RCEA Network

Rimini Centre for Economic Analysis
Working Paper Series

wp 22-06

On the Effects of Taxation on Growth: an Empirical Assessment

Marco Alfò
Lorenzo Carbonari
Giovanni Trovato

On the Effects of Taxation on Growth: an Empirical Assessment*

Marco Alfò† Lorenzo Carbonari‡ Giovanni Trovato§

April 22, 2022

Abstract

We study the effects of taxation on the growth rate of the real per capita *GDP in a sample of 21 OECD countries, over the period 1965-2010. To do this we estimate a version of the model proposed by Mankiw, Romer and Weil (1992) augmented to consider both* direct *and* indirect *effects of taxation on investment share parameters. We employ a semi-parametric technique – namely, a Finite Mixture Model – which combines features from mixed effect models for panel data and cluster analysis methods to account for country-specific unobserved heterogeneity. Our results suggest that taxes have a negative impact on growth: in the baseline model the coefficient estimates indicate that a 10% cut in personal income tax rate (respectively corporate income tax rate) may raise the GDP growth rate by 0.6% (respectively 0.3 %).*

Keywords: Economic Growth; Taxation; Finite Mixture Model; Classification.

JEL codes: H30; O30; O40.

*We thank two anonymous reviewers of this Journal for their valuable comments on the manuscript. We also thank Alberto Bucci and Pietro Peretto for their kind suggestions. The usual disclaimer applies.
Corresponding author: Lorenzo Carbonari, Dipartimento di Economia e Finanza, Università degli Studi di Roma "Tor Vergata", Via Columbia 2, 00133 – Roma, Italia. E-mail: `lorenzo.carbonari@uniroma2.it`.

†Sapienza Università di Roma.

‡Università degli Studi di Roma "Tor Vergata", DEF and CEIS.

§Università degli Studi di Roma "Tor Vergata", DEF and CEIS.

1 Introduction

In this paper, we consider a traditional issue in the empirics of growth and economic policy: the evaluation of the potentially long-lasting effects that taxation may have on the real GDP dynamics. Growth theorists have proposed a variety of paths that can explain how this can happen.[1] We propose an *augmented* version of the model in Mankiw, Romer and Weil (1992), which accounts for the effects of taxation on GDP growth. From an econometric standpoint, our main departure from the existing literature is the use of a semi-parametric approach based on a Finite Mixture Model, which employs a discrete distribution to describe country-specific unobserved heterogeneity in the input effects on *per capita* GDP.[2] This allows to tackle one relevant source of bias in growth regressions, due to omitted covariates/factors which influence the GDP dynamics but cannot be observed. It is important to appropriately address unobserved heterogeneity since it may cause correlation between model covariates and residuals, thus leading to biased estimates and, therefore, to wrong policy recommendations. Furthermore, to account for serial correlation in time-varying unobservable factors, we incorporate in the Finite Mixture the so-called auxiliary regression approach, see Mundlak (1978, 1988) and Chamberlain (1980, 1984). In that sense, our approach gives a new contribution to the quantification of the impact that taxation has on growth.

The paper is structured in two parts. In the first, we extend the model presented by Mankiw, Romer and Weil (1992) to account for potential effects of taxation, and introduce our semi-parametric approach. The underlying assumption is that countries share common unobserved economic structures (e.g. public debt sustainability, reliability and fairness of the legal system, etc.) whose effects are proxied by country-specific parameters. These are, in turn, considered as random variables with an unspecified distribution function, which can be estimated by a discrete distribution. In this way, countries can be considered as belonging to a set of *hidden* homogeneous clusters (components), sharing some common economic

[1] See, among the others, Barro (1990), Jones and Manuelli (1990), Jones, Manuelli and Rossi (1993), Stokey and Rebelo (1995), Peretto (2003 and 2007) and Jaimovich and Rebelo (2017).

[2] See Alfò, Trovato and Waldmann (2008), Owen, Videras and Davis (2009), Pittau, Zelli and Johnson (2010), Cohen-Cole, Durlauf and Rondina (2012) and Bucci, Carbonari and Trovato (2021) for related approaches.

features represented by cluster-specific parameters.[3] Following this approach, we restrict the country-specific effect to take values in a small, discrete set accommodating extreme and/or strongly asymmetric departures from usual parametric assumptions.[4] The first contribution of the paper is, then, to define a model describing the impact of taxation on growth, by allowing parameter heterogeneity among countries. In our model, taxes have both a *direct* and a *indirect* effect on GDP growth: the former is measured by the actual tax rates while the latter is measured by the interaction between the capital shares and the mean values of our measures of taxation for each country in the sample over the period under observation.[5] We consider several fiscal instruments. As it is standard in cross-sectional studies, we assume that: i) tax rates are proxied by the ratio between revenues coming from each specific tax and overall fiscal revenues and ii) country tax burden is proxied by the ratio between total fiscal revenues and GDP.[6]

In the second part of the paper, we test our model using data from a sample of 21 OECD countries over the period 1965-2010. Using the proposed model specification, the best model is obtained with three components, describing three clusters of countries with homogeneous values of regression parameters. Our main finding is that taxation (when statistically significant) has a negative effect on *per capita* GDP growth rates, both *directly*, via aggregate Total Factor Productivity (TFP), and *indirectly*, via aggregate saving rates. On average, the magnitude of such estimated effects, however, is not that large. The estimates are proved to be robust to several modifications of the basic model structure and this represents the second contribution of the paper. In times in which several political leaders across the world have based their economic agenda on tax cuts, it is clearly important to assess the effective role that taxes have on growth. Our cross-country analysis makes a clear point on this, at least for the analyzed sample of OECD countries: tax cuts produce a beneficial impact on GDP growth, but not all the tax cuts are alike. Specifically, we find that lowering the personal

[3]See Arminger, Stein and Wittenberg (1999), Fraley and Raftery (2002), Alfò, Trovato and Waldmann (2008), Owen, Videras and Davis (2009) and Ng and Mclachlan (2014).

[4]See e.g. Alfò and Trovato (2004).

[5]See the Paragraph "Modelling assumptions" in Section 3.

[6]Notice that these ratios are a *sort of* effective tax rates and not statutory tax rates. In Paragraph 4.4, we check the robustness of our estimates by replacing these tax rates with the *effective* tax rates provided by Vegh and Vuletin (2015). This exercise, however, leads to a reduction of the sample size.

income tax rate is more beneficial for growth than lowering the corporate income tax rate: in the baseline model, a cut by 10% in personal income tax rate generates an increase in the real *per capita* GDP growth rate of about 0.6% while the increase due to a cut by 10% in corporate income tax rate is about 0.3%.

The rest of the paper is structured as follows. Section 2 reviews the main empirical literature on the impact of taxation on growth. Section 3 lays down the modelling strategy. Section 4 describes data, presents the estimates, provides countries' classification and assesses the robustness of the results. Section 5 concludes.

2 Literature review

Traditionally, the literature on economic growth identifies two main sources of economic development: i) investments in new capital, physical and/or human, and ii) technological change, i.e. improvements in the aggregate TFP. Taxation may have negative effects on investments' returns and/or the expected profitability of R&D, which is one of the main driver of technological innovation. According to this view, taxation is expected to exert a negative impact on the real GDP growth rate (see Lucas 1990). This negative effect, though, can be, in line of principle, counter-balanced by the gain in aggregate TFP arising from productive public expenditures (e.g. infrastructure, public R&D, etc.), which are (largely) financed through taxation.[7]

While the theoretical paths for an increase in taxes to affect growth are clear, empirical works aimed at quantifying the effects of fiscal policy on macroeconomic performance have not produced a conclusive evidence. In particular, the correlation between taxation and real GDP growth is often found to be non significant. Even when the correlation is significant, the result is often not robust to the inclusion of other controls or to changes in the sample composition. Nonetheless, a consensus has emerged on that some fiscal instruments are indeed more harmful to economic growth than others. In this section, we briefly and separately

[7]Since the seminal paper of Barro (1990), the question of whether public expenditure has a significant impact on TFP and real GDP growth has been the object of a great debate in the economic literature. The evidence on this virtuous relationship, however, is mixed, at best.

review the main contributions to this topic.

Taxation and growth In an early work, Lucas (1990) shows that eliminating capital income taxation would produce a very small (about 0.03%) increase in real GDP long-run growth. Considering a sample of 18 OECD countries over the period 1965-1988, Mendoza, Razin and Tesar (1994) find no relevant correlation between tax rates and growth rates; similar results are presented by Mendoza, Milesi-Ferretti and Asea (1997). Daveri and Tabellini (2000) find a negative effect of labor taxes on employment and growth while other studies, see e.g. Koester and Kormendi (1989) and Easterly and Rebelo (1993) do not document empirical evidence of such effect. Tax revenue over GDP is significantly and negatively correlated with GDP growth according to Angelopoulos, Economides and Kammas (2007). For a sample of 21 OECD countries over the period 1971-2004, Arnold (2008) finds a substantial (negative) correlation between corporate/personal income taxation and growth, while property taxes seem to have a milder (but negative) effect. Through a "narrative approach", Romer and Romer (2010, 2014) remark that tax increases have a temporarily negative impact on GDP dynamics. More recently, Piketty, Saez and Stantcheva (2014) find no significant correlation between growth rates and changes in marginal income tax rates observed for OECD countries since 1975.

Tax composition and growth Calibrating his model using US and East Asian NIC data, Kim (1998) shows that the difference in tax systems across countries explains a significant proportion (around 30%) of the difference in growth rates. For a sample of 22 OECD countries over the period 1970-1995, Kneller, Bleaney and Gemmell (1999) find a slight growth-enhancing effect in case of shifting the revenue stance away from "distortionary" taxation (i.e. income tax, social security contribution, tax on property, and tax on payroll) towards "non-distortionary" taxation (i.e. consumption tax). Using data on 17 OECD countries, from the early 1970s to 2004, Bleaney, Gemmell and Kneller (2001) obtain similar results, by taking explicitly into account disaggregated revenues and expenditures. For a sample of 23 OECD countries, over the period 1965-1990, Widmalm (2001) finds that the proportion of tax revenues raised by taxing personal income exhibits a robust negative correlation with economic growth. In two papers, focused on high-income countries, Padovano and Galli (2001, 2002) find a relevant association between lower income rates and faster economic growth. Li and Sarte (2004) offer evidence that the decrease in progressivity associated with the 1986 U.S. *Tax Reform Act* leads to small but non-negligible increases in US long-run growth (from 0.12% to 0.34%). For a sample of 70 countries over the period 1970-1997, Lee and Gordon (2005) find that higher corporate tax rates are significantly and negatively correlated with cross-sectional differences in average economic growth rates. According to their results, a cut in the corporate tax rate by 10% would raise the annual GDP growth rate by 1-2%. Using data for 116 countries, over the period 1972-2005, Martinez-Vazquez, Vulovic and Liu(2011) find that an increase of 10% in the direct to indirect tax ratio reduces economic growth and FDI inflows by 0.39% and 0.57% respectively. Using an updated version of the dataset used by Bleaney, Gemmell and Kneller (2001), Gemmell, Kneller and Sanz (2011) document rare episodes in which fiscal policy changes affect real GDP long-run growth rates. More recently, Jaimovich and Rebelo (2017) show that low tax rates have a small, nonlinear, impact on long-run growth: as tax rates rise, the negative impact on growth may dramatically rise.

3 The econometric strategy

Building on Mankiw, Romer and Weil (1992, hereafter MRW), we consider an aggregate technology in which capital accumulation adjusts in response to taxation, i.e. we allow for a direct effect of taxation on the magnitude of the effects associated to physical and human capital accumulation shares. We assume that sources of country-specific unobserved heterogeneity may influence the growth process of the (country-specific) *per capita* GDP. To capture the effects of unobserved heterogeneity, we let the coefficients in the production function vary among countries. Unobserved heterogeneity is used to proxy the effects of country-specific, time-invariant, unobserved covariates.[8] We further allow for potential correlation between the country-specific effects and the observed covariates, by adopting the

[8] See Engen and Skinner (1992 and 1996), Fulginiti and Perrin (1993), Pedroni (2007), Phillips and Sul (2007), Alfò, Trovato and Waldmann, (2008), Mundlak, Butzer and Larson (2012) and Wouterse (2016).

auxiliary regression approach by Mundlak (1978).

The model As in MRW we assume a Cobb-Douglas production function for country $i = 1, \ldots, n$:

$$Y_{it} = (A_{it} L_i t)^{(1-\lambda-\nu)} K_{it}^{\lambda} H_{it}^{\nu} \qquad \text{with } \lambda, \nu \in (0,1), \tag{1}$$

where Y denotes the output, K the capital, H the human capital, L the quantity of labor and A reflects both technological progress and country-specific conditions (e.g. soundness of public finance, quality of institutions, natural resources, etc.).

