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**TAX BURDEN SHIFT IN EUROPEAN UNION: DOES TAX  
STRUCTURE HAVE IMPACT ON ECONOMIC GROWTH?**

Master's thesis

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Tartu, 2018

Name and signature of supervisor.....

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I have written this master's thesis independently. All viewpoints of other authors, literary sources and data from elsewhere used for writing this paper have been referenced.

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## **Abstract**

This paper estimates the effects of revenue-neutral tax structure changes on the long-run level of income per capita using panel data for 30 EU countries (+ Norway and Switzerland) over the period 1995-2016. While no tax “ranking” can be established using full data sample, in terms of their effect on economic growth, slightly different “ranking” can be established when model is applied to smaller data samples, divided between “new” and “old” EU countries. As oppose to previous studies, we found that for both “new” and “old” countries most “distortive” are private income taxes and social security contributions. Property taxes are associated with higher level of income per capita in the long-run only in “old” EU countries. Corporate income taxes correspond to positive long-run effect on income per capita in “old” EU countries, while in “new” EU countries these effects are not robust.

**JEL Classification: E62; H2; O47**

**Keywords:** economic growth, tax burden, fiscal policy

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## **1. Introduction**

Creation of country specific optimal tax structure has always been a major goal for every country at all times. This question becomes especially essential, after larger economic crises (eg. after 2008 Global economic crisis) or during periods of slow economic growth. Although, taxes in general are considered distortive in their effect on economic performance, during mentioned periods “shifts” towards least distortive taxes can help “boost” economic developments both in short and long run.

When countries consider tax system reforms, be that after crisis or during slow economic growth periods, or when simply looking at revenue increase from specific tax, it is always useful to identify effects of tax instruments on growth. It is worth mentioning, that negative effect on growth from certain tax instrument does not imply that government should restrain from changes in this instrument. It all comes down to what government wants to tax and what do they want to accomplish by altering specific tax instrument. Thus tax instrument not only serves as an income source for government but can help accomplish different government targets. Optimal tax instrument has to accomplish several tasks. There are four basic “cornerstones” which optimal tax instrument should follow and find optimal balance between: efficiency, equity, simplicity and optimal tax revenue. Thus not only general tax level, but combination between fairness in tax redistribution, simplicity in tax administration and efficiency in discouraging tax evasion and avoidance affects governments decisions about tax instrument changes. Based on that households decide whether to save or to take part in labor market, or to invest, similarly, firms decide whether to produce, thus creating demand for labor, or to invest in research and development, or to save. Thus tax instrument serves as a government tool to control for all these effects. While it is impossible to observe all these effects, we can look at more specific case where government is considering tax structure changes in order to increase economic growth while maintaining same level of tax revenue for public goods and services. Thus aim of this paper is to observe what are certain tax structure effects on economic growth.

One of the most widely discussed issues remains on premise that direct taxes are more distortionary than indirect taxes<sup>1</sup>. While this topic is researched extensively, both theoretically and empirically, conclusions over one's superiority over other remains inconclusive.

While there is wide body of theoretical and empirical literature on fiscal policy and tax levels, only small number of these concentrate on empirical research on tax structure effects on long-run growth in revenue-neutral tax system. Early studies by Kneller, Bleaney and Gemmell (1999), and later Widmalm (2001) use five-year average aggregate data to separate between short business cycles and long-run effects and apply traditional econometric tools (Pooled Ordinary Least Squares (OLS) and fixed effects (FE) regressions). Later they found that five-year averaging does not fully separate short-run effects and, as previously used regression models restrict coefficients to be equal across groups, that could lead to estimator bias.

Later, to avoid this issue, Arnold et al. (2011) uses Pooled Mean Group (PMG)<sup>2</sup> estimator to observe tax structure effects on growth in "revenue-neutral"<sup>3</sup> system. PMG estimator constraints the long-run coefficients to be identical but allows the short run coefficients and error variances to differ across countries. Using different tax structure revenue shares of GDP, Arnold et al. (2011) shows that increase in the revenue share of income taxes while decreasing the revenue share of consumption taxes, corresponds to negative effect on long-run income per capita. Furthermore, Arnold et al. (2011) establishes certain tax "distortion" ranking in terms of their effect on long-run income per capita. Ranking shows that least "distortive" taxes are property, followed by consumption, personal income and corporate income. More specifically, that recurrent taxes on immovable property are associated with highest positive impact on GDP per capita. Additionally, Arnold et al.

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<sup>1</sup> Henderson (1948); Little (1951); Corlett and Hague (1953); Atkinson (1976); Chamley (1986); Judd (1985); Bankman (1991); Cunningham (1996); Auerbach (2006).

<sup>2</sup> Developed by Pesaran, Smith and Shin (1999)

<sup>3</sup> Revenue-neutral tax structure issue was addressed by Bleaney, Michael F., Norman Gemmell and Richard Kneller. 2001. And is further discussed in Section 3.

(2011) shows that ranking remains robust when model is expressed with additional policy variables.

This paper contributes to the existing literature by studying effects between tax structure and economic growth using cross-country panel data on 30 EU countries (EU28 + Norway and Switzerland) over the period 1995-2016. Additionally, author studies tax structure effects between “new” and “old” EU member states and compares them with benchmark results from full data sample and with the results from Arnold et al. (2011). Using PMG estimator on all 30 countries, author cannot establish similar tax “distortion” ranking achieved by Arnold et al. (2011). But certain ranking can be established when benchmark model is used with smaller data samples on “new” and “old” EU member states. Moreover, author shows that these results are robust when additional control variables are added to the model. Author also shows that estimates are consistent and efficient when test on validity of homogeneity restriction on long-run coefficients is performed.

The rest of the paper is structured as follows. Section 2 provides literature review on existing theories and empirical studies. Section 3 provides overview of applied methods and models. Section 4 briefly describes the data. Section 5 reports benchmark and alternative tax structure combination results of PMG estimator and compare them with Arnold et al. (2011) estimated results. In Section 6, author tests robustness of benchmark model when it is applied to smaller sample, divided between new (Section 6.1) and old (Section 6.2) EU member states. Sections 6.3 and 6.4 test robustness of newly estimated models by adding additional control variables. Section 7 tests validity of identical constraints in the long-run coefficients by using Hausman test. Section 8 provides conclusions.

## 2. Literature review

There is a wide amount of literature on tax level effect on economic growth, but literature amount of tax structure effects as a whole on economic growth in revenue-neutral system is limited. Thus Arnold et al. (2011)<sup>4</sup> study about tax structure effects on income growth, being one of the most prominent, lead to further fiscal policy recommendations by OECD. But before that, it is necessary to acknowledge earlier studies in this field to better understand the development of research topic through other authors work.

