UK, 1970-2019)



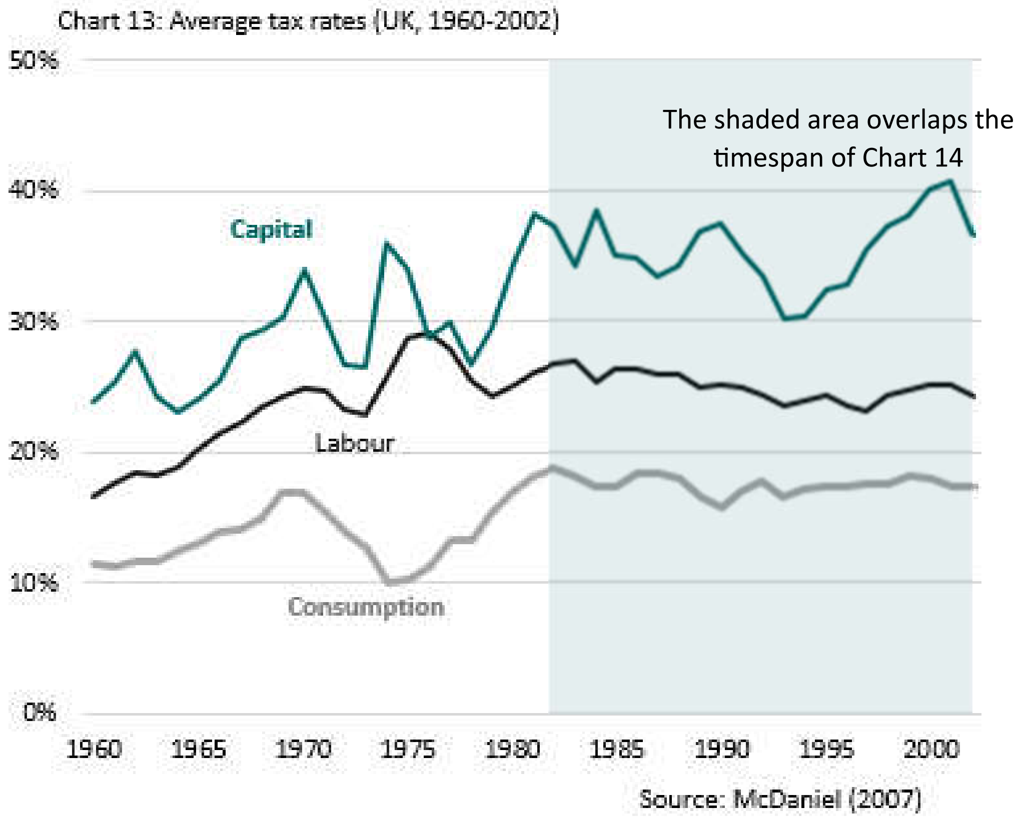


Chart 13: Average tax rates (UK, 1960-2002)
50%
40%
30%
20%
10%
0%
The shaded area overlaps the timespan of Chart 14
Capital
Labour
Consumption
1960
1965
1970
1975
1980
1985
1990
1995
2000
Source: McDaniel (2007)