The model is based on the hypothesis that, for each country, the rates of investment in physical and human capital are determined by a constant fraction of the output, with a common and constant depreciation rate (d), a constant and exogenous rate of growth for the labor/population ratio (n) and technological progress (g). Based on these assumptions and taking logs, the (estimable) equation for the level of *per capita* GDP, $y \equiv Y/L$, can be written as[9]

$$\begin{aligned} \log(y)_{it} &= \log(A)_{it} + \frac{\nu}{(1-\lambda-\nu)} \log(s_h)_{it} + \frac{\lambda}{(1-\lambda-\nu)} \log(s_k)_{it} + \\ &\quad - \frac{\lambda+\nu}{1-\lambda-\nu} \log(n+g+d), \end{aligned} \tag{2}$$

where s_h and s_k are the exogenous shares of total income invested in human capital and physical capital accumulation. Here, country-specific heterogeneity in technological parameters is meant to capture the differences in country-specific GDP dynamics. From an empirical point of view, MRW assume that $\log(A)_{it} = \alpha + \epsilon_i$, with $\epsilon_i \sim N(0,1)$ representing a country-specific shock. A possible way to let a fiscal variable, say τ_{it}, affect the level of TFP is to assume $\log(A)_{it} = f(\tau_{it}) + \epsilon_{it}$, where $f(\cdot)$ can be nonlinear. A more general way to model the effects of the explanatory variables on growth (via technological progress) is to rely on an additional *design* vector. Assuming an endogenous process for $\log(A)_{it}$, the dynamics

[9] See Mankiw, Romer and Weil (1992), p. 417, for the derivation of equation (2).

corresponding to equation (2) is given by

$$E(\gamma_{it} \mid \mathbf{x}_{it}, \mathbf{z}_{it}) = \alpha_i + \beta_0 \log(y_{i,0}) + \mathbf{x}'_{it}\beta + \mathbf{w}'_{it}\delta, \tag{3}$$

where $\mathbf{x}_i$ is a vector including the *observed* Solow-type covariates (i.e. physical and human capital accumulation shares and effective units of labor growth adding depreciation rates), $\gamma_{it} \propto (1/T)(\log(y)_{it} - \log(y)_{i,0})$ is the 5-years average growth rate of the *per capita* real GDP, α_i measures country-specific innovation, β_0 is the convergence parameter and $\mathbf{w}_{it}$ is an additional design vector including factors that may affect country-specific technological progress. Specifically, $\mathbf{w}_{it}$ includes information on country-specific tax structure, proxied by total tax revenues, personal income and corporate tax rates. Equation (3) raises several econometric issues that need to be addressed.[10] Correlation between variables in $\mathbf{w}_{it}$, $\mathbf{x}_{it}$ and the initial conditions $\log(y_{i,0})$, endogeneity and unobserved heterogeneity may cause bias in parameter estimates.[11] Regression results may be inflated by collinearity and, since initial GDP is likely correlated with capital saving rates, covariate effects – e.g. those measuring tax policies – may be ill-estimated.[12] Moreover, since it is based on macro-level measures, this class of models does not properly take into account heterogeneity at micro-level.[13] In this sense, micro-level interactions can be viewed as *hidden* relationships underlying the macro-level data generating process. Therefore, if taxation influences both capital accumulation and

[10]See e.g., Brock and Durlauf (2001) for a discussion.

[11]Consider the case of varying parameters and suppose that the influence of x_i on the response, y_i, is country specific. In this case, $\beta_i = \beta + u_i$ where u_i is the country specific effect for subject $i = 1, \ldots, n$, with $E(u_i) = 0$, and β captures the average effect of x_i on y_i. Formally,

$$y_i = \alpha + (\beta + u_i)x_i + \epsilon_i.$$

If we ignore the country specific heterogeneity and estimate the model with a homogeneous estimator (e.g. OLS), we get

$$\begin{aligned} y_i &= \alpha + \beta x_i + (\epsilon_i + u_i x_i) \\ &= \alpha + \beta x_i + \tilde{\epsilon}_i. \end{aligned}$$

As in case of endogeneity bias, the variable x_i is correlated with the error term $\tilde{\epsilon}_i$. Hence, the standard errors of estimated parameters are biased.

[12]See Durlauf, Johnson and Temple (2005).

[13]See e.g. van Garderen, Lee and Pesaran (2000) and Blundel and Stocker (2005).

growth dynamics, the estimated coefficient for δ in equation (3) may mix different effects.[14] To deal with this issue, we modify the model specification to allow for dependence between fiscal policy, technology and capital stocks.

The *augmented* model Following Barro (1990), we assume that taxation affects GDP dynamics both *directly*, via aggregate efficiency, and *indirectly*, through (its effect on) aggregate saving rates. We estimate a linear model for the mean growth rate γ_{it} under potential misspecification due to unobserved covariates and wrong assumptions on the shape of the GDP growth rate function.[15] When we allow for country-specific heterogeneity, equation (3) can be written as follows:

$$\mathrm{E}\left(\gamma_{it} \mid \mathbf{x}_{it}, \mathbf{w}_{it}, \phi_i\right) = \mathbf{x}_{it}'\beta + \mathbf{w}_{it}'\phi_i, \tag{4}$$

where $\mathbf{x}_{it}$ now denotes the *global* vector of observed covariates with non country-specific effect, i.e. $\log(y_{i,0})$, $\log(n+g+d)_{i,t}$ and the fiscal policy instruments τ_{it}, while $\mathbf{w}_{it}$ includes the intercept and covariates $\log(s_h)_{it}$ and $\log(s_k)_{it}$ that are assumed to be associated with country-specific effects ϕ_i, $i = 1, \dots, n$. The country-specific effects ϕ_i are zero-mean deviation from the corresponding effects in $\mathbf{x}_{it}$. We assume that ϕ_i are i.i.d. draws from a distribution g_ϕ, with zero mean and covariance matrix $\mathbf{\Sigma}_\phi$.

Notice that, in equation (4), the intercept and slopes for investment shares are free to vary across countries, conditional on the country-specific fiscal policy variables, whose direct effects on GDP are supposed to be constant across countries. As the random parameters are unobserved, and potentially high-dimensional, we proceed by employing a random effect estimator.[16] When integrating the random parameters out of the model equation, however, we need to account for potential dependence between controls and unobservable heterogeneity. For this purpose, we employ the so-called *auxiliary* regression approach, proposed by

[14] As in Hauk (2017).

[15] See e.g. Aitkin, Francis and Hinde (2005) and Ng and McLachlan (2014).

[16] See Wooldridge (2009).

Mundlak (1978, 1988) and generalized by Chamberlain (1980, 1984):

$$\phi_i = E(\phi_i \mid \mathbf{X}_i) + \tilde{\phi}_i = \mathbf{\Psi}\overline{\mathbf{x}}_i + \tilde{\phi}_i, \tag{5}$$

where $\overline{\mathbf{x}}_i = T^{-1}\sum_{t=1}^{T}\mathbf{x}_{i,t}$ denotes the mean covariates values for the i-th country for the whole period; the country-specific parameter vector $\tilde{\phi}$ is now (linearly) free of observed variables and the matrix $\mathbf{\Psi}$ describes the dependence of its elements on the country-specific mean $\overline{\mathbf{x}}_i$. To tackle endogeneity issue, due to fact that the vector of observed covariates $\mathbf{x}_{it}$ also includes the *initial conditions* $\log(y)_{i,0}$, we assume the *sequential exogeneity* condition to ensure identification of elements in β (Wooldridge, 2009):

$$E(\epsilon_{it} \mid \mathbf{x}_{it}, \ldots, \mathbf{x}_{it}, \tilde{\phi}_i) = 0. \tag{6}$$

This implies that the dynamics in the mean is completely specified when the lagged response is considered and $\mathbf{x}_{it}$ reacts to shocks affecting γ_{it}.[17] Substituting (5) in equation (4), we obtain

$$\mu_{it}^{\gamma} = E\left(\gamma_{it} \mid \mathbf{x}_{it}, \mathbf{w}_{it}, \tilde{\phi}_i\right) = \ \mathbf{x}_{it}'\beta + \mathbf{w}_{it}'\mathbf{\Psi}\bar{\mathbf{x}}_i + \mathbf{w}_{it}\tilde{\phi}_i. \tag{7}$$

Equation (7) defines a random coefficient model corrected for potential endogeneity. Vector β in equation (7) measures the (so-called *within*) effect that the dynamics of the observed $\mathbf{x}$ has on the growth rate of GDP. Note that, for construction, matrix $\mathbf{\Psi}$ measures not only the *indirect* effect of $\mathbf{x}$, mediated by the unobserved covariates via the *correlated* country-specific random coefficients, but also the effects of other unobserved covariates that are potentially correlated with the country-specific tax structure (e.g. the prevalence of tax evasion in a country, the type of countries' institutional setting, etc.). In this sense, $\mathbf{\Psi}$ represents an extension to general Random Coefficient Models of the so-called *between* effect in random intercept models. Last, $\tilde{\phi}$ measures country-specific departures from the homogeneous model,

[17]Notice that $\tilde{\phi}_i$ also accounts for the existence of further, unobserved growth determinants, so that we overcome model uncertainty and potential violations of the sequential exogeneity condition.

unrelated to the observed covariates.

In equation (7), both the country-specific intercepts and the saving rates may be function of tax policy instruments. In this sense, we say that our model is an extension of MRW. The *indirect* effect of $\mathbf{x}_{it}$ is summarized by the effects associated to $\bar{\mathbf{x}}_i$ and its interaction with saving rates (as a result of the product $\mathbf{w}'_{it}\boldsymbol{\Psi}\bar{\mathbf{x}}_i$). Notice that this equation also defines a two-level mixture regression model (Muthén and Asparouhov, 2009), with two different sources of variation: i) residual, at the country/time level, and ii) unit-specific, at the country level. The country-specific parameters lead to country-specific relationships between investment shares and growth rate of *per capita* GDP.

We approximate the distribution of country-specific parameters by using a discrete distribution and employ a Finite Mixture Model (hereafter, FMM). The discrete distribution may be considered as a non-parametric estimate of the unspecified random parameter distribution.[18] This distribution is described by masses π_k associated with location ζ_k, $k = 1, \ldots, K$, that is $\tilde{\phi}_i \sim \sum_k \pi_k \delta_\phi(\zeta_k)$, where $\delta_x(a) = 1$ if $x = a$, and 0 otherwise. By using this approach, we try to minimize the impact of potential misspecification of the random effect distribution.[19] Details of the maximum likelihood estimation are provided in Appendix A.

Modelling assumptions Rather than assuming that mean tax levels (of any type) influence any of the effects in ϕ_i, we introduce some identifying restrictions on the elements of the matrix $\boldsymbol{\Psi}$ in equation (5). The auxiliary equation system in (5) would need the mean values for all the observed covariates to be inserted in the linear predictor, to be used as a sort of *weak* instruments for unobserved, country-specific and time-invariant, covariates. However, due to the high dimensionality of the problem, we make the following assumptions on the mechanisms through which mean level of tax-related variables affects country-specific parameters. First, the overall tax burden, τ_T, affects the country-specific coefficient associated with the aggregate TFP. Second, the personal income tax share, τ_w, impacts the country-specific parameter for the accumulation rate of human capital (s_h).[20] Third, taxation on corporate

[18] See e.g. Aitkin and Rocci (2002).

[19] For a review, see Neuhaus and McCulloch (2006).

[20] Personal income tax influences income (and savings) but also the return on financial savings, and therefore the individual savings/investment process. High income tax and social security contributions on low-

income, τ_k, influences the country-specific coefficient for physical capital accumulation rate (s_k). Once the above assumptions are included in the empirical model – equations (4) and (5) – we obtain the following system of equations:

$$\begin{cases} \gamma_{it} = \alpha_i + \beta_0 \log(y_{i0}) + \beta_i^h \log(s_h)_{it} + \beta_i^k \log(s_k)_{it} + \beta_3 \log(n+g+d)_{it} + \\ \qquad +\delta_1 \tau_{T,it} + \delta_2 \tau_{w,it} + \delta_3 \tau_{k,it} + \varepsilon_{it} \\ \alpha_i = \tilde{\phi}_i^A + \psi_{00} \overline{\tau}_{T,i} + \psi_{01} \overline{\log(s_h)}_i + \psi_{02} \overline{\log(s_k)}_i \\ \beta_i^h = \tilde{\phi}_i^h + \psi_{10} \overline{\tau}_{w,i} + \psi_{12} \overline{\log(s_k)}_i \\ \beta_i^k = \tilde{\phi}_i^k + \psi_{20} \overline{\tau}_{k,i} + \psi_{21} \overline{\log(s_h)}_i, \end{cases} \tag{8}$$

where:

i) the $\tilde{\phi}$ terms capture the effect of omitted covariates, once we condition on the observed ones;

ii) $\alpha_i, \beta_i^k, \beta_i^h$ are allowed to vary across countries as a function of mean levels for tax policy measures $\overline{\tau}_{T,it}, \overline{\tau}_{w,it}, \overline{\tau}_{k,it}$, and mean levels for investment shares $\overline{\log(s_k)}_i$ and $\overline{\log(s_h)}_i$;

iii) δ_1, δ_2 and δ_3 measure the *direct* effect of tax-related variables on the growth rate of *per capita* GDP, while $\psi_{00}, \psi_{10}, \psi_{20}$ represent the corresponding effect on the growth path, due to *indirect* paths and to correlation between tax policy variables in the growth rate equation and omitted country-specific variables.[21]

iv) $\tilde{\phi}_i^A, \tilde{\phi}_i^h, \tilde{\phi}_i^k$ are country-specific random terms that are linearly free of observed covariates.