### *Early empirical studies*

Majority of early empirical studies on fiscal policy effects on growth concentrates on neoclassical growth models using tax income/GDP and government spending/GDP ratios as their main variables (Easterly and Rebelo, 1993; and Folster and Henrekson, 2001) and (Kormendi and Meguire, 1985; Grier and Tullock, 1987; and Barro, 1989; 1990; 1991). Kneller, Bleaney and Gemmell (1999) tested impact of fiscal policy on growth through tax structure, tax level and government expenditure. Kneller, Bleaney and Gemmell (1999), and later Widmalm (2001) use five-year average aggregate data to avoid short-run effects, arguing that this allows to distinguish steady state variables from policy variables on the transition. Authors use pooled OLS and fixed-effects models on panel data set for 22 OECD countries over the period 1970–95. In their study, authors choose initial level of GDP per capita, investment/GDP ratio, labor force growth rate and “distortionary” and “non-distortionary” tax to GDP ratios<sup>5</sup> to estimate five-year average annual growth rate of real GDP per capita. Results suggested that increase of “distortionary” tax levels decreases income per capita and are consistent with Barro (1990) model. While authors state that their models are robust with various changes in specification, they also state that estimated effect *magnitudes* are sensitive to the five-year averaged dataset. They show that even lowest estimates, when increasing productive expenditure or decreasing “distortionary” taxes by 1% of GDP, increase growth rate by 0.2% per year (Kneller, Bleaney and Gemmell, 1999).

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<sup>4</sup> Earlier studies of Arnold et al. (2011) include Arnold (2007 & 2008) and Johansson et al. (2008)

<sup>5</sup> Distortionary taxes are defined as taxes on income and profit, payroll and manpower, property, and social security contributions. Non-distortionary taxes are defined as those imposed on domestic goods and services. Both are expressed as percentages of total GDP.

Bleaney et al. (2001), in their later study, found that five-year averaging on dataset does not fully separate short-run effects, thus estimated results should not be used to interpret long-run growth effects.

Widmalm (2001) uses similar dataset over period of 1965-1990 but estimates effects on growth while tax structure changes are revenue-neutral. Widmalm (2001), in his study, additionally includes export/GDP ratio and the variability of the inflation rate. Widmalm (2001) also includes total tax revenue/GDP ratio, measure of progressivity<sup>6</sup> and chooses different tax/total tax revenue classification ratios<sup>7</sup>. Widmalm (2001) uses Extreme Bounds Analysis (Leamer, 1983) and estimates robust negative effects of labor and capital tax revenue/total tax revenue ratio on GDP per capita growth rate. He also finds that corporate income revenue/total tax revenue ratio has fragile<sup>8</sup> positive effect on income growth. Estimated results are also fragile for other tax revenue/total tax revenue ratios: payrolls and social security contributions, property tax, goods and services.

#### *Recent empirical studies*

Recent empirical studies started to address issue of homogeneity across countries in panel datasets. Equilibrium long-run growth paths may be similar within countries, while short-run effects may vary (Xing, 2011). For models where short-run dynamics and long-run effects are clearly determined this observation would imply biased estimators leading to invalid conclusions thus making pooled OLS and fixed-effects model not the best option for particular studies.

To avoid possible estimator bias Gemmell et al. (2007) and Arnold et al. (2011) use Mean Group (MG) or Pooled Mean Group (PMG) estimator, which constraints the long-run coefficients to be identical but allows the short run coefficients and error variances to differ across groups (Shin, Smith and Pesaran, 1998).

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<sup>6</sup> Widmalm (2001) measures tax progressivity by estimating the elasticity of total tax revenue /GDP ratio.

<sup>7</sup> Widmalm (2001) uses five additional specific tax revenue/total tax revenue ratios: corporate income, labor and capital income, property, goods and services, payroll and social security contributions.

<sup>8</sup> When using Extreme Bounds Analysis: “fragile” is *vice versa* of “robust”.

Gemmel, Kneller and Sanz (2007) compares robustness of long-run effects of fiscal policy on growth between MG and PMG versus previous – dynamic fixed-effects(DFE) model used by Bleaney et al. (2001). Bleaney et al. (2001) estimated positive long-run growth effects on productive public expenditures and budget surpluses and negative effects on distortionary taxes. Gemmel, Kneller and Sanz (2007) use OECD panel dataset from 1970-2004 for 17 countries. Major disadvantage of MG and PMG estimators is degrees of freedom if available time series is short, thus certain restrictions on lag lengths are vital. Gemmel, Kneller and Sanz (2007) compare PMG and DFE with same length lags(2). While both models show similar parameter sizes, standard errors for PMG are higher. Both models identify long-run parameters less precisely, when compared with DFE with 8 lags.

Arnold et al. (2011) uses same period OECD dataset as Gemmel, Kneller and Sanz (2007) but with 21 countries. He examines revenue-neutral tax structure changes on long-run level of GDP per capita. Similarly as Widmalm (2001), Arnold et al. (2011) categorizes taxes in groups as a ratio between group tax revenue/total tax revenue<sup>9</sup>. Arnold et al. (2011) PMG estimation results suggest certain ranking between four major tax groups on their long-run effects on GDP per capita. Ranking shows that least “distortive” taxes are property, followed by consumption, personal income and corporate income (i.e. increase in property taxes will have less negative effect on GDP per capita than increase in corporate income taxes). Additionally, ranking remains robust when model is expressed with additional policy variables – inflation, trade openness and expenditures on research and development (Arnold et al., 2011).

Later Xing (2012) conducted similar empirical study, comparing PMG and MG estimates with simple OLS and Fixed Effects model results. While estimated coefficients varied between models in their signs, significance levels and magnitudes due to different model specification, by conducting Hausman test, Xing (2012) showed that PMG estimates are consistent and efficient regards other models. At the same time, increasing data sample with additional countries causes changes in tax structure variable significance levels. Thus

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<sup>9</sup> Arnold et al. (2011) categorizes taxes in four major groups: personal income, corporate income, consumption and property.

her results could not establish similar ranking as Arnold et al. (2011), as there were no significant differences between private and capital income taxes on their impact on economic growth. Similarly, there were no differences between recurrent property and other property taxes. Only significant result was that property taxes has a positive effect on long-term per capita growth.

#### *Empirical studies focusing on tax rates*

It is also necessary to acknowledge empirical studies where authors estimate different tax level effect on growth.

Lee and Gordon (2005), using cross-country data to determine tax policies effect on countries growth rate, showed that decrease in corporate tax rate by 10 percentage points returns positive (1-2%) annual growth rate.

Vermeend et al. 2008 found that capital income taxes can affect the rate of capital accumulation. Increase in capital income taxes could discourage investments and savings by firms and households. Decrease in investments lower capital stock, which further distorts economic growth over time.

Karras and Furceri (2009), using annual panel data for 19 European economies, explored that increase in total tax rate to GDP by 1% in long term decreases GDP per capita by 0.5 – 1%.

Prammer (2011) indicated that taxes on labor can affect growth relevant decisions by altering: the allocation of time between labor and leisure; human capital accumulation; occupational and entrepreneurial behavior and choices.

#### *Summary*

Early empirical studies concentrate on estimating tax structure effect on long-run level of growth of GDP by using aggregate averages to distinguish steady state variables from policy variables on the transition. In later studies, issue of all parameter restriction across countries, except for growth equation, were addressed. This restriction would create biased estimates and fragile conclusions if short-run effects would indeed vary across countries

while converging to steady state. Gemmell et al. (2007) and Arnold et al. (2011) in their studies relax this restriction by using estimators which fix long-run coefficients while allowing short-run coefficients to vary across groups. Thus allowing for Arnold et al. (2011) to establish certain ranking on tax “distortion” towards growth. Xing (2012) in later studies tests robustness of empirical results of Arnold et al. (2011) and shows that tax ranking is not consistent when increasing data sample with additional countries.

