Fiscal Policy Impacts on Growth: an OECD Cross-Country Study with an Emphasis on Capital Rates Accumulation

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Abstract

A growing body of literature tests the effects of different tax structures on long-run economic growth. The paper aims at testing if the composition of tax revenue affects economic growth in the long run via the capitals saving rates. To avoid heterogeneity and endogenous bias in the estimation process we use a multivariate finite mixture model with regressors measurement error. We argue that these tests do not properly account for endogeneity between supposedly independent variables. We run Dynamic Fixed Effect regression and finite mixture models with special attention to capital saving rates coefficients, and show how those parameters can be affected by different tax policies. Moreover we find that effects of taxation on capital accumulation rates and growth is different for different countries. **keywords**: Tax policy, Finite Mixture Models, Dynamic Fixed Effect Regression.

1 Introduction

The paper aims at testing if the tax mixing affects economic growth in the long run via the capitals accumulation rates. To avoid heterogeneity and endogenous bias in the estimation process we use a multivariate finite mixture model with regressors measurement error.

Solow's (1956) approach does not allow for fiscal policy effects on growth rates at steady state, moreover it implies that lower rates of capital accumulation will lead to lower per capita levels at steady state. This could be due to taxation if it affects the savings rates also in the long-run equilibrium. Endogenous growth models even imply that distorted accumulation rates affect the steady-state growth rate as well. Therefore, from a theoretical point of view, taxes that do not distort accumulation rates dynamic are to be considered preferable by a welfare-maximizing government (of course, not taking into account equity needs). Judd (1999) argued how capital taxation, including taxation on the return-to-factor of investments in human capital, should be kept at zero rate in the long run if some restrictive assumptions are met, while only a positive tax burden on labor incomes to satisfy revenue needs should be levied.

While such theoretical analysis seems rather clear-cut, empirical evidence is not univocal.

Starting from Barro (1989) a number of studies have attempted to identify how the overall level of taxation affects growth performance. Higher taxation may be the outcome of the economic and social development of an industrial economy with and increased share of public expenditure in gross national product, and thus richer countries would display higher overall taxation burdens (the so called "Wagner's Law"). More open countries could adopt higher taxation to provide insurance against externally induced fluctuations of domestic production to their citizens, as inquired in Rodrik (1998; but on this subject see also Alesina and Wacziarg, 1998). Moreover, higher taxation could be linked to bad economic performance due to a political response to worsening economic conditions. Barro (1989) finds a negative correlation between real government consumption expenditure and growth, Koester and Kormendi (1989) find only mild evidence of a relationship between tax rates and growth. Similarly, Easterly and Rebelo (1993) and Levine and Renelt (1992) or Slemrod et al. (1995).

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On the relationship between fiscal policy and economic growth, Kneller et al. (1999) find that only taxes on income affect growth while Lee and Gordon (2005) find that corporate taxation is negatively related to growth. Moreover Arnold (2008) split income taxes into corporate, property, and personal taxes. Results point to a relevant negative correlation between corporate taxation and growth, while property taxes show milder negative effects. Gemmel et al (2011) suggest among other things, that tax rates affect gdp growth rate via factor productivity more then capital accumulation rates. Our work starts from these results to empirically study the relationships between capital accumulation rates, fiscal tax policy and growth dynamic.
One important problem is that saving rates dynamic and growth rate of percapita (or per worker) gdp could be endogenously determined since saving rates are highly likely to be correlated with country specific initial conditions (see among others Binder and Pesaran, 1999; Caselli, 2001). In the same line Alfó et al. (2008) show as initial conditions and saving rates are correlated and then the standard univariate augmented empirical model is biased.
Moreover Durlauf et al. (2005) emphasize that economic growth regressions are difficult to define since the model uncertainty is a problem which is only partially solved by nonlinear specifications (Kalaitzidakis, et al., 2000).
This means that OLS based estimates obtain coefficients relative to the tax policy or saving rates but it could mixing together different kinds of effects.
We have to disaggregate the direct effect of saving capitals rates on the per capita GDP (as predicted by Solowian models) from the effects of taxes through endogenous responses of savings and education.
For all of the above problems we estimate the relation between tax policies, capitals saving rates and economic growth using a finite mixture model. It assumes that countries differences are captured by some latent structures both in country specific socio-political environments and human and physical capitals formation (Lindsay, 1983a and 1983b; Alfó et al., 2008; Duraluf, 2012), allowing for parameters correlations.
In particular, we assume that the production function is different for different countries and we model this source of heterogeneity by finite mixture in a Solow augmented specification, in this way we can obtain varying specific country physical and human capital rates.
To better clarify if tax policy jointly impacts country capitals accumulation and growth, we specify an empirical functional form for the country parameters allowing for the endogeneity arising from country specific links between fiscal policy regimes, capitals accumulation and growth rates.
A secondary product of our mixed random coefficients model (estimated according a finite mixture) is that identifies subgroups of countries with homogeneous production functions (countries in each cluster have the same capitals coefficients and the same tax policy effects on saving and growth rates).
From a statistical point of view, the estimated model, when compared to a panel fixed effect approach, has the advantage of restricting the individual effects to a small discrete set of possible values and of accommodating extreme and/or strongly asymmetric departures from the normality assumptions of most parametric estimators (Lindsay, 1983a, 1983b, Lindsay and Lesperance, 1995, MacLachlan and Peel, 2000, Alfó and Trovato, 2004) since parameters are completely free to vary over the corresponding density functions. Our main findings show that, once heterogeneity is taken into account, countries show different growth paths driving to different steady states. Moreover, once the model has been conditioned to the tax policy, we show that such variables affects asymmetrically the growth dynamics of different groups of countries. These results are consistent with theoretical growth models with multiple equilibria (see among others Azariadis and Drazen, 1990).

The paper is divided in d sections. The second .....

2 Empirical model

At least three serious problems are generally identified in growth empiric literature: departures from normality, misspecification of the production function and the restrictive assumption of among countries homogeneity in the effect of inputs on per capita GDP (see among others Zelli, 2011, Di Vaio, 2011, Pittau et al. 2010, Owen et al, 2009, Alfó et al., 2008, Bianchi, 1997; Bloom, et al., 2003; Brock and Durlauf, 2000; Desdoigts, 1999; Durlauf, 2001a; Durlauf et al., 2001; Durlauf and Johnson, 1995;

Kalaitzidakis et al., 2001; Liu and Stengos, 1999; Masanjala and Papageorgiou, 2004; Paap and Van Dijk, 1998; Paap et al., 2005 and Quah, 1996 and 1997).
Valuable approaches which try to address thes problems - and are closer to our own - are those of Paap et al. (2005), Mamuneas et al. (2006), Alfó et al. (2008) and Tsionas and Kumbakhar (2004), as well as those based on threshold models (see, among others, Kalaitzidakis et al., 2001; Liu and Stengos, 1999; Masanjala and Papageorgiou, 2004). All of them conclude that estimations' results could be biased if these sources of heterogeneity are not included in the empirical specification. In the literature on convergence, among others, Goetz and Hu (1996) argue that the convergence results based on standard empirical models are biased since physical and human capital accumulations are endogenous on per capita (or per worker) income. On the same line Cohen (1996) shows a feedback effect between human capital and income level.