Notice that due to these modeling assumptions and corresponding identifying restrictions, parameter estimates may be biased. Therefore, in order to check for the stability

wage workers can reduce the individual incentive to supply hours worked, see e.g. Brewer, Saez, and Shephard (2010). This can negatively affects households' investments in education and/or training.

[21] This is an observational effect, linked to country-specific mean levels of taxation on the GDP growth path. Notice that the system of equations (8) is reminiscent of Pesaran and Smith (1995) and Pedroni (2007). We do not impose any restrictions on the distribution of the random terms ($\tilde{\phi}$), which are free to vary across countries according to an unspecified density function $g(\cdot)$.

and robustness of parameter estimates to modeling assumptions, in Paragraph 4.4 below we discuss the results obtained by fitting several alternative models, associated with different assumptions on the dependence path between random coefficient and observed covariates.

After some algebra, system (8) can be rewritten as follows:

$$\begin{aligned}
\gamma_{it} &= \left(\tilde{\phi}_i^A + \psi_{00}\overline{\tau}_{T,i} + \psi_{01}\overline{\log(s_h)}_i + \psi_{02}\overline{\log(s_k)}_i\right) + \beta_0 \log(y_{i0}) + \\
&+ \left(\tilde{\phi}_i^h + \psi_{10}\overline{\tau}_{w,i} + \psi_{12}\overline{\log(s_k)}_i\right) \log(s_h)_{it} + \\
&+ \left(\tilde{\phi}_i^k + \psi_{20}\overline{\tau}_{k,i} + \psi_{21}\overline{\log(s_h)}_i\right) \log(s_k)_{it} + \\
&+ \beta_3 \log(n+g+d)_{it} + \delta_1\tau_{T,it} + \delta_2\tau_{w,it} + \delta_3\tau_{k,it} + \varepsilon_{it}.
\end{aligned} \tag{9}$$

The FMM is based on a (multivariate) discrete estimate for the distribution of the country-specific random terms $\tilde{\phi}_i^A$, $\tilde{\phi}_i^h$ and $\tilde{\phi}_i^k$, obtained once we account for the effect of mean tax and shares levels on unobserved country-specific effects.

4 The empirical analysis

In this section, we use the framework developed above to disentangle the sources of the cross-country relation between different taxation instruments and the growth rate of *per capita* GDP.

To evaluate the findings of the FMM, after having described the analyzed sample, we present the estimates for equations (3) and (9) obtained by well-known alternative estimators. We start by considering a model with country-specific intercept only, i.e. we estimate the reduced form of equation (9) (i.e. the model in equation (3)) by the OLS Fixed Effects estimator. To deal with potential reverse causation between the real *per capita* GDP growth rates and the country-specific tax policy measures,[22] we employ an IV-GMM estimator.[23] We then proceed to the general model in equation (9); we employ the GLS Random Effects

[22]See e.g. Weil (2014), and Linden and Ray (2017).
[23]See e.g. Lewbel (1997 and 2012).

estimator, with Gaussian assumptions on the random effects, and an auxiliary regression approach to account for potential correlation between observed and unobserved (country-specific, time invariant) covariates. Since country-specific random parameters cannot be enough to account for potentially dynamic, multi-factor dependence, we employ the estimator proposed by Pesaran and Smith (1995) and extended by Chudik and Pesaran (2015). Finally, we present the proposed FMM, which allows for country-specific, time-invariant, parameter heterogeneity among countries with similar fundamentals.[24] Based on the results obtained by the FMM, we proceed to sort countries into homogeneous groups of the conditional distribution of *per capita* GDP growth rate.

4.1 The data

Our sample includes 21 OECD countries, observed over the period 1965-2010.[25] The Summers-Heston dataset (PWT 9) provides information on *per capita* GDP, rate of physical capital accumulation (s_k), employment, rates of change in population (n) and technological progress (g) and depreciation rate (δ). The rate of human capital accumulation (s_h) has been proxied by the Human Capital Index reported by PWT 9. OECD fiscal database (2017) provides information on taxes. Following Kneller, Bleaney and Gemmell (1999), Lee and Gordon (2005), Arnold (2008) and Gemmell, Kneller and Sanz (2013), we focus on the following fiscal instruments: personal income tax rate (τ_w), corporate income tax rate (τ_k), total tax burden (τ_T). To describe the clusters, we also consider additional fiscal variables, namely: personal income taxes (including social security contributions and taxes on payroll, τ_n), tax

[24]Notice that measurement error, omitted variables and varying parameters may be additional source of unobserved heterogeneity (and thus, model misspecification).

[25]To fairly assess the impact of taxation on growth and to grant comparability between our study and those reviewed in Section 2, we deliberately restrict our attention to a time period not including recent years characterized by the aftermath of Global Financial Crisis and the EU Sovereign Debt Crisis. The effects of modifications in the time span are discussed in Paragraph 4.4. Our sample consists of a sub-sample of OECD countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Ireland, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland the United Kingdom and the United States). Due to lack of data on taxation, we did not include in the sample transition economies (Albania, Bulgaria, Croatia, Czech Republic, FYR Macedonia, Hungary, Poland, Romania, Slovak Republic, Slovenia). We also exclude Greece because of the serious doubts cast on the reliability of its national accounts at the beginning of 2000s. Finally, we exclude Turkey because it is associated to high leverage as measured by the Cook distance 0.052 against a sample average of 0.0013.

on consumption (τ_c), tax on sales (τ_s), and social security contributions (ssc). Tables A7 and A8 in the Appendix report variable definitions and descriptive statistics.[26]

To reduce the problem of endogeneity between future income and past tax rates, we build the covariate set by using a five-years lag.[27]

Table A9 in the Appendix shows that the association between fiscal policy variables and growth rates of *per capita* GDP are not homogeneous across countries. In the next paragraph, we assess whether these correlations are linked to some country-specific characteristics. Figure 5 shows the clusters growth rates of *per capita* GDP during the analyzed period.

4.2 A comparison with alternative estimators

We start by estimating a reduced form of the proposed model in equation (9), where only country-specific intercepts are used to represent unobserved heterogeneity, while the coefficients for investment share (s_k) and the rate of human capital accumulation (s_h) are kept constant across countries. Hence, equation (9) becomes

$$\begin{aligned} \gamma_{it} &= \alpha_i + \beta_0 \log(y_{i0}) + \beta^h \log(s_h)_{it} + \beta^k \log(s_k)_{it} + \beta_3 \log(n+g+d)_{it} \\ &\quad + \delta_1 \tau_{T,it} + \delta_2 \tau_{w,it} + \delta_3 \tau_{k,it} + \varepsilon_{it}. \end{aligned} \tag{10}$$

Parameters are obtained by using a fixed-effect estimator. The corresponding estimates are reported in the first column of Table 1. Several other estimators have been considered to disentangle the correlation among residuals and covariates. Table 2 reports the parameter estimates obtained via IV-GMM, which addresses the endogeneity issue by using as instruments up to four differences of covariates and variables' transformations as in Lewbel (1997, 2012). Results obtained by IV-GMM(I) and IV-GMM(II) are quite similar despite

[26]For a complete definition of the taxation variables, the interested reader may refer to http://www.oecd.org/tax/tax-policy/global-revenue-statistics-database.htm.

[27]The choice of five-years lag is standard in the growth literature with panel data. Such a choice ensures both enough degrees of freedom and avoids the negative effects of strong auto-correlation of dependent variables (see e.g. Bond, Hoeffler and Temple, 2001).

Table 1: Fixed-Effect OLS, Random-EffectE GLS and Dynamic Common Correlated Effect estimates

	OLS FE	**RE GLS**	**DCC**
Intercept	17.855***	26.86***	6.069
$\log(s_k)$	0.720	0.127	0.147***
$\log(s_h)$	8.215***	7.549***	0.779
		Direct Effects	
$\log(y_{0,i})$	−2.522***	−2.267***	−0.932***
$\log(n+g+d)$	−5.117**	−5.267**	0.265
τ_T	0.016	0.016	0.285
τ_w	−0.044**	−0.037**	−0.748**
τ_k	0.050	0.047*	0.514
		Indirect Effects	
$\overline{\tau}_{T,i}$		0.000	
$\overline{\tau}_{w,i} \times \log(s_h)$		−0.011	
$\overline{\tau}_{k,i} \times \log(s_k)$		0.074*	
$\overline{\log(s_h)}_i$		−6.477***	
$\overline{\log(s_k)}_i$		2.064	
R-squared	0.12	0.12	0.85
Shapiro-Wilk (p-value)	0.000	0.001	0.000
Shapiro-Francia (p-value)	0.000	0.000	0.000
CD-test (p-value)			0.432
Observations	835	835	797

Significance: *** : 0.001, ** : 0.01,* : 0.05; Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 in the Appendix for tax variables definition and sources.

Table 2: Instrumental Variables estimates

	IV-GMM(I)	IV-GMM(II)
	Direct effects	
Intercept	39.822***	45.901***
$\log(s_k)$	0.987	4.942***
$\log(s_h)$	27.608***	38.762***
	Direct Effects	
$\log(y_{0,i})$	-3.766***	-4.4936***
$\log(n+g+d)$	1.917	1.791
τ_T	-0.115**	-0.201***
τ_w	0.023	0.041
τ_k	0.145**	0.127**
	Indirect Effects	
$\overline{\tau}_{T,i}$	0.013**	-0.000
$\overline{\tau}_{w,i} \times \log(s_h)$	-0.051	-0.072
$\overline{\tau}_{k,i} \times \log(s_k)$	0.133**	0.134*
$\overline{\log(s_h)}_i$	-23.608***	-38.584***
$\overline{\log(s_k)}_i$	0.488	-3.58
Controlled for Time and Subjects	YES	YES
	Underidentification tests	
Kleibergen-Paap LM $\chi^2(6)$	18.031**	17.922**
	Weak-instrument-robust inference	
Kleibergen-Paap Wald F	24.154	45.499
$Stock-Yogo$ critical values		
5% maximal relative bias	17.30	16.88
10% maximal size	15.64	23.72
	Overidentification test	
Jensen Statistic	6.28	8.822
$\chi^2(5)$ $P-$values	0.392	0.1164
	Orthogonality test instruments	
Jensen Statistic (excl. condit.)	3.027	3.027
$\chi^2(2)$ $P-$values	0.220	0.220
C Statistic	5.794	5.794
$\chi^2(5)$ $P-$values	0.122	0.122
	Test for Normal Residuals	
Shapiro-Wilk	0.979***	0.980***
R-squared	0.60	0.665
Observations	772	772
Instruments	*q vector as in Lebwel (1997 and 2012) up to the third lags*	*up to fourth differences of covariates*

Significance levels: *** : 0.001, ** : 0.01,* : 0.05; Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 in the Appendix for tax variables definition and sources.

the different instruments used to correct for endogeneity.[28]

We then proceed with the Random-Effect GLS (RE GLS) estimator with the auxiliary regression approach, which includes both *direct* and *indirect* effects of taxation. This leads to the following specification

$$
\begin{aligned}
\gamma_{it} &= \alpha_i + \beta_0 \log(y_{i0}) + \beta^h \log(s_h)_{it} + \beta^k \log(s_k)_{it} + \beta_3 \log(n+g+d)_{it} \\
&+ \delta_1 \tau_{T,it} + \delta_2 \tau_{w,it} + \delta_3 \tau_{k,it} \psi_{00} \overline{\tau}_{T,i} + \psi_{01} \overline{\log(s_h)}_i + \psi_{02} \overline{\log(s_k)}_i \\
&+ \psi_{10} \overline{\tau}_{w,i} \times \log(s_h)_{it} + \psi_{20} \overline{\tau}_{k,i} \times \log(s_k)_{it} + \varepsilon_{it}. \qquad (11)
\end{aligned}
$$

Estimates are reported in the second column of Table 1. Parameters for τ_k and its *indirect* effect on growth ($\overline{\tau}_{k,i} \times \log(s_k)$) are weirdly positive. Notice also that this model specification is actually based on a simple structure of the measurement error with a dependence between longitudinal values referring to the same country, entirely explained by country-specific parameters. However, the estimates may be biased if time-varying forms of dependence occur, due e.g. to the presence of 1-year lagged response variable among the covariates. To address this specific issue, we consider the Dynamic Common Correlated Effects Estimator (CDD)[29] based on the following model parameterization:

$$
\begin{aligned}
\gamma_{it} &= \alpha_i + \beta_{0i} \log(y_{i0})_i + \beta_i^h \log(s_h)_{it} + \beta_i^k \log(s_k)_{it} + \beta_{3i} \log(n+g+d)_{it} \qquad (12) \\
&\quad + \delta_1 \tau_{T,it} + \delta_2 \tau_{w,it} + \delta_3 \tau_{k,it} + \sum [d_i \times Z_{i,S}] + \varepsilon_{it}
\end{aligned}
$$

where $Z_{i,S}$ is now the matrix including means of lagged covariates and response at time S and the sum is over $S = t, \ldots, t - \rho(T)$ where ρ is the lag operator for the cross section correlation, $\mathbf{d}_i$. The DCC estimator allows for heterogeneous, country-specific, parameters in regression models for large panels with dependence between cross sectional units. However,

[28]The under identification test rejects the assumption of unidentified model while the weak instrument test rejects the assumption of a negligible correlation between instruments and covariates.