Although there is wide body of literature on tax structure effect on economic growth, empirical evidence is inconclusive and present certain empirical research gaps. Firstly - “aged” empirical results. Most of the empirical research has been done on relatively old datasets. Secondly – empirical research only on OECD countries. Most of the studies on EU research tax level, not tax structure, effect on economic growth.<sup>10</sup> Thirdly – are estimated results consistent between countries with different economic conditions?<sup>11</sup> Thus author, further in paper, will address all three points by using new dataset on EU countries while addressing possible tax structure effect differences between countries with different economic conditions.

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<sup>10</sup> Similar research on EU countries is more logical from simple geographical stand point. Labour mobility is “easier” and much more plausible between EU countries than it is for OECD countries (includes countries like: USA, Australia, Japan, New Zealand etc.). Both, Arnold et al. (2011) and Xing (2012), use these countries in their data sample.

<sup>11</sup> Previous empirical researches on OECD, uses countries with similar economic conditions. For example, Xing (2012) omits Spain, Luxembourg, Portugal and Turkey from her data sample, which is reasonable, as it is necessary to control for outliers. But this also implies, that estimated results would apply only for countries with similar economic conditions. Thus we are unable to conclude how these estimates would correspond for countries with worse or better economic conditions.

### 3. Methods

Analysis is based on constant-returns-to-scale technology, more specifically, on Solow model with augmented human capital and takes the form of Cobb-Douglas production function.

$$Y_t = K_t^\alpha H_t^\beta (A_t L_t)^{1-\alpha-\beta} \quad (1)$$

Where  $Y$  is output,  $K$  – physical capital,  $H$  – human capital,  $L$  – labour,  $A$  – level of technology.  $\alpha$  - partial elasticity of output with respect to physical capital,  $\beta$  – partial elasticity of output with respect to human capital,  $t$  – time period; Arnold et al. (2011)<sup>12</sup>.

Further, author's chosen econometric model is based on Arnold et al. (2011) where he uses error correction model (ECM), which allows to include independent variables in levels and first differences to show transition dynamics as well as lagged dependent variable in levels. Thus empirical model takes the following error correction form:

$$\Delta \ln y_{i,t} = a_{i,0} - \phi \left( \ln y_{i,t-1} - a_1 \ln s_{i,t-1}^k - a_2 \ln h_{i,t-1} - a_3 n_{i,t-1} - a_4 T_{i,t-1} - \sum_{j=4}^m a_j * V_{i,t-1}^j \right) \quad (2)$$

$$+ \beta_{1,i} \Delta \ln s_{i,t}^k + \beta_{2,i} \Delta \ln h_{i,t} + \beta_{3,i} \Delta n_{i,t} + \beta_{4,i} \Delta T_{i,t} + \sum_{j=4}^m \beta_j * \Delta V_{i,t}^j + \gamma_i * t + \varepsilon_{i,t}$$

where  $y$  is GDP per capita in purchasing power standards for country  $i$  at year  $t$ ;  $s^k$  is physical capital;  $h$  is human capital,  $n$  is working population growth rate;  $T$  is total tax revenue to GDP ratio;  $V$  denotes a vector of tax classification in subcategories expressed as ratio from subcategory tax revenue to total tax revenue;  $\gamma_i$  is vector of coefficients;  $\phi$  is convergence parameter;  $t$  is function of time and  $\varepsilon$  is white noise error term. First line captures long-run linear equilibrium relation while second lined captures short-run dynamics.

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<sup>12</sup> Author will not present further calculations, as full formulation of the model is easily accessible in Arnold et al. (2007)

Author applies Pooled Mean Group (PMG) estimator to equation (2), proposed by Pesaran et al (1999). Pesaran (1999) introduced three estimators for analyzing dynamic panel models. Dynamic Fixed Effects (DFE) estimator – one of the extreme methods – assumes homogeneity, that all long-run and short-run coefficients and error variances across all countries are the same. Mean Group (ME) estimator – other extreme method – separately estimates long-run and short-run coefficients for each country and examines average distribution of country specific estimates. PMG estimator constraints the long-run coefficients to be identical but allows the short run coefficients and error variances to differ across countries.

It is necessary to acknowledge the fact that author is analyzing tax structure, not their respective levels. With that in mind, there are significant differences between countries and their tax levels which, if not controlled, can cause spurious correlations. Thus tax levels are based on their revenue shares from total tax revenue.

Further, Kneller et al. (1999)<sup>13</sup> and Bleaney et al. (2001) argue about the role of government budget constraint (GBC) in interpretation of estimated results. As GBC has to be “respected”, this implies that changes in one instrument has to be balanced by changes (opposite) in other instrument so that GBC is not violated. Failing to account for this constraint will, likely, introduce estimation bias due to the linear relationship between fiscal variables and implicit financing assumption in regressions (Bleaney et al. 2001).

For estimation purposes this implies that omitted variable automatically becomes compensating variable in GBC. Thus interpretation becomes in a form of “*a unit change of fiscal variable compensated by a unit change in the fiscal element(s) omitted from regression*” Kneller et al. (1999).

In context of authors analysis, from regression omitted variable (tax category) will act as compensating variable (will be decreased) in order not to violate revenue neutrality.

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<sup>13</sup> Full theory and calculations accessible: Bleaney, Michael F., Norman Gemmill and Richard Kneller. 2001. Testing the endogenous growth model: public expenditure, taxation, and growth over the long run.

This gives possibility to evaluate different tax structure reforms as long as revenue neutrality is kept and correct interpretation is given.

#### 4. Data

Author combines data from Eurostat and OECD databases. Author's used dataset is longitudinal data on countries and year by year observations on general economic indicators and revenue statistics on taxes. The data set covers all 28 EU countries + 2 additional located in Europe (Norway and Switzerland) over the time period of 1995 – 2016. Detailed information on variable definitions and descriptive statistics is presented in Appendix B.

To be able to observe and compare results between countries with different economic conditions, author divides dataset into two subsets. One subset consists EU15<sup>14</sup> + 2 additional countries. Countries included in this subset are those who became EU member states before 2004 - also in paper referred as “Old” EU countries. Other subset of EU13<sup>15</sup> includes those countries who became EU member states after 2004 - also in paper referred as “New” EU countries. It is worth mentioning, that one can think of these country groups also as “high income” and “low income” as countries included in “New” EU country group have relatively lower income per capita than those in “Old” EU group.

Appendix A Figure 1 illustrates average tax burden (total tax revenue) in % of GDP evolution over sample period between full data sample, old and new EU countries. Overall tax burden in EU countries remains relatively flat at 36% of GDP. The average tax burden as a share of GDP is highest in Denmark (around 47%) and lowest in Romania (around 26%). Figure demonstrates significant differences between old and new EU member states. Over sample period, tax burden in new EU member states has remained on average between 6-8 percentage points lower than in old EU member states. Another difference between old and

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<sup>14</sup> EU15 countries: Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom.

<sup>15</sup> EU13 countries: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia.

new EU member states is effect of “crisis”<sup>16</sup> on tax burden. Effect on old EU member states remains relatively low as total tax revenue as a share of GDP decreases by a small margin and lasts for two periods<sup>17</sup>. In new EU countries effect is more significant both in magnitude and time period. Starting from 2010 total tax revenue as a share of GDP has experienced steady increase and has reached highest point in old and new EU member states.