We define our empirical specification following Mankiw, Romer and Weil (1992), in which the expected values of the empirical growth specification can be described by the standard log-linear function of the specific workers stocks of human and physical capitals. The corresponding canonical parameters are modeled in the balanced growth path as follows

$$\begin{aligned} \ln(y_{it}) &= \ln(A) + g + \frac{\alpha_K}{(1-\alpha_K-\alpha_H)} \ln\left[\frac{sk^*_{i,t}}{(n_i+g+\delta)}\right] + \\ &+ \frac{\alpha_H}{(1-\alpha_K-\alpha_H)} \ln\left[\frac{sh^*_{i,t}}{(n_i+g+\delta)}\right] + \varepsilon_{it} \end{aligned} \tag{1}$$

where $\alpha_K, \alpha_H \in (0,1)$ represent the shares of physical and human capital, respectively; $\ln(y_{i,t})$ is the log of output per worker, A captures the labor augmenting component, $sk^*_{i,t}$ and $sh^*_{i,t}$ are the observed fractions of income invested in physical and human capital, respectively, and $(n_i+g+\delta)$ is the sum of population growth, rate of technological progress and capital depreciation.
In other words equation (1) tells us that the steady state value of GDP per effective labor depends on the shares of capital inputs, on the growth of labor force and on the depreciation rate. In the following for each time $t = 1, \dots, T$ and country $i = 1, \dots, I$, the rate of growth of per capita income $\gamma_{i,t} = t^{-1}(ln(y_{i,t}) - ln(y_{i,0}))$ is a realization of a data generation process depending on the specific variables defined in a solowian type model. Following MRW, Durlauf et al. (2004) show that, from function in (1), is possible to obtain the following estimable equation for growth dynamic once defining the specification $ln(A_{i,t}) = ln(A_0) + \varepsilon_i$ for the unobservable technological progress[1] and subtracting from both side of the balanced the initial income $ln(y_{i,0})$ and taking logs

$$\begin{aligned} \gamma_{it} &= \beta ln(A_0) - \beta \left[\frac{\alpha_K}{1-\alpha_K-\alpha_H} \ln(sk^*)_{i,t} + \right. \\ &\left. + \frac{\alpha_H}{1-\alpha_K-\alpha_H} \ln(sh^*)_{i,t} - \frac{\alpha_K+\alpha_H}{1-\alpha_K-\alpha_H} \ln(gd)_{i,t} - ln(y_{i,0})\right] + \varepsilon_{it} \end{aligned} \tag{2}$$

where $\beta = -t^{-1}(1-e^{-\lambda_i t})$ (with $\lambda_i > 0$) measures the convergence rate of the output per labor force to its steady state value[2]. We rewrite the equation 2 in compact form

$$E(\gamma_{it}|\mathbf{x}_i, \varepsilon_i) = \alpha + \beta_0 \ln(y_{i,0}) + \mathbf{x}_i^{\top}\boldsymbol{\beta} \tag{3}$$

[1]MRW stress that $ln(A_{it})$ reflects not only the technological progress but also all the "not directly" estimable country specific conditions as like as climate or institutions or resources endowments. MRW assume that these differences vary across countries following the relationship: $ln(A_{i,t}) = ln(A_0) + \upsilon_i$ in which the random term ε_i is normally distributed and independent from the n_i, $s_{K,i}$ and $s_{H,i}$ distributions, with $ln(A_0)$ being constant across time periods and countries

[2]Assuming that $\lambda_i = \lambda$, $\forall i$ we derive that the steady-state value for ouput/labor ratio is

$$y^E_{i,t} = \left[\frac{s^{\alpha_K}_{K,i} s^{\alpha_H}_{H,i}}{(n_i+g+\delta)^{(\alpha_K+\alpha_H)}}\right]^{\left[\frac{1}{1-\alpha_K-\alpha_H}\right]}$$

In other words the equation above says us that the steady state value of gdp per effective labor depends on the shares of capital inputs, the growth of labor force and on the depreciation rate.

where $\alpha = \ln(A)$ is the intercept measuring innovation and $\mathbf{x}_i = [\ln(sk^*)_{i,t}, \ln(sh^*)_{i,t}, \ln(gd)_{i,t}]$ denotes the matrix design for the "observed" solowian type variables. The empirical strategy, followed after Barro, to test effects of taxes on growth is to added a matrix Δ to the equation 3 obtaining

$$E(\gamma_{it}|\mathbf{x_i}, \varepsilon_\mathbf{i}) = \alpha + \beta_\mathbf{0} \ln(\mathbf{y_{i,0}}) + \mathbf{x_i}^\mathsf{T} \beta + \boldsymbol{\Delta}_\mathbf{i}^\mathsf{T} \delta \tag{4}$$