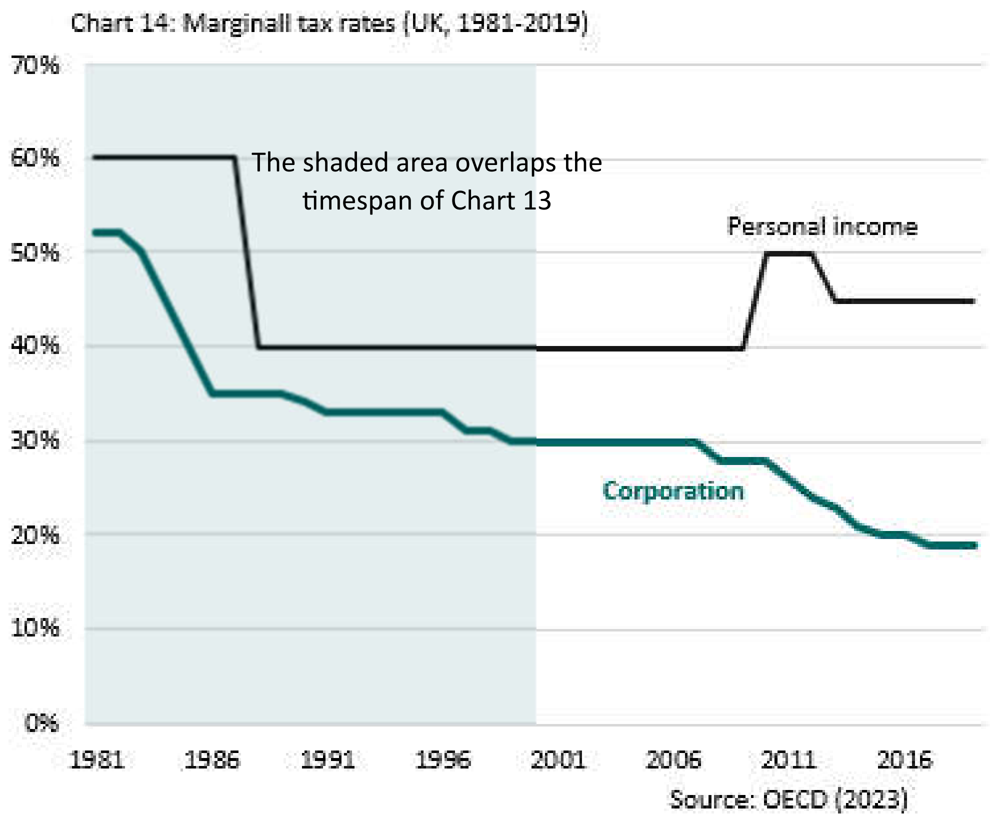
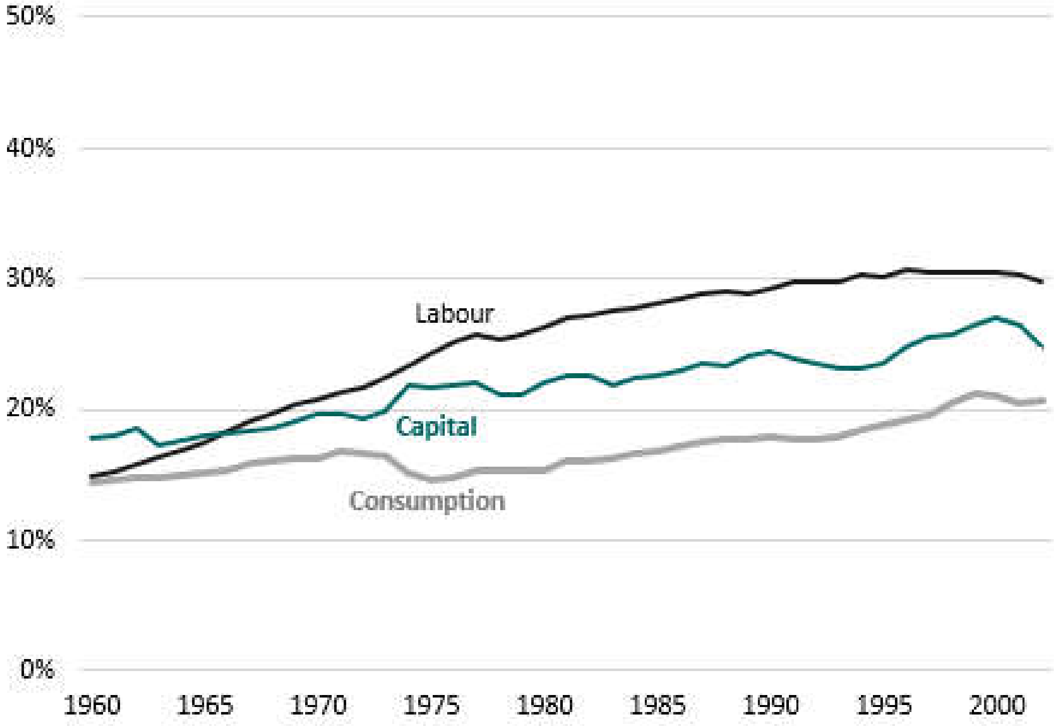
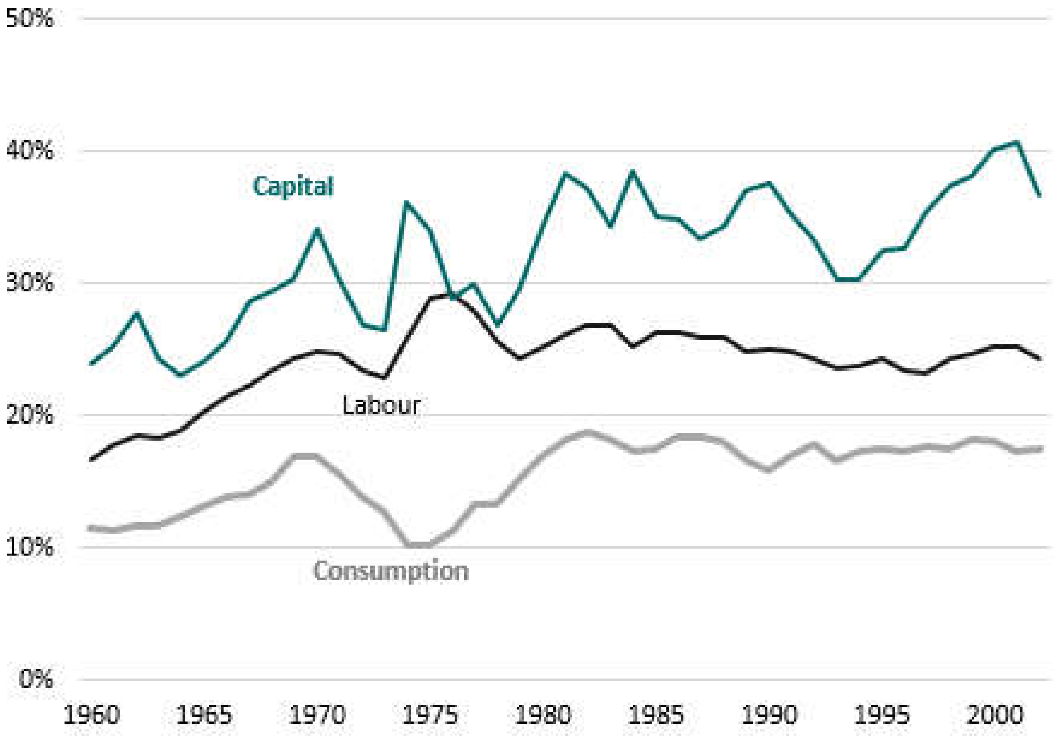


Chart 14: Marginall tax rates (UK, 1981-2019)
70%
60%
50%
40%
30%
20%
10%
0%
The shaded area overlaps the timespan of Chart 13
Personal income
Corporation
1981
1986
1991
1996
2001
2006
2011
2016
Source: OECD (2023)

Chart 15: Average tax rates comparison, 15 OECD countries (top) vs UK (bottom), 1960-2002



Source: McDaniel (2007)



Source: McDaniel (2007)