Figure 2 and 3 illustrates tax structure by its main components as a percentage of total taxation in 1995 and 2016. Figure demonstrates significant differences in personal income taxes between old and new EU member states which remains in both 1995 and 2016. Personal income taxes are around 26% of total taxation for old EU member states and remains relatively flat comparing 1995 and 2016. For new EU member states, personal income taxes are around 17% in 1995 and 13.5% in 2016 of total taxation. For new EU member states figure illustrates slight increase in consumption taxes (from 39% to 43%) of total taxation between 1995 and 2016 while for old EU member states consumption taxes has remained at the same level (34% of total taxation).

## **5. Results**

### **5.1 Benchmark results on EU28+2**

Appendix A Table 1 reports benchmark results of long-run coefficients of PMG estimates, omitted tax variable, mean convergence coefficient, observation count and log-likelihood value. Based on Equation (2), ECM estimates also report short-run coefficients, but as author is interested only in long-term effects, short-run coefficients are not presented. Columns (1) to (5) report estimates of the base model and different tax structure combinations. It is worth mentioning that omitted tax variable represents the rest of the total

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<sup>16</sup> Global financial crisis of 2007-2008.

<sup>17</sup> It is worth mentioning that decrease in total tax burden could have happened not only because of decrease in tax levels, but as well as increase in unemployment, drop in efficiency of State Tax department, increased “shadow economy” etc.

revenue share omitted from model, thus achieving revenue-neutrality<sup>18</sup> which author discussed in Section 3.

Mean convergence coefficient is in the range between 0.00 and -0.14 under different tax structure specifications. For Column (3) mean convergence coefficient is 0.00 and is statistically insignificant thus implying that estimated coefficients are highly imprecise (also shown by large standard errors) and should be interpreted with caution. As expected, long-run coefficients on physical capital and human capital are positive and statistically significant, except in Column (4) where physical capital has a small negative coefficient. Overall, one percent increase in the share of physical capital would correspond to long-run increase in GDP per capita by 0.5-1%. Similarly, one percent increase in years spent on schooling correspond to 3.4-4.1% increase in long-run GDP per capita. Working population growth rate estimates are negative but are not always significant. One percentage point increase in working population growth rate would correspond to 0.03-0.16% decrease in long-run GDP per capita. Coefficients on tax burden in Column (1) and (5) are positive and significant at 10% level while in Column (2) and (4) they are negative and significant at 1% level.

Column (1) reports that one percentage point increase in the share of Income Taxes & Social Security Contributions (IT&SSC), while decreasing share of Consumption Taxes (CT) by the same amount, would correspond to negative long-term effect on GDP per capita for about 0.6%.

Column (2) separates between Private Income Taxes & Social Security Contributions (PIT&SSC) and Corporate Income Taxes (CIT). While both are negative, PIT&SSC is more distortive towards long-run level of income per capita than CIT (significant at 10% level).

Column (3) estimates the effects of Consumption Taxes (CT) while omitting (IT&SSC). Increase in the share of CT corresponds to negative effects on long-run income

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<sup>18</sup> Included tax structure variables and omitted tax variable will always sum to 1 (100% of tax revenue). Statement is true for all tables included in this paper, where certain tax variables are omitted, unless stated otherwise.

per capita, but as stated before, due to insignificant mean convergence coefficient, estimated coefficients are highly imprecise.

Column (4) separates between VAT Type Taxes (VAT), Other Consumption Taxes (OCT) and Property Taxes (PT). All have negative effects while only OCT and PT are significant. Estimated coefficient on OCT in its magnitude is reasonable (-5.43) while PT coefficient is highly questionable (-24.15). Especially, because in Column (5), where author separates between PT and Consumption Taxes (excl. Property Taxes)<sup>19</sup>, coefficient on PT is still significant but positive at much more reasonable magnitude (4.12). While combining VAT and OCT makes coefficient insignificant.

## **5.2 Alternative combinations of Tax structure variables**

Table 2 reports results of long-run coefficients using same benchmark model while alternating different combinations of Tax structure variables. This allows to observe how all other tax structure variables will effect long-run income per capita when specific tax variable is omitted. This also allows to compare estimated coefficient magnitudes and significance levels with the ones from Table 1.

Mean convergence coefficient is in the range between -0.06 and -0.15 under different tax structure specifications and in all cases is significant. As expected, estimated long-run coefficients on physical capital, human capital and working population growth rate are in line with those observed in Table 1. Estimated coefficients on tax burden remain inconclusive. In Table 2 Column (1) estimated coefficient on tax burden is positive while in others it is negative with significant changes in their magnitude.

In Column (1) only CIT and VAT&OCT have positive significant effect on long-run income per capita while PIT&SSC is omitted. PT is negative and insignificant.

In Column (2) PIT&SSC and VAT&OCT are both positive and significant while PT remains negative and insignificant when CIT is omitted.

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<sup>19</sup> VAT and OCT combined. Further in paper author uses abbreviation – VAT&OCT.

In Column (3) CIT and PT are both positive and significant while PIT&SSC becomes negative and insignificant when VAT&OCT is omitted.

In Column (4) CIT and VAT&OCT are both positive and significant while PIT&SSC remains insignificant but positive when PT is omitted.

### **5.3 Comparison with Arnold et al. (2011)**

Comparing author's results with Arnold et al. (2011) estimated long-run coefficients it is possible to establish first conclusions about benchmark model. Physical capital and human capital estimated coefficients are in line with Arnold et al. (2011) findings but greater in their magnitudes. Coefficients on working population growth rate are very close. Authors estimated coefficients on tax burden are inconclusive in their sign and magnitude, oppose to Arnold et al. (2011) ~ -0.25.

Author is unable to establish similar "tax distortion" ranking from benchmark model as Arnold et al. (2011) did. While author can be sure about negative effects of income taxes on long-run income per capita, it is impossible to "rank" them due to certain tax variable unreasonable magnitudes or low significance levels.

It is import to acknowledge the main differences between Arnold et al. (2011) and author's paper. Firstly, author uses data sample on EU28+2 countries for time period from 1995-2016, oppose to 21 OECD countries for time period from 1970-2004. Secondly, author uses gross fixed capital formation (share of GDP) as a proxy for physical capital while Arnold et al. (2011) uses non-residential gross fixed capital formation (share of GDP). Thirdly, author uses slightly different approach calculating average years of schooling.

To address these differences and inconclusive results, author proposes to use smaller data samples and add extra control variables to test robustness of benchmark model. In sections 6.1 and 6.2, author uses smaller samples divided in new and old EU countries respectively. In sections 6.3 and 6.4 author adds additional control variables to further test robustness on newly estimated models.

## **6. Robustness checks**

### **6.1 Results on EU13(New)**

Smaller data sample includes all countries who joined EU in 2004 and after. In Table 3, for long-run coefficient estimation author uses same benchmark model setup and reports results in the same manner.