where the matrix Δ_i could contain different things: some measures for countries taxes structure, geographical environment, government size, political status or other measures as like as foreign direct investments or migration flows. Also assuming that variables in $\boldsymbol{\Delta}$ do not violate the exchangeability assumptions of OLS[3], the problem, in the above empirical model, is that $\boldsymbol{\Delta}$ and $\mathbf{x}$ could be correlated or endogenous to the initial conditions measured by the lagged level of per capita gdp ($\ln(y_{i,0})$).
Stressing just on taxes effects, one of the most critical points is that tax levels affect the individual saving decision process and then, via investments, the aggregated levels of capitals saving rates, both human and physical ones. Moreover changes in the aggregated levels of capital saving rates determine the gdp growth rate defining country tax revenues; if that is true, capital saving rates could be determined by some linear combination of tax policy measures. From a statistical point of view, this "hidden" relationship implies that, OLS estimated βs are still unbiased but their standard errors are not. This means that estimated significance of $\hat{\delta}$s and $\hat{\beta}$s in equation 4 could conduct to erroneous economic policies.
Furthermore, $\ln(y_{i,0})$ is the measure of the per capita gdp and it is wide interpreted as proxy for the steady-state value of the output per efficiency labor input, its parameter β give us the measure of the convergence rate of the output per labor force to its steady state value. In this aspect initial condition of gdp could be determined by some country characteristics captured by the intercept or by both the solowian model covariates and the fiscal measures in $\boldsymbol{\Delta}$. According to Durlauf et al (2005) saving rates can be correlated with initial conditions. For a similar reason, according to Goetz and Hu (1996), convergence results based on equation (4) may be biased since physical and human capital accumulations may depend on income per capita (or per worker). From the perspective of model formulation, Durlauf et al. (2005) stress that Barro-type regressions may be difficult to estimate since uncertainty upon the adopted model structure is a substantial problem, which can be only partially solved by means of nonlinear model specifications (as in Kalaitzidakis, et al., 2000). Results stress that cross-sectional tests on convergence may be inflated by collinearity and, since initial per capita gdp is closely related to capital saving rates, additional covariates effects may be ill-estimated.
To avoid these biases two different approaches could be followed to study the effects of changes in tax policy to gdp growth. The first possibility is that one could isolate some country-specific changes in the progressivity of the tax structure, proving that they are exogenous to capitals investment decisions, then trying to establish their effects on gdp.
Alternatively, one might draw directly on micro or macro evidence about the responsiveness of capitals saving rates to the growth rates, then using such evidence to draw lessons about the likely response to tax policies altering growth rate dynamic.
The problem is that both approaches require that the tax structure and saving rate have to be empirically independent. We instead start with the idea that investment decisions are endogenous to the tax structure, and we point out the implications for OLS growth regressions. In other words, we explicitly consider endogeneity and multicorrelation among regressors using semi parametric approach to estimate the impact of the tax structure.
Aitkin and Rocci (2003) stressed that a source of endogeneity is due to the measurement error bias and it could be treated inside the finite mixture approach. Since finite mixture can address for error-in-variable (or endogenous bias) we can avoid problems as like as those boosted by Hall and Jones to schooling coefficients correction for example.
As stressed by Durlauf et al. (2004) and Alfó at al. (2008) the problem is that human and physical saving rates are themselves endogenously determined, at least, by the initial conditions measured in growth model by initial per capita gdp level. This is why we handle unobserved heterogeneity directly

[3]See Brock and Durlauf (2001) on the violation of the exchangeability assumptions of OLS residuals due to omitted regressors and parameter heterogeneity.

inside the data generation process. Moreover, strictly speaking, we want to test if the relationships between saving rates and tax policy could affect growth rates dynamic. To that as before specified, to understand empirically how fiscal policy can affect growth, we have to disaggregate their direct effects on gdp per capita from the indirect effects on saving capitals rates. Then the above empirical specification have to be modified to allow for the dependence among fiscal policy indicators and capital stocks. The empirical literature widely converges on the results that human or physical capital investment shares are difficult to measure without errors (among others see Cohen and Soto, ...) and it proposes some measures of capital saving rates. We follow the literature on errors-in-variables to define an empirical model in which we assume that what we observe as capital shares is a realization of a process involving the country-specific fiscal policy.

In other words, we assume that the endogeneity bias between saving capital rates and tax policy could be resolved hypothesizing that covariates $\ln(sk^*)$ and $\ln(sh^*)$ are measured with error, and their "true" values ($[\ln(sk), \ln(sh)]$) (unobservable or "latent") depends on country specific fiscal policy[4]. To simplify the notation we put in the matrix $\mathbf{w}_i^\mathsf{T}$ the observed measures of the "true" covariates, in $\mathbf{z}_i^\mathsf{T}$ the unobserved "true" covariates and in matrix $\mathbf{f}_i^\mathsf{T}$ the variables designing the fiscal policy[5]. The expected per capita rate of growth γ conditioned to the model variables can be written as

$$\begin{aligned} E(\gamma_{it}|w_{it}, z_{it}, f_{it}) &= \alpha + \mathbf{f}_i^\mathsf{T}\phi + \mathbf{w}_i^\mathsf{T}\zeta && (5) \\ E(w_{it}|z_{it}, f_{it}) &= \mathbf{z}_i^\mathsf{T} && (6) \\ E(z_{it}|f_{it}) &= \mathbf{f}_i^\mathsf{T}\delta && (7) \end{aligned}$$

The measurement errors in equation 6 are independently normally distributed with zero mean and constant measurement error variance σ_w and are independent of the true covariate $\mathbf{z}_i^\mathsf{T}$. This implies that the measurements are conditionally independent given the true covariates. From that derive that substituting 7 in equation 5 we obtain the reduced form of the expected rate of per capita gdp

$$E(\gamma_{it}|w_{it}, z_{it}, f_{it}) = \alpha + \mathbf{f}_i^\mathsf{T}[\phi + \delta\zeta] \tag{8}$$

We see that the covariates in $\mathbf{f}_i^\mathsf{T}$ have an indirect effect on the per capita rate of growth of gdp via the coefficient $\delta\zeta$ mediated by the "true" covariates in addition to the direct effect ϕ. The total effect is simply the sum of these effects. The equation for the "measurement" model will be

$$E(w_{it}|z_{it}, f_{it}) = \mathbf{f}_i^\mathsf{T}\delta \tag{9}$$

From that derive that the joint marginal distribution $f_\gamma(\gamma, w|\Theta)$ of the observed γ and $\mathbf{w}$ given $\mathbf{z}$ and $\mathbf{f}$ and all the parameters $\Theta = (\alpha, \phi, \zeta, \delta, \sigma, \sigma_w, \sigma_f)$ is given by

$$f_\gamma(\gamma, w|\Theta) = \int F(\gamma|w, z, \Theta) m(w|f, \Theta) \vartheta(f|\Theta) df \tag{10}$$

where F is the density of the model for γ, m the density of the model for endogenous covariates and ϑ is that for the fiscal policy. The marginal density f_γ is a mixture over the fiscal variables in $\mathbf{f}$ with respect to its marginal density ϑ. As to be noted here that now the model has variables that ar endogenously determined since regressors in z_i are correlated with the composed error vector producing downward biased estimated parameters (see among others Griliches and Hausman, 1986, Davidson and Mckinnon, 1993). Moreover the model in system 5 cannot be estimate, at least parametrically. If we assume, indeed, a normal distribution for the "true", but unobserved, capital shares the model is not identified and we need to know exactly the variance of the true-measure or of the measurement errors (Aitkin and Rocci, 2002).

[4] Moreover we employ Davidson and MacKinnon test for exogeneity of fiscal policy instruments on capitals shares. As better specified in the results's section, tax policies measured by tax revenues over gdp, income and corporate taxes seem to be exogenously determined looking at capital shares.

[5] In the above notation we exclude, to simplify, the other standard variables in the solowian models i.e. lagged per capita gdp level and growth population rate. Those covariates will be supposed not to be an heterogeneity source and they will be included in the empirical application.

The problem then is to estimate a linear model for the response variable $\gamma_{i,t}$ in which some covariates are endogeneously determined.
For that following Aitkin *et al.*, (2005) and Aitkin and Rocci, (2002) we consider the "true" measures for capital shares as omitted variables, and we propose to estimate their effects on growth by Generalized Linear Models adopting a semi-parametric technique based on finite mixture models, relaxing the assumption of *i.i.d.* residuals.