[29]See e.g. Pesaran (2005) and Chudik and Pesaran (2015).

issues may arise when either the number of statistical units (here, the number of countries) or the number of time periods are not large enough. Despite the similarities between this approach and our FMM, it must be noticed that our model does not require any parametric restriction on the country-specific parameter distribution.

The third column of Table 1 reports the estimates of the DCC model. Parameters associated with fiscal policy variables have no effect or are negatively related to the GDP growth. However, they are often not significant. The CD statistic (Pesaran, 2005) indicates that we cannot reject the hypothesis that the correlation between units at each point in time converges to zero.[30]

Importantly, for all the parametric methods presented in this paragraph, the normality tests, i.e. the Shapiro-Wilk test and the Shapiro-Francia test, suggest to reject the hypothesis of Gaussian errors. This indicates that even after controlling for observed covariates and unobserved heterogeneity, residuals are far from being symmetric none of these estimators is able to correct the bias in parameter and standard error estimates due to unobserved heterogeneity. We deem that the FMM in equation (9), which is based on a discrete estimate of the country-specific random parameter distribution, may address this issue, providing a consistent estimate of the *true* distribution of the random effects.[31] Furthermore, as the assumption of Gaussian errors is now conditional on the mixture component, the marginal error distribution is estimated through a finite mixture of Gaussian densities, which may be seen as a nonparametric density estimate for the marginal error distribution. In this sense, the FMM may help to relax some of the unverifiable modeling assumptions and produce a more robust estimates.

4.3 The Finite Mixture Model (FMM)

Table 3 presents the estimates obtained by using the proposed the FMM. Notice first that the FMM has a better fit than that provided by the OLS FE estimator. This is evident looking at Figure 2, in which we overlay the empirical density functions of γ, obtained via either

[30]This is probably due to the small sample size we deal with.

[31]See Simar (1976), Laird (1978), and Lindsay (1983a, 1983b).

Table 3: Model I, equation (9)

	Cluster 1	**Cluster 2**	**Cluster 3**
		Cluster-specific parameters	
Intercept	17.16***	34.38***	49.04***
$\log(s_k)$	-1.96*	1.78*	4.37***
$\log(s_h)$	37.76***	27.19***	15.35***
		Direct Effects	
$\log(y_{0,i})$	-4.02***	-4.02***	-4.02***
$\log(n+g+d)$	-6.70***	-6.70***	-6.70***
τ_T	0.04	0.04	0.04
τ_w	-0.06***	-0.06***	-0.06***
τ_k	-0.03	-0.03	-0.03
		Indirect Effects	
$\overline{\tau}_{T,i}$	0.03	0.03	0.03
$\overline{\tau}_{w,i} \times \log(s_h)$	-0.10***	-0.10***	-0.10***
$\overline{\tau}_{k,i} \times \log(s_k)$	-0.06*	-0.06*	-0.06*
$\overline{\log(s_h)}_i$	-14.69***	-14.69***	-14.69***
$\overline{\log(s_k)}_i$	0.13	0.13	0.13
Implied ν	0.87	0.61	0.71
Implied λ	-0.11	0.09	0.03
$\hat{\sigma}^2$	1.60		
$\hat{\pi}_k$	0.096	0.333	0.571
$\hat{z}_k$	0.099	0.588	0.313
Log-likelihood	-1596.478		
BIC	3340.96		
Observations	835		
Shapiro-Wilk	0.989	0.995	0.997

Significance levels: ***: 0.001 **: 0.01 *: 0.01.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 in the Appendix for tax variables definition and sources.
Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities. See Table A7 in the Appendix for tax variables definition and sources.

FMM (dotted line) or OLS FE (dashed line), on the observed data distribution. Moreover, while the OLS estimates may be biased due to residuals' non-normality, as the Shapiro-Wilk test rejects this hypothesis (with a p-value=0.000), the hypothesis is not rejected for all the three components identified via FMM.

As mentioned above, the FMM approach also allows to group units into homogeneous components, with the same values of model parameters.[32] Here, each component is a cluster of countries and each country is assigned to a cluster according to the maximum *a posteriori*

[32]This means that, conditionally on the observed covariates, countries belonging to the same cluster have a similar "structure", at least along the period under observation. See Ng and McLachlan (2014).

Table 4: Clusters' composition

Country	**GDP growth (%)**	**Investment share**	**HC index**
Cluster 1:			
Ireland	4.643	0.264	2.716
Norway	4.055	0.287	3.174
Mean	4.349	0.276	2.945
Cluster 2:			
Australia	2.176	0.289	3.330
Belgium	2.664	0.290	2.748
Canada	2.101	0.255	3.271
Denmark	2.331	0.267	3.105
Finland	2.950	0.336	2.910
France	2.325	0.263	2.732
Italy	3.212	0.268	2.519
Japan	3.444	0.338	3.161
Luxembourg	2.844	0.327	2.710
New Zealand	1.696	0.234	3.232
Spain	3.102	0.279	2.416
United Kingdom	2.221	0.233	3.209
Mean	2.589	0.281	2.945
Cluster 3:			
Austria	3.057	0.285	2.948
Germany	2.850	0.270	3.353
Netherlands	2.856	0.245	2.974
Portugal	3.218	0.296	2.217
Sweden	2.356	0.286	3.065
Switzerland	1.912	0.331	3.428
United States	1.969	0.256	3.432
Mean	2.603	0.281	3.059

(MAP) rule, i.e. the i-th country is assigned to the l-th component if $\widehat{z}_{il} = \max(\widehat{z}_{i1}, \ldots, \widehat{z}_{iK})$. Since the Bayesian information criterion (BIC) for model in equation (9) achieves its minimum with three components, we opt for a classification with three clusters of countries. Posterior rootogram in Figure 3 shows that components are quite well separated. Table 4 reports the summary of GDP, investment share and Human Capital (HC) index stratified by components of the FMM. Countries in Cluster 1 (Ireland and Norway) have grown faster that the others: the average *per capita* GDP growth rate in Cluster 1 is 4.3% while it is about 2.6% for both Cluster 2 and Cluster 3. Values for the average investment share and Human Capital Index do not display differences of the same magnitude. This suggests that the origin of such growth differentials should be sought elsewhere.

The coefficient for the initial level of income ($\log(y_0)$) is significant and negative (-4.02), indicating a clear tendency towards convergence across OECD countries. Coefficients for savings rates, which are cluster-specific[33], when statistically significant are in line with the theory except the parameter for $\log(s_k)$ in the Ireland and Norway cluster (-1.96, p-value < 0.10). This result could be explained by the fact that the two growth miracles appear to be driven by other than physical capital accumulation. Klein and Ventura (2021) point out that changes in aggregate TFP are the primary drivers of the Irish spectacular growth performance over the period 1980-2005. They also acknowledge crucial roles for intangible capital, openness to multinational firms and changes in labor market regulation. None of these factors, however, is directly taken into account in our analysis. Norway is rather a success of natural resource economy with one of the highest "natural capital" share among rich economies (12% in 2006).[34] This kind of capital is not captured by the variable "Share of gross capital formation at current PPPs" provided by PWT and, therefore, our estimate can not directly account for it.[35] Consistently with these considerations, Cluster 1 presents the highest coefficient for human capital (37.76).[36] Moreover, along the sample period, both Ireland and Norway have behaved as outliers in the distribution of one or more variables:

[33]The Jennrich test gives a $\chi^2 = 476.11$ (p-value=0.001), thus rejecting the hypothesis of an equal effects among components.

[34]See van der Ploeg (2011).

[35]See Table A7 in the Appendix for variable definition and source.

[36]This is true also in the specifications presented below as robustness checks.

Ireland has grown at the highest growth rate (4.6%) while Norway, despite its sustained growth (4%), has shown the largest decrease in s_k (-54.5%) among the countries in the sample.

Table 3 also gives the values of factor shares (ν and λ) implied by the coefficients in the restricted regression à la MRW. In particular, the estimated impact of saving is much lower than in MRW, i.e. the values of the implied λ, which are never statistically significant, range from 0.03 to 0.09.

Overall, the FMM estimates clearly indicate that not all taxes have the same impact on growth (see also the discussion on Table 5 below). Specifically, while we find a negative *direct* effect (-0.06) on growth of the tax rate on personal income (τ_w), the same is not necessarily true for the tax rate on corporate income (τ_k) and the total tax burden (τ_T), for which we find no statistically significant *direct* effects. Estimates for the interaction between taxation instruments and, respectively, s_k and s_h indicate a negative *indirect* effect of both τ_k (-0.06) and τ_w (-0.10).[37] The intuition behind this result is that increases in τ_k and τ_w lower the return of physical and human capital respectively, thus reducing the incentives to accumulate them. Finally, the negative coefficient of $\overline{\log(s_h)}_i$ (-14.69) suggests that a higher average endowment of human capital is associated with a lower growth rate over the observation window. In our framework, this negative correlation can be taken as evidence in favor of the convergence hypothesis.

4.4 Robustness

Robustness is a distinctive feature of the estimates obtained by the proposed model, when compared to estimates of the competing approaches. Our results do not change when we divide the sample into two sub-periods "pre great moderation"(1965-1990) and "great moderation"(1990-2007) or when we exclude the years of the Global Financial Crisis (2008-2010).[38] As shown in Table A10, our result are also confirmed, when we replace our measure

[37] We should stress, once again, that these estimates are only "instrumental", in the sense that they represent the effect of country-specific unobserved covariates correlated with fiscal policy variables mean values.

[38] These estimates are available upon request.

for τ_k and $\overline{\tau}_k$ with the *effective* corporate tax rates proposed by Vegh and Vuletin (2015).[39]

Qualitatively, the results hold even when the *true* model departs from the reference specification (8). As a robustness check, we estimated five additional specifications by modifying the dependence structure of GDP growth on taxation. To start, we assume, in Model II, that fiscal instruments affect the aggregate TFP only, while the other random parameters are free to vary, so that the term α_i is replaced by:

$$\tilde{\phi}_i^A + \psi_{00}\overline{\tau}_{T,i} + \psi_{01}\overline{\tau}_{w,i} + \psi_{02}\overline{\tau}_{k,i} + \psi_{04}\overline{\log(s_h)}_i + \psi_{05}\overline{\log(s_k)}_i. \tag{13}$$

In Model III, we assume that the aggregate TFP is affected by public capital accumulation k_g (as a share of national GDP) and mean values of investment shares s_k and s_h. Since public capital is financed by taxes (and debt), this specification assesses the taxes' effect on growth by controlling for the potential productive use of tax proceeds. The random parameters associated with s_k and s_h are described as a function of the income and investment rates as in equation (8) and the term α_i is replaced by:

$$\tilde{\phi}_i^A + \psi_{00}\overline{k}_g + \psi_{01}\overline{\log(s_h)}_i + \psi_{02}\overline{\log(s_k)}_i. \tag{14}$$

In the same vein, to account for the *direct* and *indirect* effects of current public expenditure, we include in Model IV the government spending to GDP ratio (G) as follows:[40]

$$\begin{aligned}
\gamma_{it} &= \left(\tilde{\phi}_i^A + \psi_{00}\overline{\tau}_{T,i} + \psi_{01}\overline{\log(s_h)}_i + \psi_{02}\overline{\log(s_k)}_i + \psi_{03}\overline{G}_i\right) + \beta_0\log(y_{i0}) + \\
&+ \left(\tilde{\phi}_i^h + \psi_{10}\overline{\tau}_{w,i} + \psi_{12}\overline{\log(s_k)}_i\right)\log(s_h)_{it} + \\
&+ \left(\tilde{\phi}_i^k + \psi_{20}\overline{\tau}_{k,i} + \psi_{21}\overline{\log(s_h)}_i\right)\log(s_k)_{it} + \\
&+ \beta_3\log(n+g+d)_{it} + \delta_1\tau_{T,it} + \delta_2\tau_{w,it} + \delta_3\tau_{k,it} + \delta_4 G_{it}\varepsilon_{it}.
\end{aligned} \tag{15}$$

[39] We thank an anonymous referee for the suggestion on this point.