Mean convergence coefficient is in the range between -0.05 and -0.11 under different tax structure specifications and are significant at 1% and 10% levels. For Column (4) mean convergence coefficient is -0.05 and is statistically insignificant thus, as previous, implying that estimated coefficients are imprecise and should be interpreted with caution. Physical capital long-run coefficients are positive and significant. One percent increase in the share of physical capital would correspond to increase in GDP per capita by 0.5-1.2% which is in line with the results from full sample. Human capital long-run coefficients are positive and significant, but the magnitudes are much higher than in full sample. One percent increase in average years spent on schooling correspond to 5.3-9.4% increase in GDP per capita. Working population growth rate is significant and would correspond for slight increase in income per capita. Long-run coefficients on tax burden are negative and significant. One percentage point increase in tax burden would correspond to -1.7% to -6.7% decrease in GDP per capita.

Column (1) reports that one percentage point increase in the share of IT&SSC, while decreasing share of CT by the same amount, would correspond to negative long-term effect on GDP per capita for about 0.84%.

In converse, Column (3) reports slightly higher positive effect of CT on long-run income per capita when IT&SSC is omitted.

Column (2) reports that both PIT&SSC and CIT are negative and significant while PIT&SSC are more distortive towards long-run income per capita.

Column (4) shows that both VAT and OCT are significant while VAT has positive effect and OCT has higher negative effect on long-run income per capita. Due to insignificant mean convergence coefficient estimated coefficients are imprecise but are somehow

consistent with coefficients estimated in Column (5). VAT&OCT remains significant and positive while PT remains insignificant in both Column (4) and (5).

## **6.2 Results on EU15+2(Old)**

Table 4 reports benchmark results of long-run coefficients for data sample consisting of countries who joined EU before 2004. Mean convergence coefficient is in the range between -0.18 and -0.20 under different tax structure specifications and are significant at 1% level. Physical capital and human capital have expected signs and are significant. Overall, one percent increase in the share of physical capital would correspond to increase in GDP per capita by 0.3-0.7%. Similarly, one percent increase in years spent on schooling correspond to 3.8-4.4% increase in GDP per capita. Working population growth rate is significant and would correspond for slight decrease in income per capita. Long-run coefficients of tax burden are significant and positive, except Column (2) – negative and insignificant. One percentage point increase in tax burden would correspond to 0.8-0.9% increase in GDP per capita.

Column (1) reports that one percentage point increase in the share of IT&SSC, while decreasing share of CT by the same amount, would correspond to negative long-term effect on GDP per capita for 0.57%.

In converse, Column (3) reports slightly higher positive effect of CT on long-run income per capita when IT&SSC is omitted.

Column (2) reports that both PIT&SSC and CIT are significant. While PIT&SSC is, unsurprisingly, negative, CIT has higher positive effect on long-run income per capita than CT.

Column (4) and Column (5) reports positive and significant effect of PT on long-run income per capita. While VAT and OCT are independently significant and have expected signs in Column (4), in Column (5) combination of two becomes insignificant.

### **6.3 Results on EU13(New) with additional control variables**

Similarly, as in Arnold et al. (2011), author will include in the model additional control variables, as there are other variables which correspond behind driving forces of GDP per capita growth. Arnold et al. (2011) uses inflation, inflation volatility, trade openness and research and development (R&D) to test robustness of benchmark model. Author will use same control variables to test robustness of the split dataset models, discussed in previous two subsections. It is worth mentioning, that PMG estimator runs a complex non-linear maximum likelihood algorithm thus there are only certain number of independent variables one can include in regression. Large number of independent variables may cause endless iterations thus algorithm will not converge. As a result, author could use only two out of four additional variables – trade openness and R&D. Also, for the same reason, Table 5 and Table 6 report only four columns as models with VAT, OCT and PT did not converge.

In Table 5, mean convergence coefficient is in the range between -0.07 and -0.09 under different tax structure specifications and are significant at 1% level. Physical capital remains significant and positive with slight increase in magnitude. Human capital and working population growth rate remains significant only in Column (2). Tax burden remains negative and significant in its long-run effects on income per capita with significant increase in its magnitude (7.4-8.2%). Trade openness has significant and positive effect, except Column (2) – negative effect. Overall, one percent increase in the share of trade openness would correspond to 0.7-0.9% increase in income per capita. R&D long-run effects are minimal in their magnitude and insignificant.

All tax variables remain their significance levels as in Table 3. While coefficient magnitudes increase, general ranking remains. IT&SSC and CT have opposite effects on long-run income per capita with almost identical magnitudes. PIT&SSC remains most “distortive” while VAT&OCT remains positive and significant. PT remains insignificant. Only surprising result is that CIT corresponds to positive long-run effect on income per capita when additional control variables are included as oppose to negative effect observed in Table 3.

#### **6.4 Results on EU15+2(Old) with additional control variables**

In Table 6, mean convergence coefficient is in the range between -0.11 and -0.15 under different tax structure specifications and are significant at 1% level. Physical capital remains significant and positive with slight decrease in magnitude. Human capital remains positive and significant in its long-run effects on income per capita with significant decrease in its magnitude (0.9-3.1%). Working population growth rate and tax burden become insignificant. Increase in the share of trade openness has a slightly lower effect on long-run income per capita than that observed in new EU countries (0.4-0.8%). R&D is significant in Column (2) and (4) and present low negative effect.

All tax variables remain their significance levels as in Table 4. Similarly, as in previous subsection, addition of extra control variables, change coefficient magnitudes but not their “ranking”. IT&SSC and CT (significant at 10% level) have opposite effects on long-run income per capita with almost identical magnitudes. PIT&SSC remains most “distortive” while CIT remains with significant positive effect on long-run income per capita. PT remains least “distortive” while VAT&OCT remains insignificant.

#### *Summary*

In this section, author tests robustness of benchmark model by estimating long-run coefficients on two subsets – new and old EU countries, and by adding additional control variables. Estimated models show more conclusive and robust results compared to benchmark model. While no “distortion” ranking can be established in benchmark model, broad conclusions on ranking and comparison to Arnold et al. (2011) results can be made when using split subsets.

In both, old and new EU countries, PIT&SSC are most “distortive” towards long-run GDP per capita. PT are least “distortive” only in old EU countries while in new EU countries estimated coefficients on PT are insignificant. In new EU countries least “distortive” are VAT&OCT while in old EU countries these taxes are insignificant. As oppose to Arnold et al. (2011) results, CIT are not “most” distortive and suggest positive, significant and robust

long-term effect on income per capita in old EU countries. In new EU countries, CIT estimated effects are significant but not robust and changes sign when additional control variables are included.

## 7. Validity of identical constraints in the long-run coefficients

So far, author has only observed the results from PMG estimations which constraints the long-run coefficients to be homogenous but allows the short run coefficients and error variances to differ across groups. To be able to prove validity of constraint, it is necessary to test estimation results against model with different parametric assumptions. Author chooses unweighted Mean Group (ME) estimator which separately estimates long-run and short-run coefficients for each group and examines average distribution of group specific estimates. To compare PMG estimates and unweighted MG estimates, author uses Hausman test<sup>20</sup>.

Table 7 reports PMG and unweighted MG estimates, standard errors and significance levels on benchmark model using full dataset. Last row in table reports Hausman joint test statistic and p-value. From table, it can be seen that MG estimates are statistically insignificant and with large standard errors thus, already, establishing why to use PMG over MG estimates. Hausman test statistic in second column  $\chi^2(5) = 2.51$  with  $\text{Prob} > \chi^2 = 0.77$  suggest that author cannot reject  $H_0$  and joint long-run coefficients are homogenous across groups. Same applies for all other estimated models from full dataset, except column 4 where Hausman test statistic is negative.