As evidenced before, failure of the adopted model is handled by using omitted variables (for a detailed discussion of this topic see Aitkin *et al.*, 2005). Instead of assuming a normal distribution for the true covariates $[\ln(sk)_{i,t}, \ln(sh)_{i,t}]$, or for the residuals, we leave those distributions unspecified. The nonparametric maximum likelihood estimator (NPMLE) of the distribution is discrete (Laird 1978; Heckman and Singer 1984) with at a finite number of locations and masses. In other words the error terms, with an unknown distributions, are the latent variables representing the difference between country i-th's measure for capitals stocks and the mean of $[\ln(sk)_{i,t}, \ln(sh)_{i,t}]$. The number of masses is determined to achieve the largest possible likelihood. Attempts to estimate the model with $k+1$ masses would result either in one mass having an estimated probability approaching zero or two masses nearly sharing the same estimated location. In this respect, the joint effect of the tax policy variables can be summarized by a set of those variables to the linear predictor. Let u_i for $i = 1, \ldots, n$ denote this set of subject and outcome-specific random coefficients[6]. The hypothesis is that γ_{it}'s represent conditionally independent realization of the potential growth of the output per capita $\mathbf{\Gamma_{it}}$, given this set of random factors, which vary over countries and account for both individual variation and dependence among country specific rate of growth.

Treating the u_i's as nuisance parameters and integrating them out, we obtain for the likelihood function the following expression

$$L(\cdot) = \prod_{i=1}^{n} \prod_{t=1}^{T} \left\{ \int_{\mathcal{U}} F(\gamma|w, z, \Theta) m(w|f, \Theta) \vartheta(f|\Theta) \mathrm{d}G(u) \right\} \tag{11}$$

where $\mathcal{U}$ represents the support for $G(u)$, the distribution function of u_i; and where we assume conditionally independence among outcomes.

According to the likelihood function in 11, the log-likelihood for the model in equation 8 will be:

$$l(\cdot) = \sum_{t=1}^{T} \left\{ \begin{array}{l} -\frac{1}{2}\log(2\pi) - \log(\sigma) - \frac{1}{2\sigma^2}\left[\gamma_{it} - \alpha_i - \mathbf{f}_i^{\mathsf{T}} \phi^\star\right]^2 + \\ \\ -\frac{1}{2}\log(2\pi) - \log(\sigma_{u_w}) - \frac{1}{2\sigma_{u_w}^2}\left[w_{i,t} - \mathbf{z}_i^{\mathsf{T}} - \mathbf{f}_i^{\mathsf{T}} \delta\right]^2 + \\ \\ -\frac{1}{2}\log(2\pi) - \log(\sigma_{u_z}) - \frac{1}{2\sigma_{u_z}^2}\left[\mathbf{z}_i^{\mathsf{T}} - u_z\right]^2 \end{array} \right\} \tag{12}$$

where for simplicity we define $\phi^\star = \phi + \delta\zeta$.

In other words both the us and the $\mathbf{z}_i^{\mathsf{T}}$ appear as missing data in the complete data log-likelihood and they have been estimated follow EM algorithm (Dempster, Laird and Rubin 1977)[7].

In practice, recalling the literature of LISREL models or latent multivariate structural equation models we assume that the latent part in $\mathbf{w}_{ij}$, for $j = 1, 2$ with $j = 1 \Rightarrow w_{i1} = \ln(sh)_{i,t}$ and with $j = 2 \Rightarrow w_{i2} = \ln(sk)_{i,t}$, can be structurally modeled as:

$$u_s = \mathbf{r}_s^{\mathsf{T}} \lambda + \xi_s \tag{13}$$

where: the matrix $\mathbf{r}$ has a matrix of ones in the first column, so that both the models for the "true" measures ($\ln(sh^*)_{i,t}$ and $\ln(sk^*)_{i,t}$) and the model for growth contain an intercept, the following columns include all the variables that we assume to have an impact on the random terms of the model (i.e. the explicative variables in $\mathbf{z}$), and $\xi \sim N(0, \tau^2)$ is a error term. This model is obtained from the well known maximum likelihood estimation of the covariate measurement errors by the

[6]The tax variables are here considered as unobserved factors underlying the data generation process of the per capita gdp growth

[7]For the computational details see Rabe-Hesketh et al. 2001, Aitkin and Rocci, 2002 and Alfó et al. 2008

finite mixture approach with EM algorithm (see Skrondal and Rabe-Hesketh, 2007, Rabe-Hesketh et al. 2001 and Aitkin and Rocci, 2002). The side result of mixture models is the classification of units in clusters with homogeneous unobserved characteristics, based on the the posterior probability estimates $\widehat{\pi}_{ik}$[8]. According to a simple mapping rule, in fact, the i-th country can be classified in the l-th component if $\widehat{\pi}_{il} = \max(\widehat{\pi}_{i1}, \ldots, \widehat{\pi}_{iK})$. It is worth noticing that each component is characterized by homogeneous values of the estimated latent effects, i.e. conditionally on the observed covariates, countries from that group show a similar structure, at least in the steady state. It has to be noted that this kind of classification is possible only if country heterogeneity exist. Secondly, since locations and corresponding probabilities are completely free to vary over the corresponding supports, the proposed approach can readily accommodate extreme and/or strongly asymmetric departures from the normality assumptions of parametric approaches. We use EM algorithm to obtain maximum likelihood estimation of model parameters in the semiparametric approaches to multivariate data modelling discussed before. The univariate algorithm is well known (see among others Aitkin, 1996, Wang et al., 1996), while for the multivariate one we remand to Alfó and Trovato (2004). Penalized likelihood criteria (such as AIC, CAIC or BIC) have been used to choose the exact number of mixture components.

3 Data description and results

The model above empirically specifies that if taxes are distortionary then they at least affect the subset of unobserved latent variables underlying the true measures of capital shares. Further, as recalled above, a bias is introduced adding tax rates (or taxation shares over total tax revenues) to measure the distinct impact of different tax policies on growth, given levels of capital accumulation rates.