[40] Following an anonymous referee advice, we also estimate a model in which both the government spending to GDP ratio *and* the budget deficits appear among the covariates. However, because of collinearity between the two variables, some coefficients are very imprecisely estimated.

Notice that both Model III and Model IV allow to control for the potential simultaneous conflict between growth-enhancing (i.e. tax cuts) fiscal changes and growth-retarding fiscal changes (i.e. the public expenditure reduction induced by fiscal revenues drop).[41]

In Model V, we modify the auxiliary regression in equation (8), by assuming that corporate taxation, reducing firms' investment in incremental know-how, influences the human capital accumulation, so that the term β_i^h is now replaced by:

$$\tilde{\phi}_i^h + \psi_{11}\overline{\tau}_{Ti} + \psi_{12}\overline{\tau}_{wi} + \psi_{13}\overline{\tau}_{ki} + \psi_{14}\overline{\log(s_h)}_i + \psi_{15}\overline{\log(s_k)}_i. \tag{16}$$

Last, in Model VI, we modify the auxiliary regression in equation (8) and assume that the variability in country-specific parameters for physical capital is partially explained by fiscal policy variables, so that the term β_i^k is now replaced by:

$$\tilde{\phi}_i^k + \psi_{21}\overline{\tau}_{Ti} + \psi_{22}\overline{\tau}_{wi} + \psi_{23}\overline{\tau}_{ki} + \psi_{24}\overline{\log(s_h)}_i + \psi_{25}\overline{\log(s_k)}_i. \tag{17}$$

The results for models specifications (II)-(VI) are presented in Tables A11–A13. The estimation of these models provides similar results in the random part and differences in the tax policy effects. For all model specifications, *direct* effects are always found to be negative: the coefficient of τ_w ranges in the interval [-0.09, -0.05], while the coefficient for τ_k ranges in the interval [-0.05, 0], even if it is never statistically significant. Moreover, the coefficient for the total tax burden τ_T is never statistically significant. When we restrict the effect of taxation on TFP as in Model II, the coefficient of τ_w is -0.06 (with a p-value=0.000), that of τ_k is -0.02 (with a p-value > 0.05). Regarding the *indirect* effects on the GDP growth rate, we observe that parameter estimates, often not statistically significant, for the interactions between tax and saving rates reinforce the negative *direct* effects in model specifications II, III, IV and V. The coefficient for $\tau_k \times \log(s_k)$ is significant (-0.08, p-value=0.05) only in Model III while that for $\tau_w \times \log(s_h)$ is significant but positive (0.05, p-value=0.001) in Model VI, thus compensating the negative *direct* effect of τ_w (-0.05, p-value=0.000). Finally, estimates for Model IV document a negative *direct* and *indirect* impact of public spending

[41] On this point, see the discussion in Gemmell, Kneller and Sanz (2011).

on growth (-0.01 each).

Globally, the results confirm the general negative impact of a higher taxation on GDP growth and suggest that taxation has quite homogenous effects (in magnitude, sign and significance) among countries. Further research is, however, needed to understand which covariate better discriminates between clusters. We briefly elaborate on this point at the end of the following paragraph.

4.5 Discussion

The models presented so far are (empirical) variations of a neoclassical theme, where *per capita* GDP growth is assumed to depend on the accumulation of physical and human capital and on the rate of technical changes. Fiscal policy modifications can generate output growth along the transition path; transitions, however, can last for decades.[42]

The main message of the present empirical exercise is that, based on different samples and specifications, taxes seem to have some negative effect on growth. Our estimates, however, call into question the size of such harmful effect. Table 5 reports the results of a "what if" exercise, in which we compute the changes in the 5-years average *per capita* GDP growth rate generated by a *ceteris paribus* cut by 10% in τ_w and τ_k, respectively. Here we focus only on the *direct* effects, since the *indirect* ones are related to the sample means ($\overline{\tau}_k$, $\overline{\tau}_w$ and $\overline{\tau}_T$), which are not affected by such *una tantum* fiscal intervention. Despite the exercise is somewhat moot, it is instructive to quantify the impact of fiscal policy on GDP dynamics and allows to compare our results with those established by the existing literature.[43]

In the baseline model (Model I), these (sizable) tax cuts produce positive effects on growth, being associated with an increase in the GDP growth rate of 0.61% for the cut in τ_w and of 0.32% for the cut in τ_k. Expansionary effects of the same size are found in Model II, where taxes exclusively affect the aggregate TFP, and in Models IV and V, where the

[42] As pointed out by Lee and Gordon (2005), fiscal policy typically adjusts in response to business-cycle fluctuations and this can cause short-run correlation between tax rates and growth rate. Since our exercise focuses on the links between tax rates and average growth rates over more than thirty years, we may guess that such short-run effects tend to average out.

[43] Since, as we noted, not all the parameters capturing the *direct* effect of taxation on growth are estimated with precision the figures in Table 5 should be taken cautiously.

Table 5: Effect on the 5-years average *per capita* GDP growth rate of a 10% cut in τ_w and τ_k

	$\Delta\gamma$ due to a 10% cut in τ_w	**$\Delta\gamma$ due to a 10% cut in τ_k**
Model I	0.61	0.32
Model I "with effective corporate tax"	0.20	0.81
Model II "with effects only on TFP"	0.62	0.22
Model III "with public capital"	0.50	0.51
Model IV "with public spending"	0.93	0.22
Model V "with effects only on s_h"	0.50	0.30
Model VI "with effects only on s_k"	0.50	0.05

indirect effect are only on s_h and s_k, respectively. When we consider the effective corporate tax provided by Vegh and Vuletin (2015) the beneficial effect of a cut in τ_w declines a bit (+0.20%) while that of a cut in τ_k increases dramatically (+0.81%). Such expansionary effects can be due to the fact that, in this hypothetical scenario, tax cuts are implemented keeping the level of public spending constant. However, including the public spending among the covariates, allowing for both *direct* and *indirect* effects of it as we do in Model IV, further increases the positive effect of γ of a cut in τ_w (+0.93%), while the impact of a cut in τ_k is substantially unchanged. These results partially contrast with those of Lee and Gordon (2005), who find a virtually zero impact for the cut in τ_w and a more beneficial effect for the cut in τ_k (around a 1.8% increase in the GDP growth rate).

In our set-up, where taxation has a *direct* effect on growth through the TFP and an *indirect* effect through the saving rates, tax cuts are beneficial for growth. Despite being focused only on the *direct* effects, the simple "what if"exercise presented above clearly indicates the detrimental role of taxation on personal income. To understand why a cut on personal income tax is generally found to be more beneficial than a cut on corporate tax rate it must be considered that τ_w is not exclusively related to labor income (despite its base is largely determined by wages and salaries). This implies that changes in τ_w actually affect GDP dynamics through both the interaction between leverage and dividend taxation and, for instance, its impact on investment in intangibles.[44]

Last, to give further insights on the mixture components, we estimated a Multinomial

[44] The same argument is given by Madsen, Minniti and Venturini (2021).

Table 6: Multinomial Logit Model estimates for cluster membership

	Cluster 1	**Cluster 2**
Intercept	18.296**	24.237**
τ_T	-0.089**	-0.162**
ssc	0.0183	0.043*
τ_c	0.065**	-0.326**
τ_s	-0.1916**	-0.092**
γ	-0.439**	-0.492**

Significance: *** : 0.001, ** : 0.01,* : 0.05

Logit Model to assess the role of some explanatory variables in describing cluster membership; here, Cluster 1 is taken as the reference. The model evaluates the relative probability of being in the two remaining clusters versus the reference, using a linear combination of explanatory variables. The obtained ML estimates represent the discriminating power of every covariate when we look at the log-odds of being in any other cluster versus the reference one. We consider the total tax burden (τ_T), the tax on sales (τ_s), the tax on consumption (τ_c) and the social security contributions (ssc) for this purpose. Results in Table 6 indicate the estimated log-odds of being in each cluster. Tax on consumption increase the odds to be in Clusters 1-2, the social contribution increases the probability to belong to Cluster 2, while an increase on the tax on sales increases the probability to belong to the reference one.

5 Concluding remarks

In this paper, we propose and estimate an *augmented* Solow model to test the effects of taxation on growth. The model allows for heterogeneity in the intercept and the effects associated to capital (both physical and human) savings rates. Sources of unobserved heterogeneity are partially explained by country-specific taxation characteristics, through an auxiliary regression, controlling for potential endogeneity. In the Finite Mixture Model, the random intercept captures country-specific institutional features, while the random parameters for investment shares s_k and s_h are influenced by some fiscal policy variables, such as the personal income tax rate and the corporate income tax rate.

Taxes affect the GDP growth both *directly* and *indirectly*. Direct effects refer to the impact that taxation has on the level of technology while indirect effects arise from the results of the interaction between (average) tax rates and (average) aggregate saving rates. By analyzing a variety of model specifications, we document a positive impact of tax cuts on real income dynamics. The effects are quite homogenous across countries. Our results are robust to changes in the analyzed period and to modifications of the reference empirical model.

References

[1] Akaike, Hirotogu (1973) Information theory and an extension of the maximum likelihood principle, in Boris Nikolaevich Petrov and F. Csaki (ed.) *Second International Symposium on Information Theory*, pp. 267-281. Budapest: Akademiai Kiado.

[2] Aitkin, Murray (1997) Contribution to the discussion paper by S. Richardson and P.J. Green, *Journal of The Royal Statistical Society*, B 59, 764-768.

[3] Aitkin, Murray, Brian Francis and John Hinde (2005) *Statistical Modelling in GLIM*, Oxford University Press, Oxford, 2nd edition.

[4] Aitkin, Murray and Roberto Rocci (2005) A general maximum likelihood analysis of measurement error in generalized linear models. *Statistics and Computing* 12,163-174.

[5] Alfò, Marco and Giovanni Trovato (2004) Semiparametric mixture models for multivariate count data, with application. *Econometrics Journal* 7, 1-29.

[6] Alfò, Marco, Giovanni Trovato and Robert Waldmann (2008) Testing for country heterogeneity in growth models using a finite mixture approach. *Journal of applied econometrics* 23, 487-514.

[7] Angelopoulos, Konstantinos, George Economides and Pantelis Kammas (2007) Tax-spending policies and economic growth: Theoretical predictions and evidence from the OECD. *European Journal of Political Economy* 23, 885-902.

[8] Arminger, Gerhard, Petra Stein and Jörg Wittenberg (1999) Mixtures of conditional mean- and covariance-structure models. *Psychometrika* 64, 475-494.

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

[10] Arnold, Jens, Bert Brys, Christopher Heady, Åsa Johansson, Cyrille Schwellnus and Laura Vartia (2011) Tax Policy for economic recovery and growth. *Economic Journal* 121, F59-F80.

[11] Barro, Robert (1990) Government Spending in a Simple Model of Endogenous Growth. *Journal of Political Economy* 98, 103-125.

[12] Barro, Robert (2001) Human Capital and Growth. *American Economic Review* 91, 12-17.

[13] Bleaney, Michael F., Norman Gemmell and Richard Kneller (2001) Testing the Endogenous Growth Model: Public Expenditure, Taxation, and Growth Over the Long-Run. *Canadian Journal of Economics* 34, 36-57.

[14] Blundell, Richard and Thomas M. Stoker (2005) Heterogeneity and Aggregation? *Journal of Economic Literature*, 43, 347-391.