Table 8 and Table 9 reports results for EU13(New) and EU15+2(Old) accordingly. In all models in both tables, author cannot reject  $H_0$  thus suggesting that joint long-run coefficients are homogenous across groups and PMG estimator is consistent and efficient.

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<sup>20</sup>  $H_0$ : long-run coefficients are homogenous across groups;  $H_1$ : long-run coefficients are heterogenous; Under  $H_0$  both, MG and PMG, are consistent, while PMG is more efficient; Under  $H_1$  only MG is consistent. Author uses Stata command: hausman MG PMG, sigmamore; sigmamore - specifies that the covariance matrices be based on the estimated disturbance variance from the efficient estimator. (Stata Journal Vol. 7)

## 8. Conclusions

The primary aim of this paper is to examine revenue-neutral tax structure effect on long-run economic growth using panel data growth regression for 30 countries located in Europe (EU, Norway and Switzerland) over time period of 1995 - 2016. Secondary aim is to compare results with Arnold et al. (2011) achieved results where author established certain ranking on tax structure “distortion” on economic growth. Tertiary aim is to test coefficient robustness and validity when benchmark models are applied to smaller subset of countries, divided between new and old EU countries. Author uses Pooled Mean Group estimator which constraints the long-run coefficients to be identical but allows the short run coefficients and error variances to differ across countries.

Benchmark model estimation results on all 30 countries are only partially in line with Arnold et al. (2011). While estimated parameter signs and significance levels are almost identical to the ones found in Arnold et al. (2011), for some parameters, magnitudes are slightly higher. Furthermore, author is unable to establish similar “tax distortion” ranking from benchmark model as Arnold et al. (2011) did. While estimation results support positive long-run effect on income per capita when shift in total tax revenue is away from income taxes, no further “ranking” can be established due to certain tax structure variable parameter unreasonable magnitudes or low significance levels.

When benchmark model is applied to smaller subsets, estimation results on tax structure effect on long-run income per capita become more conclusive. Personal Income Taxes & Social Security Contributions are most “distortive” towards long-run income per capita in both, old and new EU countries. Similarly, as Arnold et al. (2011) reported, property taxes are least “distortive” and shift in total tax revenue towards these taxes could be associated with positive effect on long-run income per capita. Although, this is only true for old EU countries while for new EU countries estimated parameters on property taxes are insignificant. In new EU countries, least “distortive” are other consumption taxes (excl. property taxes) while, contrary, in old EU countries estimated results on these taxes are insignificant. Oppose to Arnold et al. (2011) results, corporate income taxes are not “most” distortive and have a positive long-run effect on income per capita in old EU countries. In

new EU countries corporate income tax is significant but not robust with its long-run effect. Conclusions about other tax structure long-run effects are robust when estimated models are tested with extra variables. Furthermore, Hausman test suggests that chosen PMG estimator is consistent and efficient.

Analysis suggest that, while certain tax structure “ranking” can be established in a group of countries with similar economic conditions, there are some tax structure variables that could change in their magnitude and even in its effect between these groups. This further suggest that one has to be cautious with policy recommendations on revenue-neutral tax structure changes for individual countries.

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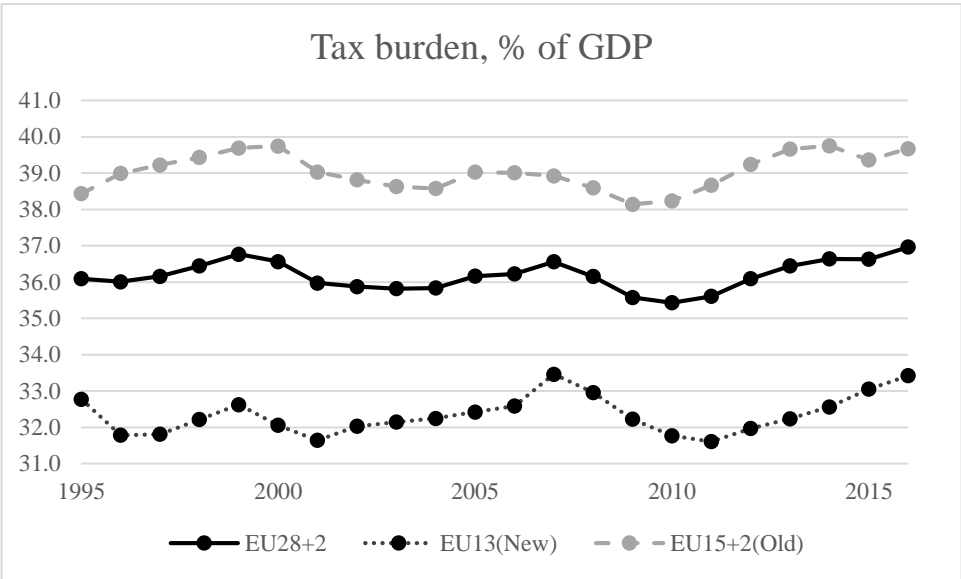
#### DATA BASES

[1] EUROSTAT - available here: <http://ec.europa.eu/eurostat/data/database>

[2] OECD – available here: <https://data.oecd.org/>

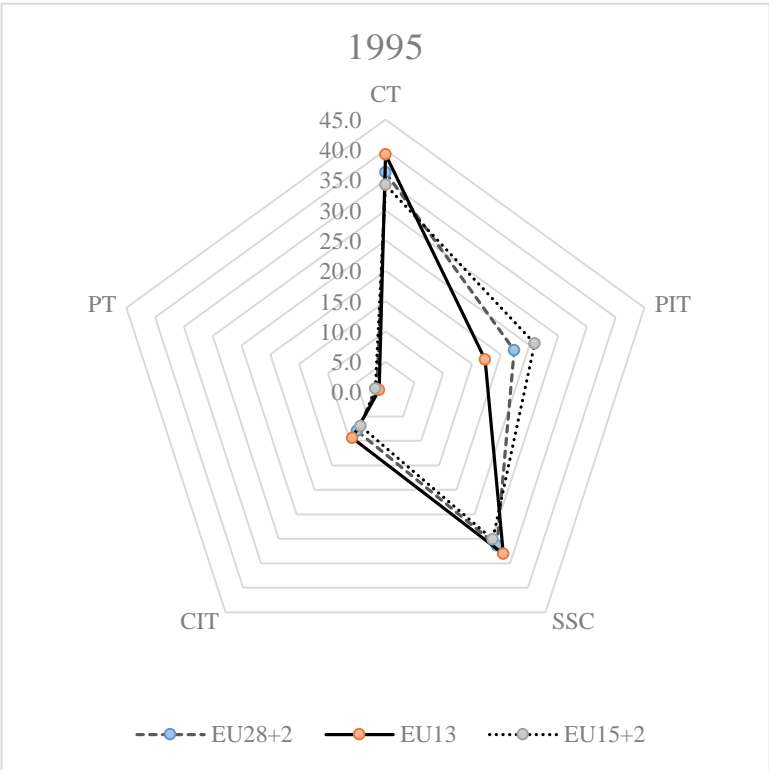
### Appendix A: Figures and tables

Figure 1: Tax burden (total tax revenue) as a share of GDP in percent.