We perform then our empirical tests estimating before the following Barro-type model

$$\boldsymbol{\gamma_{i,t} = \alpha + \beta_0 \ln(y_{i,0}) + \beta_1 \ln(sh)_{i,t} + \beta_2 \ln(sk)_{i,t} + \beta_3 \ln(gd)_{i,t} + \delta^{\mathsf{T}} \Delta_i \epsilon_{i,t}} \tag{15}$$

where we specify in the matrix Δ_i the fiscal variables. In particular we follow (among others) the approach of Arnold (2008), Gemmel et al 2011, Kneller et al. (1999) and Lee and Gordon (2005) and split the taxation policy in different measures: : (i) income personal tax $income_{it}$; (ii) property taxes $property_{it}$ and total revenues (iii), all measures derive from OECD data and we show their descriptive and definitions in table 1.

table 1 about here

table 2 about here

In the table at least descriptively the relationship between fiscal policy variables and gpd growth rate seems to be not so clearly evidenced in the sample. The pairwise correlation among five year gdp growth rates and tax revenues is only 0.0448 and is not significance with $p - values = 0.221$. On the same line the correlations for income tax share ($\rho = -0.0421$ with $p - value = 0.2539$), while quite surprisingly corporate and gdp growth are positively related ($\rho = 0.1713$, $p - value = 0.000$). But looking at table 2 we can see that correlations change among countries in both magnitude and significance. This fact could be due to the different fiscal channel transmission mechanism or could

[8]Just simplify the notation, in the case of univariate model for finite mixture model the $\widehat{\pi}_{ik}$ represents the posterior probability that the $i - th$ unit comes from the $k - th$ component of the mixture

$$\frac{\partial \log[L(\boldsymbol{\delta})]}{\partial \boldsymbol{\delta}} = \frac{\partial \ell(\boldsymbol{\delta})}{\partial \boldsymbol{\delta}} = \sum_{i=1}^{n} \sum_{k=1}^{K} \left(\frac{\pi_k f_{ik}}{\sum\limits_{k=1}^{K} \pi_k f_{ik}} \right) \frac{\partial \log f_{ik}}{\partial \boldsymbol{\delta}} = \sum_{i=1}^{n} \sum_{k=1}^{K} \widehat{\pi}_{ik} \frac{\partial \log f_{ik}}{\partial \boldsymbol{\delta}} \tag{14}$$

where $\delta = \alpha_i, \beta_i, u_i, u_i^{sh}, u_i^{sk}, \sigma, \sigma_{ush}, \sigma_{usk}, \sum_p \psi_p$, represents the complete vector of the estimated parameter be due to different country specific individual preferences, in any cases empirical models should have to face with these variability in the sample. That week relationship between tax revenues and gdo growth rates is confirmed also by looking at Figure 5 in which we plot the gdp growth rates and the tax revenues over gdp for the all considered years.

table 5 about here

To test these puzzling descriptive results, we employ several strategies. In the first steps we apply to the sample the equation 15 using both Feasible GLS and OLS FE to give some parametric benchmarks to the mixture model results. In a specific way, as suggested by Arndol et al. (2011), we take into account the revenue-neutral tax changes by always omitting some elements of the tax mix in each regression. The tax structure indicators we used are both the statuary top tax rates and the revenues over gdp shares.
Moreover we use 5 years average values of variables, as usual in economic growth econometrics to limit business cycle biases and we limit the analysis of parametric model only on personal income and corporate taxation to sake of space.
In table we can see that the estimated parameters for the fiscal variables are partially in line with what obtained from the previous literature for the analysis on per capita gdp growth dynamic: the magnitude and sign are negative for total tax revenues (the control variable) and for corporate taxation, while the personal income seems to be positively related to the per capita gdp dynamic in time. Moreover the estimated models suffer both of endogenity since the Davidson-MacKinnon test reports a P-value of $2.1e-11$ for the assumption of exogeneity.

table 5 about here

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Moreover also if the Hausman test says us that simultaneous equation bias derived from the endogeneity between the error term and the lagged dependent variable is minimal in our sample, it is well known that this kind of models while they consider both heterogeneity and non-stationary they do not take into account for spacial correlation and dependence among units (see for example Baltagi et al 2000 for a discussion on pooled regressions). Moreover to check results we employ also the feasible general least square (FGLS) as suggested among others by Kmenta (1986) and Alfó et al (2004), the FGLS results in table 5 show that the coefficients on the tax structure variables are substantially reduced in magnitude, this reduction of magnitude is a clear sign of some error-in-variable and multicorrelation bias in PMG model partially adjusted by FGLS.

The DFE model seems to be not able to capture properly the unobserved heterogeneity and the error-in-variable bias, indeed also if the results are in line with the previous literature (the fiscal policy affects negatively the per worker growth rate) looking at figure 2 we can see that the DFE model is not well specified: the estimated per worker rate of growth does not follow the observed values while the estimated residuals are not distributed according the normal distribution.
For that we apply mixture models with covariate measurement error allowing for unobserved heterogeneity and for endogeneity bias. We estimate our model allowing for the capitals accumulation parameters to depend directly to the tax structure, imposing a random structure over our capital accumulation and tax revenues parameters. These random structures are considered in t he estimation process as correlated allow us to detect for endogenity and multi-correlation bias (see among others Rabe-Hesketh et al. 2001, Aitkin and Rocci, 2002). Moreover the data for the tax are 5 years lagged.

The estimated model according finite mixture is

$$\gamma_{i,t} = \alpha_i + \beta_{i,0} \ln(y_{0,i}) + \beta_{i,1} \ln(sk)_{i,t} + \beta_{i,2} \ln(scho)_{i,t} + \beta_3 \ln ng_{i,t} + \varepsilon_{\gamma,i} \tag{16}$$

Using mixture we can estimate the distortions brought by taxation on the accumulation of capital (this is the kind of distortion embedded into equation 5) via the magnitude of the parameters in equation 16. The specification above allow for the intercept term $\hat{\alpha}_i = \hat{\alpha}_{OLS} + u_i^{\alpha}$ to vary across countries and to capture country specific effects trough outcome-specific random terms u_i^{α}, $i = 1, \ldots, n$.

In this context the random component in $\hat{\alpha}_i$ represent mean zero deviations from the fixed and homogeneous part of the estimated intercept (i.e. α_{OLS}). Strictly speaking, subject related random terms u_i^{α} capture the subject variability part of the estimated dynamic of the "technological" factor in the solowian type models of growth and it ahs been estimated free, i.e.: without imposing any model to explain the variability among countries of this "technological" factor. The parameter for convergence has been estimated fixed together with the population growth.
Moreover the random coefficient $\beta_i = \beta_2 + u_i^{sh}$, $\beta_{i3} = \beta_3 + u_i^{sk}$ and $\beta_{i4} = \beta_4 + u_i^{taxrev}$ are the adjusted estimated parameters in which the latent terms u_i^{sh}, u_i^{sk} and u_i^{taxrev} capture the measurement errors[9]. In other words all the us appear as missing data in the complete data log-likelihood and they have been estimated follow EM algorithm (Dempster, Laird and Rubin 1977)[10] Recalling equation 13 we assume that the u_is in the equation 16 depend from[11].