[15] Bond, Stephen, Anke Hoeffler and Jonathan Temple (2001) GMM Estimation of Empirical Growth Models. *Discussion Paper No. 2048, Centre for Economic Policy Research.*

[16] Bodzogan, Hamparsum (1994) Mixture-model cluster analysis using model selection criteria and a new informational measure of complexity. In Hamparsum Bodzogan (ed.) *Proceedings of the first US/Japan conference on the frontiers of statistical modelling: An informational approach, Volume 2: Multivariate statistical modeling*, pp. 69-113. Dordrecht: Kluwer Academic Publishers

[17] Brewer, Mike, Emmanuel Saez, and Andrew Shephard (2010) Means testing and tax rates on earnings, in J. Mirrlees, S. Adam, T. Besley, R. Blundell, S. Bond, R. Chote, M. Gammie, P. Johnson, G. Myles and J. Poterba (ed.), *Dimensions of Tax Design: The Mirrlees Review*, pp. 90-173, Oxford: Oxford University Press for Institute for Fiscal Studies.

[18] Brock William A. and Steven N. Durlauf (2001) What have we learned from a decade of empirical research on growth? Growth Empirics and Reality. *The World Bank Economic Review* 15, 229-272.

[19] Bucci, Alberto, Lorenzo Carbonari and Giovanni Trovato (2021) Variety, Competition, and Population in Economic Growth: Theory and Empirics. *Macroeconomic Dynamics* 25(5), 1303-1330.

[20] Caselli, Francesco (2005) Accounting for Cross-Country Income Differences. *Handbook of Economic Growth*, Volume 1, Part A, 679-741.

[21] Chamberlain, Gary (1980) Analysis of Covariance with Qualitative Data. *Review of Economic Studies* 47, 225-23.

[22] Chamberlain, Gary (1984) Panel data, In *Handbook of Econometrics*, Vol. 2, 1247-1318.

[23] Cohen-Cole, Ethan B., Steven N. Durlauf and Giacomo Rondina (2012) Nonlinearities in growth: From evidence to policy. *Journal of Macroeconomics* 34,42-58.

[24] Daveri, Francesco and Guido Tabellini (2000) Unemployment, growth and taxation in industrial countries. *Economic Policy*, 30, p. 47-104.

[25] Davidson, Russell Davidson and James G. MacKinnon (1993) Estimation and Inference in Econometrics. New York: Oxford University Press.

[26] Durlauf, Steven N. (2000) Econometric Analysis and the Study of Economic growth: A Skeptical Perspective. In: Roger E. Backhouse and Andrea Salanti (ed.) *Macroeconomics and the real world, Volume 1. Econometric techniques and macroeconomics*, pp.249-61. Oxford University Press.

[27] Durlauf, Steven N. (2005) Complexity and empirical economics. *Economic Journal* 115, 225-43.

[28] Durlauf, Steven N., Andros Kourtellos and Artur Minkin (2001) The local Solow Growth model. *European Economic Review*, 45, 928-940.

[29] Durlauf, Steven N., Paula A. Johnson and Jonathan Temple (2005) Growth econometrics. *Handbook of Economic Growth*, Elsevier.

[30] Engen, Eric M. and Jonathan S. Skinner (1992) Fiscal policy and growth. *NBER working paper* no. 4223.

[31] Engen, Eric M. and Jonathan S. Skinner (1996) Taxation and economic growth. *NBER working paper* no. 5826.

[32] Easterly, William and Sergio Rebelo (1993) Marginal Income Tax Rates and Economic Growth in Developing Countries. *European Economic Review* 37, 409-417.

[33] Fraley, Chris and Adrian E. Raftery (2002) Model-based clustering, discriminant analysis, and density estimation. *Journal of the American Statistical Association* 97, 611-631.

[34] Fulginiti, Lilyan E. and Richard K. Perrin (1993) Prices and Productivity in Agriculture. *Review of Economics and Statistics* 75, 471-82.

[35] Gemmell, Norman, Richard Kneller and Ismael Sanz (2011) The Timing and Persistence of Fiscal Policy Impacts on Growth: Evidence from OECD Countries. *Economic Journal* 121(550), F33-F58

[36] Gemmell, Norman, Richard Kneller and Ismael Sanz (2013) The Growth Effects of Tax Rates in the OECD. *Canadian Journal of Economics*, 47, 1217-1255.

[37] Glomm, Gerhardand B.Ravikumar (1997) Productive government expenditure and long-run growth. *Journal of Economics Dynamics and Control* 21, 183-2004.

[38] Hauk, William R. (2017) Endogeneity bias and growth regressions. *Journal of Macroeconomics* 51,143-161.

[39] Jaimovich, Nir and Sergio Rebelo (2017) Nonlinear effects of taxation on growth. *Journal of Political Economy* 125(1), 265-291.

[40] Jones, Larry E. and Rodolfo E. Manuelli (1990) A Convex Model of Equilibrium Growth: Theory and Policy Implications. *Journal of Political Economy* 98, 1008-38.

[41] Jones, Larry E., Rodolfo E. Manuelli and Peter E. Rossi (1993) Optimal Taxation in Models of Endogenous Growth. *Journal of Political Economy* 101,485-517.

[42] Kim, Se-Jik (1998) Growth effect of taxes in an endogenous growth model: to what extent do taxes affect economic growth? *Journal of Economic Dynamics and Control* 23, 125-158.

[43] Klein, Paul and Gustavo Ventura (2021) Taxation, expenditures and the Irish miracle. *Journal of Monetary Economics* 117, 1062-1077.

[44] Kneller, Richard, Michael F. Bleaney and Norman Gemmell (1999) Fiscal policy and growth: evidence from OECD countries. *Journal of Public Economics* 74, 171-190.

[45] Koester, Reinhard B. and Roger C. Kormendi (1989) Taxation, Aggregate Activity And Economic Growth: Cross? Country Evidence On Some Supply? Side Hypotheses. *Economic Inquiry*, 27, 367-386

[46] Laird, Nan M. (1978) Nonparametric Maximum Likelihood Estimation of a Mixing Distribution. *Journal of American Statistical Association* 73, 805-811.

[47] Lee, Young and Roger H. Gordon (2005) Tax structure and economic growth. *Journal of Public Economics* 89, 1027-1043

[48] Lewbel, Arthur (1997) Constructing instruments for regressions with measurement error when no additional data are available, with an application to patents and R&D. *Econometrica* 65(5), 1201-1213.

[49] Lewbel, Arthur (2012) Using Heteroscedasticity to Identify and Estimate Mismeasured and Endogenous Regressor Models. *Journal of Business and Economic Statistics* 30,67-80.

[50] Wenli, Li and Pierre-Daniel Sarte (2004) Progressive taxation and long-run growth. *American Economic Review* 94(5), 1705-1716.

[51] Lindsay, Bruce G. (1983a) The geometry of mixture likelihoods: a general theory. *Annals of Statistics* 11, 86-94.

[52] Lindsay, Bruce G. (1983b) The geometry of mixture likelihoods. II. The exponential family. *Annals of Statistics* 11, 783-792.

[53] Lindsay, Bruce G. and Mary L. Lesperance (1995) A review of semiparametric mixture models. *Journal of statistical planning and inference* 47, 29-39

[54] Lucas, Robert E. (1988) On the mechanics of economic development. *Journal of Monetary Economics* 22, 3-42.

[55] Lucas, Robert E. (1990) Supply-Side Economics: An Analytical Review. *Oxford Economic Papers* 42, 293-316.

[56] Madsen, Jakob B., Antonio Minniti and Francesco Venturini (2021) The Long-run Investment Effect of Taxation in OECDCountries. *NIESR Discussion Paper* No. 527.

[57] Mankiw, N. Gregory, David and Romer and David N. Weil (1992) A contribution to the empirics of economic growth. *Quarterly Journal of Economics* 107, 407-37.

[58] Martinez-Vazquez, Jorge, Violeta Vulovic and Yongzheng Liu (2011) Direct versus indirect taxation: trends, theory, and economic significance. In Emilio Albi and Jorge Martinez-Vazquez (eds) *The Elgar Guide to Tax Systems*, pp. 37-92. Georgia State University: Edward Elgar Publishing.

[59] McLachlan, Geoffrey and David Peel (2000) *Finite Mixture Models*. John Wiley & Sons Inc.

[60] Mendoza, Enrique G., Gian Maria Milesi-Ferretti and Patrick Asea (1997) On the Ineffectiveness of Tax Policy in Altering Long-Run Growth: Harberger's Superneutrality Conjecture. *Journal of Public Economics* 66(1), 99-126.

[61] Mendoza, Enrique G., Assaf Razin and Linda Tesar (1994) Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption. *Journal of Monetary Economics* 34, 297-323.

[62] Milesi-Ferretti, Gian Maria and Nouriel Roubini (1998) Growth Effects of Income and Consumption Taxes. *Journal of Money, Credit, and Banking* 30(4), 721-744.

[63] Mundlak, Yair (1978) On the Pooling of Time Series and Cross Section Data. *Econometrica* 46, 69-85.

[64] Mundlak, Yair (1988) Endogenous Technology and the Measurement of Productivity. In Susan M. Capalbo and John M. Antle (ed.), *Agricultural Productivity: Measurement and Explanation*, pp. 316-331. Washington, D.C.: Resources for the Future.

[65] Mundlak, Yair, Rita Butzer and Donald F. Larson (2012) Heterogeneous technology and panel data: The case of the agricultural production function. *Journal of Development Economics* 99, 139-149.

[66] Muthén, Bengt and Tihomir Asparouhov (2009) Multilevel Regression Mixture Analysis. *Journal of Royal Statistical Society, A* 172(3), 639-657

[67] Neuhaus, John M. and Charles E. McCulloch (2006) Separating between- and within-cluster covariate effects by using conditional and partitioning methods. *Journal of Royal Statistical Society, B* 68, 859-872.

[68] Ng, Shu-Kay and Geoffrey J. McLachlan (2014) Mixture models for clustering multilevel growth trajectories. *Computational Statistics & Data Analysis* 71, 43-51.

[69] Owen, Ann, Julio Videras and Lewis Davis (2009) Do all Countries follow the same Growth Process? *Journal of Economic Growth* 14, 265-286.

[70] Padovano, Fabio and Emma Galli (2001) Tax Rates and Economic Growth in the OECD Countries (1950-1990). *Economic Inquiry* 39, 44-57.

[71] Padovano, Fabio and Emma Galli (2002). Comparing the Growth Effects of Marginal vs. Average Tax Rates and Progressivity. *European Journal of Political Economy* 18, 529-554.

[72] Pedroni, Peter (2007) Social capital, barriers to production and capital shares: implications for the importance of parameter heterogeneity from a nonstationary panel approach. *Journal of Applied Econometrics* 22, 429-451.

[73] Pesaran, M. Hashem and Ron Smith (1995) Estimating Long-Run Relationships from Dynamic Heterogeneous Panels. *Journal of Applied Econometrics* 68, 79-113.

[74] Peretto, Pietro F. (2003) Fiscal policy and long-run growth in R&D-based models with endogenous market structure. *Journal of Economic Growth* 8, 325-47.

[75] Peretto, Pietro F. (2007) Corporate taxes, growth and welfare in a Schumpeterian economy. *Journal of Economic Theory* 137, 353-82.

[76] Phillips, Peter C.B. and Donggyu Sul (2007) Some Empirics on Economic Growth under Heterogeneous Technology. *Journal of Macroeconomics* 29, 455-469.

[77] Piketty, Thomas, Emmanuel Saez and Stefanie Stantcheva (2014) Optimal Taxation of Top Labor Incomes: A Tale of Three Elasticities. *American Economic Journal: Economic Policy* 6 (1), 230-71.

[78] Pittau, Maria Grazia Pittau, Roberto Zelli and Paul A. Johnson (2010) Mixture Models, Convergence Clubs and Polarization. *Review of Income and Wealth* 56, 101-122.

[79] Rebelo, Sergio (1991) Long-Run Policy Analysis and Long-Run Growth. *Journal of Political Economy* 99, 500-521.

[80] Romer, Christina D. and David H. Romer (2010) The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks. *American Economic Review* 100(3), 763-801.

[81] Romer, Christina D. and David H. Romer (2014) The Incentive Effects of Marginal Tax Rates: Evidence from the Interwar Era. *American Economic Journal: Economic Policy* 6 (3), 242-81.

[82] Schwarz, Gideon (1978) Estimating the dimension of a model. *Annal of Statistics* 6, 461-464.

[83] Simar, Leopold (1976) Maximum Likelihood Estimation of a Compound Poisson Process. *Annal of Statistics* 4, 1200-1209.

[84] Solow, Robert M. (1956) A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics* 70, 65-94.

[85] Stokey, Nancy L. and Sergio Rebelo (1995) Growth Effects of Flat-Rate Taxes. *Journal of Political Economy* 103, 519-550.

[86] van der Ploeg, Frederick (2011) Natural Resources: Curse or Blessing? *Journal of Economic Literature* 49(2), 366-420.

[87] Van Garderen, Kees Jan, Kevin Lee and M. Hashem Pesaran (2000) Cross-sectional aggregation of non-linear models. *Journal of Econometrics* 95, 285-331.