Source: Eurostat and author’s calculations

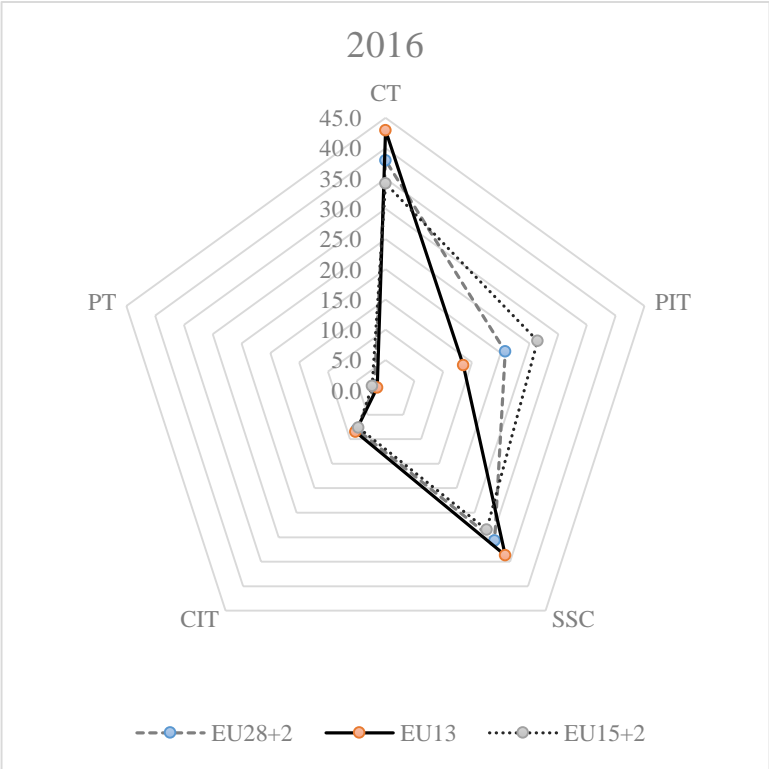
Figure 2: Tax structure by its main components as a percentage of total taxation in 1995.



Note: CT - Consumption Taxes; PIT – Personal Income Taxes; SSC – Social Security Contributions; CIT - Corporate Income Taxes; PT - Property Taxes.

Source: Eurostat and author’s calculations

Figure 3: Tax structure by its main components as a percentage of total taxation in 2016.



Note: CT - Consumption Taxes; PIT – Personal Income Taxes; SSC – Social Security Contributions; CIT - Corporate Income Taxes; PT - Property Taxes.

Source: Eurostat and author’s calculations

Table 1

Estimation results of tax structure effects on long-run GDP per capita. Full dataset.

<b>Dependent variable: Log GDP p.c.</b>	(1)	(2)	(3)	(4)	(5)
<b>Baseline model</b>					
Physical Capital	0.51*** (0.04)	1.03*** (0.14)	-5.84** (2.91)	-0.14*** (0.04)	0.72*** (0.04)
Human Capital	3.96*** (0.18)	3.38*** (0.57)	-6.19 (6.99)	3.87*** (0.31)	4.13*** (0.14)
Population Growth	-0.03*** (0.01)	-0.16*** (0.03)	0.56* (0.31)	0.00 (0.01)	-0.04*** (0.01)
<b>Control variable</b>					
Tax Burden	0.66* (0.37)	-4.01*** (0.71)	55.88* (29.48)	-4.62*** (0.69)	0.53* (0.31)
<b>Tax structure variables</b>					
Income Taxes & Social Security Contributions	-0.61*** (0.21)				
Private Income Taxes & Social Security Contributions		-5.13*** (0.76)			
Corporate Income Taxes		-1.43* (0.85)			
Consumption Taxes			-15.70* (8.96)		
VAT Type Taxes				-0.17 (0.35)	
Other Consumption Taxes				-5.43*** (0.46)	
Property Taxes				-24.15*** (2.20)	4.12*** (0.96)
Consumption Taxes (excl. Property Taxes)					-0.07 (0.21)
Omitted tax variable		Consumption Taxes	Income Taxes & Social Security Contributions		
Mean convergence coefficient	-0.14*** (0.02)	-0.08*** (0.01)	0.00 (0.01)	-0.11*** (0.03)	-0.14*** (0.03)
Observations	623	623	623	577	581
Log likelihood	1489.36	1572.56	1447.5	1429.23	1421.85

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets. All equations include short-run dynamics, but only long-run estimation coefficients are presented.

Table 2

Additional estimation results of tax structure effects on long-run GDP per capita. Full dataset.

<b>Dependent variable: Log GDP p.c.</b>	(1)	(2)	(3)	(4)
<b>Baseline model</b>				
Physical Capital	0.19** (0.08)	1.01*** (0.17)	0.52*** (0.04)	0.65*** (0.12)
Human Capital	4.52*** (0.40)	3.56*** (0.77)	4.43*** (0.12)	4.38*** (0.49)
Population Growth	0.05*** (0.01)	-0.11*** (0.03)	-0.03*** (0.01)	-0.13*** (0.03)
<b>Control variable</b>				
Tax Burden	1.35** (0.60)	-5.32*** (1.20)	-0.65** (0.28)	-3.39*** (0.57)
<b>Tax structure variables</b>				
Private Income Taxes & Social Security Contributions		3.86** (1.57)	-0.20 (0.15)	1.14 (2.25)
Corporate Income Taxes	3.49*** (0.53)		1.57*** (0.33)	5.22** (2.14)
Consumption Taxes (excl. Property Taxes)	4.02*** (0.58)	11.75*** (2.00)		4.68** (2.17)
Property Taxes	-1.71 (1.70)	-5.38 (5.73)	3.75*** (0.95)	
Omitted tax variable	Private Income Taxes & Social Security Contributions	Corporate Income Taxes	Consumption Taxes (excl. Property Taxes)	Property Taxes
Mean convergence coefficient	-0.07** (0.03)	-0.06*** (0.01)	-0.15*** (0.03)	-0.09*** (0.01)
N	581	581	581	623
Log likelihood	1463.29	1469.3	1496.23	1606.69

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets. All equations include short-run dynamics, but only long-run estimation coefficients are presented.

Table 3

Estimation results of tax structure effects on long-run GDP per capita. EU13(New).

<b>Dependent variable: Log GDP p.c.</b>	(1)	(2)	(3)	(4)	(5)
<b>Baseline model</b>					
Physical Capital	0.47*** (0.08)	1.22*** (0.15)	0.50*** (0.09)	-0.41*** (0.14)	0.49*** (0.09)
Human Capital	9.15*** (0.44)	5.34*** (1.35)	9.26*** (0.46)	1.53 (0.99)	9.38*** (0.55)
Population Growth	0.03** (0.01)	-0.09** (0.04)	0.03** (0.01)	0.09*** (0.02)	0.05*** (0.02)
<b>Control variable</b>					
Tax Burden	-1.95*** (0.45)	-6.69*** (1.47)	-2.09*** (0.45)	-6.53*** (1.17)	-1.70*** (0.56)
<b>Tax structure variables</b>					
Income Taxes & Social Security Contributions	-0.84*** (0.32)				
Private Income Taxes & Social Security Contributions		-4.84*** (1.30)			
Corporate Income Taxes		-3.18*** (1.23)			
Consumption Taxes			0.95*** (0.36)		
VAT Type Taxes				5.16*** (1.25)	
Other Consumption Taxes				-8.98*** (1.29)	
Property Taxes				1.18 (3.79)	-1.95 (2.52)
Consumption Taxes (excl. Property Taxes)					1.18*** (0.42)
Omitted tax variable		Consumption Taxes	Income Taxes & Social Security Contributions		
Mean convergence coefficient	-0.09* (0.05)	-0.08*** (0.01)	-0.09* (0.05)	-0.05 (0.04)	-0.11* (0.06)
Observations	266	266	266	241	245
Log likelihood	619.66	662.96	619.12	600.97	582.84

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets. All equations include short-run dynamics, but only long-run estimation coefficients are presented.