$$\begin{aligned} u_i^{sk} &= \lambda_0^{sk} \ln(sk)_{i,t-1} + \lambda_1^{sk} corptax_{it} \\ u_i^{sh} &= \lambda_0^{sh} \ln(sh)_{i,t-1} + \lambda_2^{sh} income_{i,t-5} \end{aligned} \tag{17}$$

while the random term for $taxrev_{it}$ and for α are free to vary over individuals without imposing any function. We make this choice to disangle the income tax to corporate tax and we assume that the former affects human capital while the second is linked with physical capital in this way we should have not confusion on which tax affects what. To obtain the results in table 4 we before running the mixture only with the augmented Solow model variables and in the second steps we use these values as starting point of the final regression presented in the table. In this way we control the parameters for the strictly augmented solowian model and we can see what happen when inserting the fiscal variables. We can see in table 6 that tax revenues affect negatively per worker gdp and personal income tax affects negatively the rate of accumulation of the human capital confirming what the theory predicts. On the rate of physical capital we can see that taxation on corporate affects it.
Moreover looking at table 7 we can observe some of interesting. The variance and covariances of the random part of the revenues tax (u^{tax}) is negligible indicating that there is not so unobserved heterogeneity on effects of tax revenues among more industrialized OECD countries, while the correlations between the "unobserved" human capital parameter and that of the intercept is bigger and positive and also the respective variances. On this respect we can assume that the link between human capital and technological improvements (or technological efficiency) exists. The correlation between the two random parts of the physical and human capital is not high and it approaches to zero. Moreover also the variance for the u^{sk} is near to zero.
From that we can conclude our analyis confirming the negative overall country effect of taxation on gdp growth but taxation has different effects (magnitude, sign and significance) among countries. Moreover once we correct for the unobserved heterogeneity and for measurement error we can observe the country classification. Moreover looking at table 8 we can see that the mixture identify two different clusters of countries each of them with a proper random parameter. The first groups of countries have a negative effects on per worker gpd of the random part of intercept, human capital and revenues tax, while is positive that for physical capital. Counties in the second group show a different environment ($\hat{u}^{sh} = 0.93$ and $\hat{u}^{\alpha} = 0.79$, while they show no effect for tax revenues and negative effect for physical capital. Maybe this countries have built their fortune on human capital accumulation more then physical investments.
A secondary products of mixture is to classify units in homogeneous clusters in which unit share the same random effects to analyze in deep which country is in which cluster. As before stressed the i-th country can be classified in the l-th group if $\widehat{w}_{il} = \max(\widehat{w}_{i1}, \ldots, \widehat{w}_{iK})$, i.e. that country maximizes the posterior probability to belong to that cluster. It is worth noticing that each component is characterized by homogeneous values of the estimated latent effects, i.e. conditionally on the observed covariates, countries from that group show a similar structure, at least in the steady state (see table

[9] As to be noted that the estimation process allows for **correlated** random terms

[10] For the computational details see Rabe-Hesketh et al. 2001, Aitkin and Rocci, 2002 and Alfó et al. 2008

[11] for the complete definition of the taxation variables used see $http\ :\ //www.oecd.org/ctp/tax - policy/revenuestatisticstaxratioschangesbetween2007and2011.htm$.

9). Countries in cluster 1 are the more historically old industrialized countries with some exceptions of Greece while in the second group we have countries as like as Japan or Netherlands with an higher propensity to innovations, moreover we find both Australia and New Zealand sharing similar socio and geographical environment .
To conclude the analysis we can look at figures 3 and 4 that our model fit very well the data.

4 conclusion

Summarizing in the present paper, we have estimate the equation for growth allowing for heterogeneity in the capital savings measures (physical and human capitals rates) and in the intercept, to account for possible unobserved heterogeneity in each country's taxation process. In the finite mixture model we assume that the random effects for intercept capture country specific institutional features that are common to all countries, while the random effect for the capital rates are affected by countries specific tax policy characteristics such as personal income or corporate taxes structures.We find that these taxes affects not homogenously the different countries in the sample also if the effect of taxation on physical capital is, in average, bigger then on human capital.

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5 tables and Figures

Table 1: Descriptive countries statistics for fiscal policy, Sample period 1975-2009

country	gw100	taxrev	income	prope	consum	corp	govfincons	housficons
Australia	2.38	28.91	13.02	2.59	8.12	5.15	75.08	57.57
Austria	1.51	40.85	25.07	0.87	12.43	1.67	75.26	56.39
Belgium	1.48	43.59	14.29	1.72	11.22	2.53	77.47	55.05
Canada	0.94	33.88	17.27	3.39	9.50	3.11	76.97	55.84
Denmark	1.48	46.05	25.27	1.98	15.62	2.31	77.26	51.29
Finland	2.03	42.40	25.31	1.05	13.58	2.35	73.75	52.41
France	1.50	42.11	23.85	2.70	11.77	2.29	79.84	57.19
Germany	1.66	36.68	19.38	0.86	10.37	1.41	77.48	58.34
Greece	1.64	27.74	12.80	1.52	11.20	1.80	85.30	68.96
Ireland	2.50	32.16	14.38	1.74	13.25	2.36	73.13	54.39
Italy	1.53	37.75	21.77	1.63	10.07	3.11	77.60	58.78
Japan	1.91	26.45	14.56	2.63	4.47	4.73	71.24	55.69
Luxembourg	2.10	36.70	19.14	2.52	8.98	6.03	65.81	49.83
Netherlands	0.86	41.42	25.07	1.64	11.28	3.15	74.18	50.24
New Zealand	0.16	33.37	16.52	2.17	10.31	3.36	77.65	58.96
Norway	2.07	42.15	20.48	1.03	14.56	6.07	68.27	47.64
Spain	1.29	30.14	17.52	1.95	8.06	2.27	77.22	60.52
Sweden	1.90	48.52	30.78	1.42	12.73	2.88	75.32	48.64
Switzerland	0.40	27.81	16.57	2.41	6.11	2.30	71.05	59.75
United Kingdom	1.73	35.05	16.61	4.02	10.85	3.15	82.78	62.25
United States	1.61	27.22	16.00	3.12	4.78	2.54	84.81	68.94
Legend:	In the table are described the values for the fiscal policy variables. *gw*100 is the 5 years average values for the rate of growth of per capita gdp (percentage values in table). *income* measures personal income taxes and includes categories 1100, 2000 and 3000 of the OECD classification of taxes.							