[88] Vegh, Carlos A. and Guillermo Vuletin (2015) How Is Tax Policy Conducted over the Business Cycle? *American Economic Review* 7(3), 327-370.

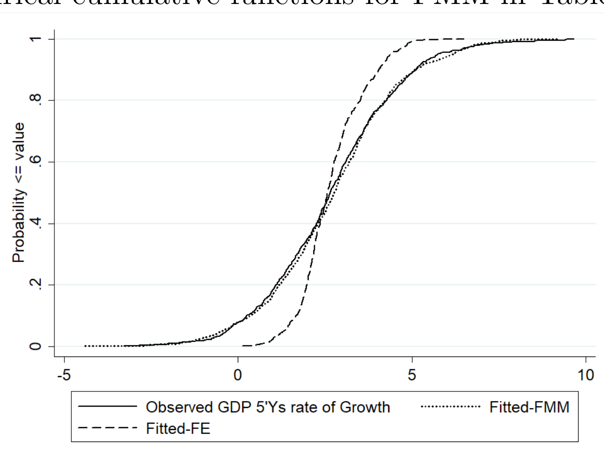
[89] Widmalm, Frida (2001) Tax Structure and Growth: Are Some Taxes Better Than Others? *Public Choice* 107, 199-219.

[90] Wooldridge, Jeffrey M. (2009) *Econometric Analysis of Cross Section and Panel Data*. Cambridge, Massachusetts: The MIT Press.

[91] Wouterse, Fleur (2016) Can human capital variables be technology changing? An empirical test for rural households in Burkina Faso. *Journal of Productivity Analysis* 45, 157-172.

Figure 1: GDP growth rates by Groups

Figure 2: Empirical cumulative functions for FMM in Table 3 and OLS FE



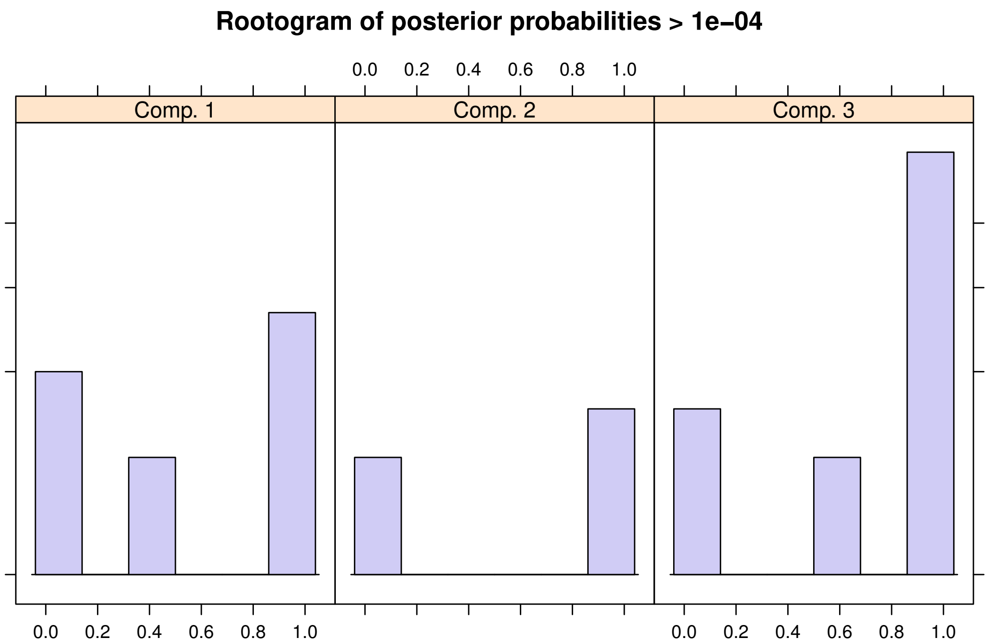


Figure 3: Rootogram for posterior component membership

Appendix

A ML parameter estimation

Our specification includes unobserved country-specific heterogeneity through Cluster-specific parameters. As discussed by Aitkin, Francis and Hinde (2005), through this approach, we may consider several sources of model misspecification, ranging from omitted covariates, to wrong assumptions on either the link function or the conditional response distributions (e.g. Cobb-Douglas vs CES production function).

Using equation (7) and assuming conditional independence for the measurements corresponding to the same country, the probability density function for the country profile γ_i can be written as

$$f\left(\gamma_i \mid \mathbf{x}_i, \tilde{\phi}_i\right) = \prod_{t=1}^{T} \left\{ \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{1}{2\sigma^2} \left(\gamma_{it} - \mu_{it}^{\gamma}\right)^2 \right] \right\}.$$

Let us assume that $\tilde{\phi}_i \sim g(\cdot)$; treating the latent effects as nuisance parameters and integrating them out, we obtain the following expression for the marginal likelihood

$$L(\cdot) = \prod_{i=1}^{n} \left\{ \int_{\oplus} f(\gamma_i \mid \mathbf{x}_i, \tilde{\phi}_i) \mathrm{d}G(\tilde{\phi}_i | \mathbf{x}_i) \right\} \simeq \prod_{i=1}^{n} \left\{ \int_{\oplus} f(\gamma_i \mid \mathbf{x}_i, \tilde{\phi}_i) \mathrm{d}G(\tilde{\phi}_i) \right\}, \tag{18}$$

since, as we showed before, $g(\tilde{\phi}_i|\mathbf{x}_i) \simeq g(\tilde{\phi}_i)$. Rather than using a parametric specification, we leave for $G(\cdot)$ unspecified and provide a nonparametric maximum likelihood estimator for this term, see Laird (1978) and Lindsay (1983a, 1983b). According to such an approach, see Lindsay and Lesperance (1995) for a review, the integral in eq (18) may be approximated by the following weighted sum

$$L(\cdot) = \prod_{i=1}^{n} \left\{ \sum_{k=1}^{K} f(\gamma_i \mid \mathbf{x}_i, \zeta_k) \pi_k \right\} = \prod_{i=1}^{n} \left\{ \sum_{k=1}^{K} f_{ik} \pi_k \right\}, \tag{19}$$

where, as mentioned above, $\tilde{\phi}_i \sim \sum_{k=1}^{K} \pi_k \delta_k(\zeta_k)$, K is the number locations ζ_k, $k = 1, \ldots, K$ (see McLachlan and Peel, 2000). The likelihood in equation (19) resembles the likelihood for a finite mixture of regression models, where groups of countries are associated with specific values of parameters. Since component memberships are unobserved, they may be thought of as missing data. For a fixed number of components K, we denote by $\mathbf{z}_i = (z_{i1}, \ldots, z_{iK})$ the latent component-indicator vector, with elements

$$z_{ik} = \begin{cases} 1 & \text{if } \tilde{\phi}_{\mathrm{i}} = \zeta_{\mathrm{k}}, \\ 0 & \text{otherwise.} \end{cases} \tag{20}$$

Were this source of heterogeneity observed, the indicator variables would be known, and the model would reduce to a simple GLM regression model with group-specific parameters. The hypothetical space defined by the complete data problem is given by $(\gamma_i, \mathbf{x}_i, \mathbf{z}_i)$. Using a multinomial distribution for the unobserved vector of component indicators, $\mathbf{z}_i$, the log likelihood for the complete data can be written as

$$\ell_c(\cdot) = \sum_{i=1}^{n} \sum_{k=1}^{K} z_{ik} \left\{ \log(\pi_k) + \log f_{ik} \right\}. \tag{21}$$

By taking derivatives with respect to the vector of model parameters, θ, we obtain

$$\frac{\partial \log[L(\theta)]}{\partial \theta} = \frac{\partial \ell(\theta)}{\partial \theta} = \sum_{i=1}^{n} \sum_{k=1}^{K} \frac{\pi_k f_{ik}}{\sum_{k=1}^{K} \pi_k f_{ik}} \frac{\partial \log f_{ik}}{\partial \theta} = \sum_{i=1}^{n} \sum_{k=1}^{K} \hat{z}_{ik} \frac{\partial \log f_{ik}}{\partial \theta}, \tag{22}$$

where $\hat{z}_{ik}$ represents the posterior probability that the i-th country comes from the $k-th$ component of the mixture, $f_{ik} = f(\gamma_i \mid \zeta_k)$ denotes the response distribution in that component, $k = 1, \ldots, K$, $i = 1, \ldots, n$, and $\theta = (\alpha_i, \beta_i^h, \beta_i^k, \Sigma_\phi)$. The corresponding likelihood equations are weighted sums of those for an ordinary regression model with log link and weights $\hat{\mathbf{z}}_{ik}$. Solving these equations for a given set of weights and updating the weights from the current parameter estimates define an EM algorithm, see e.g. McLachlan and Peel (2000).

Alfò, Trovato and Waldmann (2008) describes the EM algorithm in the context of Solow growth models. The mixture model explicitly considers country-specific growth paths, without any need to define, a priori, any threshold. It helps capture the country-specific structure, allowing for correlation between observed covariates and country-specific random parameters. A side result of FMM is that it can provide a partition of countries in clusters characterized by homogeneous unobserved characteristics, based on the posterior probabilities $\hat{z}_{ik}$. According to a simple *maximum a posteriori* (MAP) rule, in fact, the i-th country can be classified into the l-th component if

$$\hat{z}_{il} = \max(\hat{z}_{i1}, \ldots, \hat{z}_{iK}).$$

It is worth noticing that each component is characterized by homogeneous values of the estimated latent effects; that is, conditionally on the observed covariates, countries from the same group show a similar structure, at least in the steady state. Penalized likelihood criteria such as Akaike information criterion (Akaike, 1973), Bayesian information criterion (Schwarz, 1978) or Consistent Akaike information criterion (Bodzogan, 1994) can be used to choose the number of mixture components used to approximate the (potentially continuous) distribution of the random parameters. Usually, attempts to estimate the model with too many components result either in one mass having an estimated probability approaching zero or two masses having nearly the same estimated location.

Table A7: Variable definition and source

Variable	Definition (source)
γ	5-years average *per capita* GDP growth rate (PWT 9).
s_k	share of gross capital formation at current PPPs (PWT 9).
s_h	index of human capital per person, based on years of schooling and returns to education (PWT 9).
τ_T	total tax revenues as % of total GDP (OECD).
τ_w	personal income tax, including personal income, social security contributions and taxes on payroll and workforce as % of total tax revenues (OECD, categories 1100, 2000 and 3000).
τ_k	corporate taxation as % of total tax revenues (OECD, category 1200).
τ_n	income taxes including social security contributions and taxes on payroll and workforce as % of total tax revenues (OECD, categories 1110, 2000 and 3000).
τ_c	tax on consumption and property as % of total tax revenues, including tax on good and services, property and other tax (OECD, categories 5000 and 4000 and 6000).
τ_s	tax on sales as % of total tax revenues (OECD, category 5112).
ssc	social security contributions as % of total tax revenues (OECD, category 2000).