Table 2: Countries Pairwise Correlation for GDP growth rates and fiscal policy, Sample period 1975-2009

country	taxrev	corpshare	incshare
Australia	0.642 ***	0.456 **	-0.241
Austria	-0.602 ***	-0.094	0.019
Belgium	-0.589 ***	0.073	0.220
Canada	-0.198	0.667 ***	-0.281
Denmark	0.174	0.107	-0.505 **
Finland	-0.212 ***	0.605	0.004
France	-0.615 ***	0.269	-0.214
Germany	0.108	0.138	0.684 ***
Greece	0.182	0.541 ***	0.077
Ireland	-0.361 *	0.684 ***	-0.199
Italy	-0.685 ***	0.205	-0.368 **
Japan	0.062	0.84 ***	0.810 ***
Luxembourg	-0.175	-0.342 **	-0.452 *
Netherlands	-0.166	0.442 ***	-0.021
New Zealand	0.193	0.591 ***	-0.557***
Norway	-0.235	-0.532 ***	0.579***
Portugal	-0.201 ***	0.509* *	0
Spain	0.185	0.416 *	-0.056
Sweden	0.294 *	0.4471186 **	-0.3051783 *
Switzerland	0.069	0.233	-0.277
United Kingdom	0.265	0.416 *	-0.204
United States	0.372 *	0.214	0.159
Total	0.64	0.84 ***	0.81 ***

Legend: In the table are reported the countries specific pairwise correlation of per capita gdp 5 years growth rates and the fiscal policy variables Tax revenues over GDP, corporate tax and personal income tax shares over tax revenues.

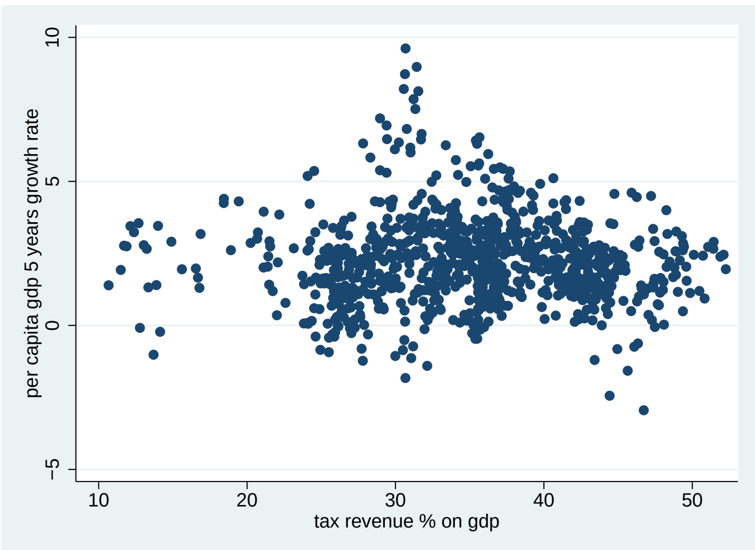

Figure 1: Scatter plot All sample countries

Table 3: Estimation results of FGLS and OLS FE models

Dept. Variable: gdp per capita 5 years growth averages				
Variable	Coefficient	Std. Err.	Coefficient	Std. Err.
log of per capita gdp level (5Y's L)	-4.260**	0.374	-1.878**	0.322
log of schooling enrolment	1.575**	0.514	2.164**	0.610
log of capital stock	2.350**	0.413	4.756**	0.475
log of working age popoluation growth	0.160	1.132	3.162**	0.885
tax revenues	-0.001	0.021	0.038	0.035
income tax	0.058*	0.027	-0.015	0.041
corporate	-0.007	0.043	0.082	0.064
Intercept	48.013**	4.313	36.509**	3.616

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

Table 4: Pooled Mean Estimator Results. 1970-2009

Variable	**Coefficient**	**(Std. Err.)**
Equation 1 : _ec		
log of schooling enrolment	0.469†	(0.262)
log of capital stock	1.170**	(0.261)
log of working age popoluation growth	-2.130**	(0.750)
tax revenues	0.018†	(0.009)
income tax	-0.077**	(0.012)
corporate	-0.069**	(0.017)
Intercept	10.556**	(1.716)

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

Table 5: Feasible general least squares results

Variable	**Coefficient** (Std. Err.)
lof of per worker gdp level(L)	-5.135** (0.428)
log of schooling enrolment	1.280** (0.454)
log of capital stock	2.171** (0.444)
log of working age popoluation growth	-2.441* (1.125)
Tax revenues %gdp	-0.015* (0.007)
Tax on personal income	0.020† (0.011)
Tax on corporate	0.029 (0.020)
Inflation, GDP deflator (annual %)	0.004 (0.010)
Intercept	55.009** (5.350)

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

Table 6: Finite Mixture Model with covariate error

Variable	**Coefficient**	(Std. Err.)
Equation for $(1/5)(lnyw_{i,t} - lnyw_{i,t-1}) * 100$		
log of per worker gdp level (L)	-1.41 **	-0.23
log of schooling enrolment	4.56 **	0.87
log of capital stock	7.35 **	0.91
log of working age pop. growth	-1.82 *	-0.83
Tax revenues %gdp	-0.08 **	-0.02
Intercept	26.32 **	3.05
Equation for random coef. of human capital		
log of schooling enrolment (L)	0.87 **	0.22
Δ personal income tax rate	-0.22	0.18
Equation for random coef. of physical capital		
log of capital stock (L)	1.34 **	0.31
Δ corporate tax rate	-0.20 **	0.04
Equation for random coef. of Tax revenues (%GDP)		
Δ Centr. Gov. Exp.	2.25E-03 **	0.00
Observations	684	
loglike	-1033.5373	

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%

Table 7: Variance and Covariance matrix for random coefficients.

	σ_u^{α}	σ_u^{sh}	σ_u^{sk}	σ_u^{taxrev}
σ_u^{α}	0.22	0.26	-0.02	1.18E-03
σ_u^{sh}		0.30	-0.02	1.38E-03
σ_u^{sk}			1.25E-03	-8.88E-05
σ_u^{taxrev}				6.33E-06

Table 8: Estimated Locations and Posterior Probabilities.

	Cluster 1	Cluster 2
$\hat{u}^{\alpha}$	0.79	-0.28
$\hat{u}^{sh}$	0.93	-0.32
$\hat{u}^{sk}$	-0.06	0.02
$\hat{u}^{taxrev}$	0.00	0.00
$\hat{pi}$	0.26	0.74

Table 9: Countries Classification

Cluster 1	Cluster 2
Austria	Australia
Belgium	Japan
Canada	Netherlands
Denmark	New Zealand
Finland	Spain
France	Switzerland
Germany	
Greece	
Ireland	
Italy	
Luxembourg	
Norway	
Sweden	
United Kingdom	
United States	