Table A8: Explanatory statistics (mean values) for used variables, 1965-2010

Country	$\gamma \times 100$	s_h	s_k	$n+g+d$	τ_T	τ_k	τ_n	τ_w	τ_c	ssc	τ_s
Australia	2.176	3.334	0.290	0.510	0.271	0.143	0.472	0.167	0.384	0.052	0.345
Austria	3.057	2.955	0.287	0.510	0.403	0.041	0.607	0.266	0.342	0.385	0.480
Belgium	2.664	2.760	0.291	0.505	0.423	0.060	0.630	0.292	0.307	0.312	0.408
Canada	2.101	3.279	0.256	0.518	0.327	0.097	0.498	0.198	0.396	0.140	0.388
Denmark	2.331	3.111	0.268	0.502	0.458	0.046	0.549	0.281	0.387	0.025	0.523
Finland	2.950	2.921	0.342	0.502	0.411	0.054	0.591	0.266	0.354	0.245	0.505
France	2.325	2.739	0.265	0.505	0.412	0.055	0.558	0.253	0.386	0.425	0.475
Germany	2.850	3.362	0.275	0.505	0.358	0.047	0.643	0.247	0.308	0.370	0.435
Ireland	4.643	2.722	0.267	0.520	0.311	0.074	0.438	0.160	0.486	0.149	0.604
Italy	3.212	2.535	0.269	0.502	0.358	0.082	0.578	0.236	0.339	0.343	0.391
Japan	3.444	3.168	0.342	0.494	0.256	0.187	0.541	0.186	0.272	0.315	0.231
Luxembourg	2.844	2.722	0.330	0.505	0.357	0.168	0.509	0.241	0.323	0.280	0.379
Netherlands	2.856	2.980	0.247	0.510	0.409	0.076	0.605	0.280	0.316	0.387	0.414
New Zealand	1.696	3.233	0.236	0.514	0.322	0.111	0.491	0.202	0.371	.	0.465
Norway	4.055	3.183	0.300	0.506	0.414	0.126	0.495	0.258	0.379	0.227	0.536
Portugal	3.218	2.219	0.297	0.504	0.308	0.098	0.444	0.167	0.455	0.268	0.651
Spain	3.102	2.426	0.281	0.510	0.284	0.072	0.584	0.187	0.338	0.393	0.360
Sweden	2.356	3.070	0.289	0.499	0.471	0.047	0.666	0.336	0.286	0.292	0.405
Switzerland	1.912	3.430	0.335	0.505	0.258	0.078	0.591	0.179	0.310	0.236	0.317
United Kingdom	2.221	3.224	0.235	0.505	0.349	0.089	0.485	0.200	0.426	0.184	0.444
United States	1.969	3.437	0.257	0.512	0.256	0.096	0.603	0.179	0.301	0.234	0.232

Table A9: Within country correlation between growth rate of *per capita* GDP and fiscal policy variables

Country	$\rho_{\gamma\tau_T}$	$\rho_{\gamma\tau_k}$	$\rho_{\gamma\tau_w}$	$\rho_{\gamma ssc}$	$\rho_{\gamma\tau_c}$	$\rho_{\gamma\tau_s}$
Australia	0.179	0.422	-0.434	-0.056	-0.399	0.077
Austria	-0.277	0.156	-0.433	0.225	-0.257	-0.205
Belgium	-0.543	0.378	-0.562	0.535	-0.096	0.248
Canada	-0.179	0.580	-0.420	0.184	-0.475	0.318
Denmark	0.360	0.454	-0.141	-0.216	0.294	-0.202
Finland	-0.284	0.512	-0.726	0.208	-0.531	0.230
France	-0.576	0.565	-0.651	0.484	-0.595	0.460
Germany	-0.107	-0.079	-0.085	0.162	-0.281	-0.063
Ireland	-0.154	0.680	-0.063	-0.312	-0.243	-0.329
Italy	-0.687	-0.243	-0.225	0.220	0.607	0.335
Japan	-0.471	0.682	-0.712	-0.248	-0.809	-0.938
Luxembourg	-0.226	0.005	-0.261	0.251	-0.235	0.086
Netherlands	-0.578	0.397	-0.404	0.355	-0.738	0.337
New Zealand	0.217	0.055	-0.358	0.410	.	0.383
Norway	0.445	0.494	-0.341	-0.568	-0.095	-0.516
Portugal	-0.379	0.342	-0.255	-0.101	-0.596	-0.231
Spain	0.084	0.561	-0.469	0.320	-0.389	0.391
Sweden	0.171	0.312	-0.309	0.232	-0.183	0.053
Switzerland	-0.047	0.625	-0.668	0.278	-0.276	0.470
United Kingdom	0.039	0.243	-0.133	-0.006	-0.091	0.076
United States	0.466	0.232	0.092	-0.298	-0.235	-0.389

Table A10: Model I, equation (9) "with *effective* corporate tax rate"

	Cluster 1	**Cluster 2**	**Cluster 3**
		Cluster-specific parameters	
Intercept	33.53***	95.06***	78.38***
$\log(s_k)$	-5.51**	0.94	2.75***
$\log(s_h)$	62.24***	15.01***	32.96***
		Direct Effects	
$\log(y_{0,i})$	-7.91***	-7.91***	-7.91***
$\log(n+g+d)$	-10.78***	-10.78***	-10.78***
τ_T	0.05	0.05	0.05
τ_w	-0.02	-0.02	-0.02
τ_k	-0.08***	-0.08***	-0.08***
		Indirect Effects	
$\overline{\tau}_{T,i}$	-9.40**	-9.40**	-9.40**
$\overline{\tau}_{w,i} \times \log(s_h)$	-0.08**	-0.08**	-0.08**
$\overline{\tau}_{k,i} \times \log(s_k)$	-1.12	-1.12	-1.12
$\overline{\log(s_h)}_i$	-13.61***	-13.61***	-13.61***
$\overline{\log(s_k)}_i$	0.94	0.94	0.94
$\hat{\sigma}^2$	1.257		
$\hat{\pi}_k$	0.316	0.052	0.631
$\hat{z}_k$	0.306	0.054	0.639
Log-likelihood	-772.8483		
BIC	1680.631		
Observations	461		
Shapiro-Wilk (p-val)	0.942	0.651	0.925

Significance levels: ***: 0.001 **: 0.01 *: 0.01.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 in the Appendix for tax variables definition and sources. In this model, τ_k is the effective *standard corporate tax rate* provided by Vegh and Vuletin (2015).
Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities. See Table A7 in the Appendix for tax variables definition and sources.

Table A11: Model II "effects only on TFP", equations (8) + (13)

	Cluster 1	**Cluster 2**	**Cluster 3**
	Cluster-specific parameters		
Intercept	27.21***	39.59***	49.73***
$\log(s_k)$	−1.86**	1.70*	4.71***
$\log(s_h)$	22.37***	14.47***	8.48***
	Direct effects		
$\log(y_{0,i})$	−3.79***	−3.79***	−3.79***
$\log(n+g+d)$	−4.54*	−4.54*	−4.54*
τ_T	0.03	0.03	0.03
τ_w	−0.06***	−0.06***	−0.06***
τ_k	−0.02	−0.02	−0.02
	Indirect effects		
$\overline{\tau}_{T,i}$	0.04	0.04	0.04
$\overline{\tau}_{w,i}$	−0.01	−0.01	−0.01
$\overline{\tau}_{k,i}$	−0.06	−0.06	−0.06
$\overline{\log(s_h)}_i$	−12.35***	−12.35***	−12.35***
$\overline{\log(s_k)}_i$	1.02	1.02	1.02
$\hat{\sigma}$	1.64		
$\hat{\pi}_k$	0.266	0.409	0.325
$\hat{z}_k$	0.273	0.391	0.336
Log-likelihood	-1617.24		
BIC	3382.49		
Observations	835		

Significance levels: ***: 0.001 **: 0.01 *: 0.05.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 for tax variables definition and sources. Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities.

Table A12: Model III, "with public capital", equations (8) + (14)

	Cluster 1	**Cluster 2**	**Cluster 3**
	Cluster-specific parameters		
Intercept	9.61^{*}	23.91^{***}	38.08^{***}
$\log(s_k)$	-1.71^{*}	1.58^{*}	6.33^{***}
$\log(s_h)$	23.05^{***}	12.35^{***}	5.22^{**}
	Direct effects		
$\log(y_{0,i})$	-2.44^{***}	-2.44^{***}	-2.44^{***}
$\log(n+g+d)$	-4.27^{*}	-4.27^{*}	-4.27^{*}
k_g	0.00	0.00	0.00
τ_w	-0.05^{***}	-0.05^{***}	-0.05^{***}
τ_k	-0.05	-0.05	-0.05
	Indirect effects		
$\overline{k}_{g,i}$	0.02^{*}	0.02^{*}	0.02^{*}
$\overline{\tau}_{w,i} \times \log(s_h)$	-0.00	-0.00	-0.00
$\overline{\tau}_{k,i} \times \log(s_k)$	-0.08^{*}	-0.08^{*}	-0.08^{*}
$\overline{\log(s_h)}_i$	-5.28^{**}	-5.28^{**}	-5.28^{**}
$\overline{\log(s_k)}_i$	2.11^{**}	2.11^{**}	2.11^{**}
$\hat{\sigma}^2$	1.62		
$\hat{\pi}_k$	0.143	0.523	0.334
$\hat{z}_k$	0.146	0.538	0.315
Log-likelihood	-1396.957		
BIC	2938.962		
Observations	835		

Significance levels: ***: 0.001 **: 0.01 *: 0.05.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 for tax variables definition and sources. Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities.

Table A13: Model IV, "with public spending", equation (15)

	Cluster 1	**Cluster 2**	**Cluster 3**
		Cluster-specific parameters	
Intercept	29.37***	49.44***	59.89***
$\log(s_k)$	-0.66	1.73*	3.33***
$\log(s_h)$	35.01***	19.35***	11.00***
		Direct effects	
$\log(y_{0,i})$	-5.06***	-5.06***	-5.06***
$\log(n+g+d)$	-4.00	-4.00	-4.00
τ_T	0.03	0.03	0.03
τ_w	-0.09***	-0.09***	-0.09***
τ_k	-0.02	-0.02	-0.02
G	-0.01***	-0.01***	-0.01***
		Indirect effects	
$\overline{\tau}_{T,i}$	0.01**	0.01**	0.01**
$\overline{\tau}_{w,i} \times \log(s_h)$	0.00	0.00	0.00
$\overline{\tau}_{k,i} \times \log(s_k)$	-0.03	-0.03	-0.03
$\overline{\log(s_h)}_i$	-16.38***	-16.38***	-16.38***
$\overline{\log(s_k)}_i$	-0.59	-0.59	-0.59
$\overline{G}_i$	-0.01***	-0.01***	-0.01***
$\hat{\sigma}$	1.591		
$\hat{\pi}_k$	0.190	0.428	0.382
$\hat{z}_k$	0.196	0.410	0.393
Log-likelihood	-1591.735		
BIC	3344.927		
Observations	835		

Significance levels: ***: 0.001 **: 0.01 *: 0.05.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 for tax variables definition and sources. Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities.

Table A14: Model V, "effects only through the coefficient for $\log(s_h)$", equations (8) + (16)

	Cluster 1	**Cluster 2**	**Cluster 3**
	Cluster-specific parameters		
Intercept	22.24***	32.49***	46.99***
$\log(s_k)$	-2.52***	1.22*	7.29***
$\log(s_h)$	18.04***	12.10***	5.68**
	Direct effects		
$\log(y_{0,i})$	-2.83***	-2.83***	-2.83***
$\log(n+g+d)$	-5.27**	-5.27**	-5.27**
τ_T	0.03	0.03	0.03
τ_w	-0.05**	-0.05**	-0.05**
τ_k	-0.03	-0.03	-0.03
	Indirect effects		
$\overline{\tau}_{T,i} \times \log(s_h)$	0.00	0.00	0.00
$\overline{\tau}_{w,i} \times \log(s_h)$	-0.02	-0.02	-0.02
$\overline{\tau}_{k,i} \times \log(s_h)$	-0.05	-0.05	-0.05
$\overline{\log(s_h)}_i$	-8.25***	-8.25***	-8.25***
$\overline{\log(s_k)}_i$	3.33***	3.33***	3.33***
$\hat{\sigma}$	1.593		
$\hat{\pi}_k$	0.191	0.568	0.241
$\hat{z}_k$	0.597	0.254	0.149
Log-likelihood	-1612.51		
BIC	3373.033		
Observations	835		

Significance levels: ***: 0.001 **: 0.01 *: 0.05.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 for tax variables definition and sources. Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities.

Table A15: Model VI, "effects only through the coefficient fo $\log(s_k)$", equations (8) + (17))

	Cluster 1	**Cluster 2**	**Cluster 3**
		Cluster-specific parameters	
Intercept	27.68***	47.03***	44.69***
$\log(s_k)$	−0.81	1.35	5.10***
$\log(s_h)$	23.00***	6.81***	13.58***
		Direct effects	
$\log(y_{0,i})$	−3.49***	−3.49***	−3.49***
$\log(n+g+d)$	−4.45*	−4.45*	−4.45*
τ_T	0.01	0.01	0.01
τ_w	−0.05***	−0.05***	−0.05***
τ_k	0.00	0.00	0.00
		Indirect effects	
$\overline{\tau}_{T,i} \times \log(s_k)$	−0.06**	−0.06**	−0.06**
$\overline{\tau}_{w,i} \times \log(s_k)$	0.05**	0.05**	0.05**
$\overline{\tau}_{k,i} \times \log(s_k)$	−0.02	−0.02	−0.02
$\overline{\log(s_h)}_i$	−14.24***	−14.24***	−14.24***
$\overline{\log(s_k)}_i$	0.01	0.01	0.01
$\hat{\sigma}$	1.593		
$\hat{\pi}_k$	0.381	0.258	0.361
$\hat{z}_k$	0.597	0.254	0.149
Log-likelihood	-1607.50		
BIC	3363.014		
Observations	835		

Significance levels: ***: 0.001 **: 0.01 *: 0.05.
Dependent variable: Real GDP growth rate computed as $(1/T) \times (\log(y)_{it} - \log(y)_{it-1})$. See Table A7 for tax variables definition and sources. Note: $\hat{\sigma}^2$, variance of the random terms; $\hat{\pi}_k$, estimated prior probabilities; $\hat{z}_k$, estimated posterior probabilities.