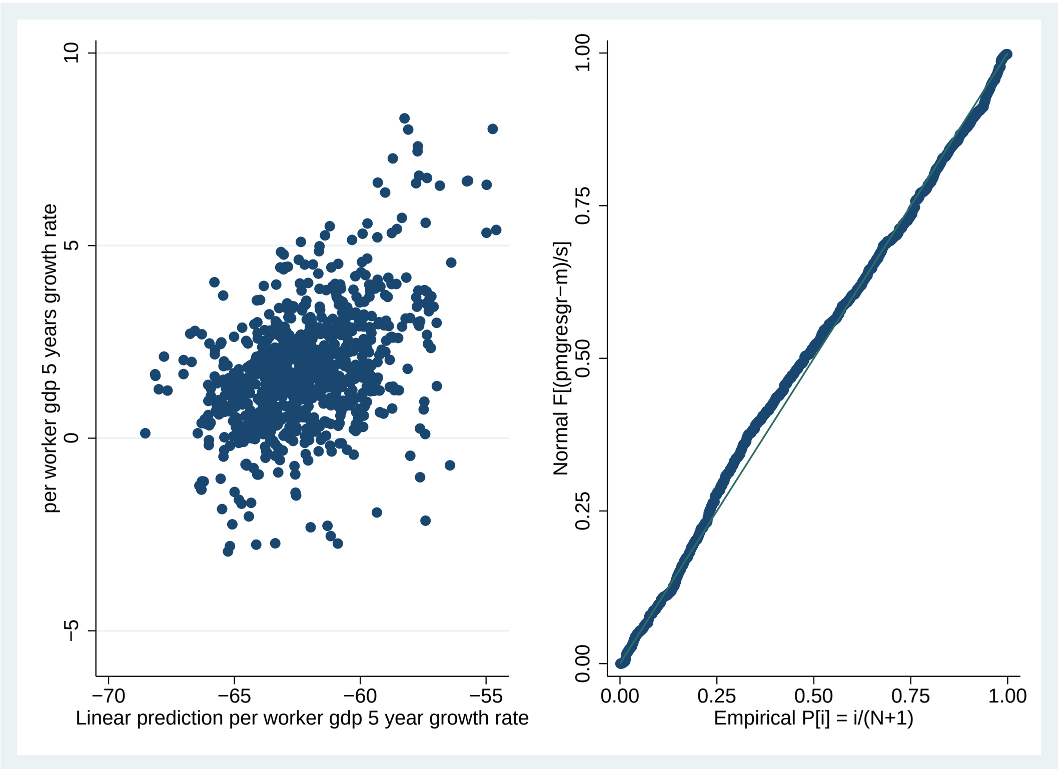

Figure 2: Goodness-of-fit PMG models

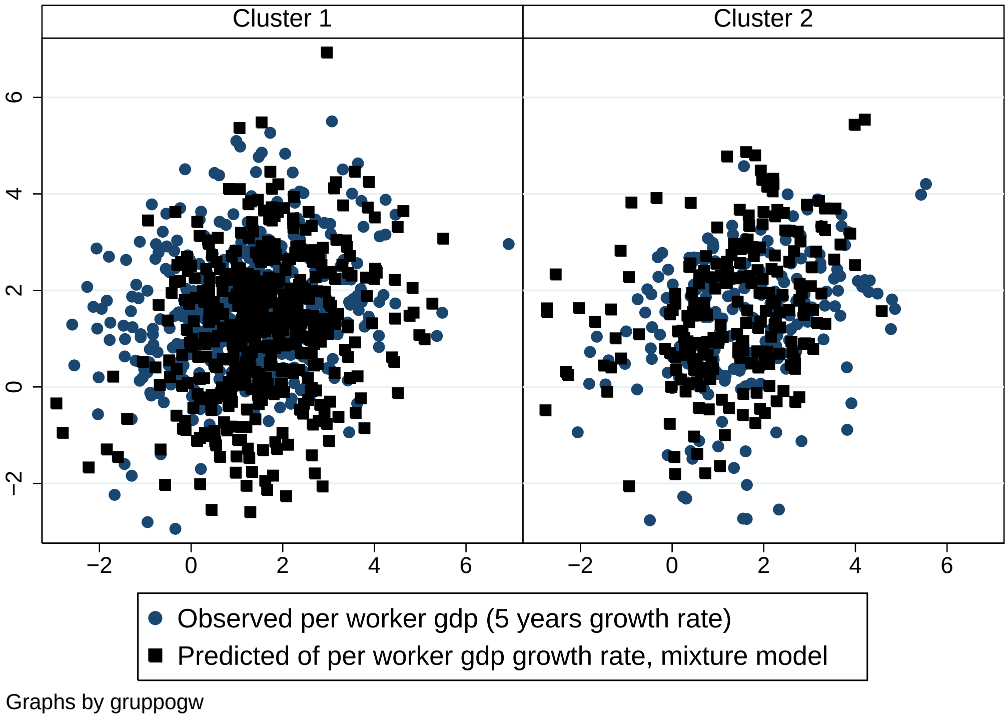

Figure 3: Goodness-of-fit Finite Mixture Model

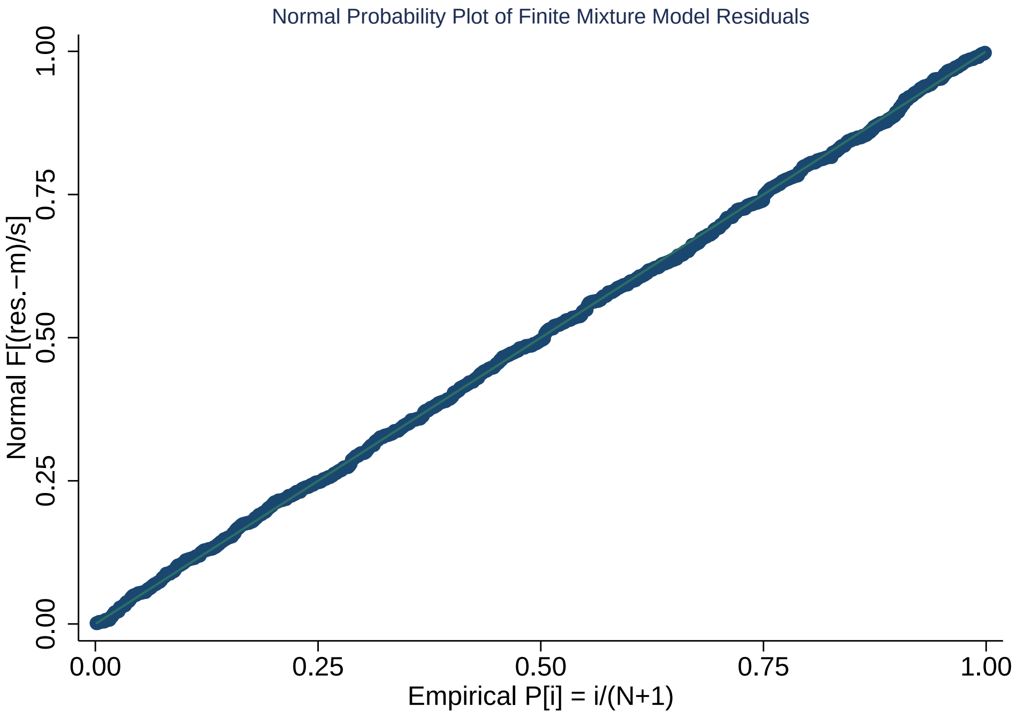

Figure 4: Normal Probability Plot of Finite Mixture Model Residuals