Table 4

Estimation results of tax structure effects on long-run GDP per capita. EU15+2(Old).

<b>Dependent variable: Log GDP p.c.</b>	(1)	(2)	(3)	(4)	(5)
<b>Baseline model</b>					
Physical Capital	0.53*** (0.04)	0.34*** (0.04)	0.50*** (0.05)	0.72*** (0.04)	0.71*** (0.04)
Human Capital	3.99*** (0.18)	4.38*** (0.12)	3.85*** (0.19)	4.00*** (0.16)	4.13*** (0.15)
Population Growth	-0.04*** (0.01)	-0.03*** (0.01)	-0.03*** (0.01)	-0.04*** (0.01)	-0.04*** (0.01)
<b>Control variable</b>					
Tax Burden	0.93** (0.39)	-0.40 (0.30)	0.79* (0.41)	0.92*** (0.29)	0.73** (0.32)
<b>Tax structure variables</b>					
Income Taxes & Social Security Contributions	-0.57*** (0.22)				
Private Income Taxes & Social Security Contributions		-1.21*** (0.17)			
Corporate Income Taxes		0.88*** (0.28)			
Consumption Taxes			0.61*** (0.21)		
VAT Type Taxes				0.91** (0.40)	
Other Consumption Taxes				-0.56** (0.26)	
Property Taxes				3.83*** (0.98)	4.15*** (1.08)
Consumption Taxes (excl. Property Taxes)					-0.12 (0.22)
Omitted tax variable		Consumption Taxes	Income Taxes & Social Security Contributions		
Mean convergence coefficient	-0.19*** (0.03)	-0.20*** (0.05)	-0.18*** (0.03)	-0.20*** (0.05)	-0.19*** (0.04)
Observations	357	357	357	336	336
Log likelihood	884.58	937.2	884.12	872.94	858.58

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets. All equations include short-run dynamics, but only long-run estimation coefficients are presented.

Table 5

Estimation results of tax structure effects on long-run GDP per capita with additional control variables. EU13(New).

<b>Dependent variable: Log GDP p.c.</b>	(1)	(2)	(3)	(4)
<b>Baseline model</b>				
Physical Capital	1.57*** (0.25)	1.14*** (0.08)	1.60*** (0.26)	1.40*** (0.24)
Human Capital	-0.54 (2.93)	6.09*** (1.28)	-0.77 (2.97)	0.87 (2.65)
Population Growth	0.04 (0.05)	-0.03** (0.01)	0.03 (0.05)	0.03 (0.04)
<b>Control variable</b>				
Tax Burden	-7.39*** (1.56)	-8.21*** (0.71)	-7.36*** (1.58)	-7.41*** (1.49)
Trade Openness	0.94*** (0.31)	-0.51*** (0.14)	0.95*** (0.31)	0.71*** (0.28)
Research & Development	0.00 (0.14)	-0.02 (0.10)	-0.01 (0.14)	0.02 (0.13)
<b>Tax structure variables</b>				
Income Taxes & Social Security Contributions	-3.23*** (0.95)			
Private Income Taxes & Social Security Contributions	-9.91*** (1.00)			
Corporate Income Taxes	1.11** (0.55)			
Consumption Taxes	3.36*** (0.97)			
Property Taxes	4.62 (7.10)			
Consumption Taxes (excl. Property Taxes)	2.84*** (1.04)			
Omitted tax variable	Consumption Taxes		Income Taxes & Social Security Contributions	
Mean convergence coefficient	-0.07*** (0.01)	-0.09*** (0.02)	-0.07*** (0.01)	-0.08*** (0.01)
Observations	266	266	266	245
Log likelihood	692.36	745.03	693.2	649.63

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets. All equations include short-run dynamics, but only long-run estimation coefficients are presented.

Table 6

Estimation results of tax structure effects on long-run GDP per capita with additional control variables. EU15+2(Old).

<b>Dependent variable: Log GDP p.c.</b>	(1)	(2)	(3)	(4)
<b>Baseline model</b>				
Physical Capital	0.40*** (0.06)	0.16*** (0.04)	0.39*** (0.07)	0.47*** (0.11)
Human Capital	1.25*** (0.44)	3.14*** (0.25)	0.91* (0.48)	1.97*** (0.48)
Population Growth	0.00 (0.01)	0.00 (0.00)	0.00 (0.01)	0.02* (0.01)
<b>Control variable</b>				
Tax Burden	0.60 (0.43)	-0.68*** (0.26)	0.61 (0.48)	0.94 (0.59)
Trade Openness	0.70*** (0.11)	0.42*** (0.07)	0.72*** (0.11)	0.80*** (0.12)
Research & Development	0.04 (0.06)	-0.09** (0.04)	0.08 (0.05)	-0.40*** (0.09)
<b>Tax structure variables</b>				
Income Taxes & Social Security Contributions	-0.38** (0.17)			
Private Income Taxes & Social Security Contributions		-1.49*** (0.14)		
Corporate Income Taxes		1.69*** (0.29)		
Consumption Taxes			0.35* (0.19)	
Property Taxes				3.82*** (1.37)
Consumption Taxes (excl. Property Taxes)				-0.19 (0.30)
Omitted tax variable		Consumption Taxes	Income Taxes & Social Security Contributions	
Mean convergence coefficient	-0.14*** (0.02)	-0.14*** (0.03)	-0.15*** (0.02)	-0.11*** (0.03)
Observations	336	336	336	315
Log likelihood	941.78	978.04	937.23	892.63

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets. All equations include short-run dynamics, but only long-run estimation coefficients are presented.

Table 7

Hausman test of homogeneity restriction on the long-run coefficients. Full dataset.

LR coefficients	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG
Physical Capital	0.49 (0.80)	0.51*** (0.04)	-1.54 (1.56)	1.03*** (0.14)	0.66 (0.96)	-5.84** (2.91)	0.61 (0.77)	-0.14*** (0.04)	0.16 (0.65)	0.72*** (0.04)
Human Capital	62.20 (55.54)	3.96*** (0.18)	0.89 (9.45)	3.38*** (0.57)	40.59 (34.38)	-6.19 (6.99)	4.31 (5.94)	3.87*** (0.31)	4.67 (5.83)	4.13*** (0.14)
Pop. growth	-0.22 (0.24)	-0.03*** (0.01)	-0.09 (0.20)	-0.16*** (0.03)	0.22 (0.25)	0.56* (0.31)	0.17 (0.21)	0.00 (0.01)	0.11 (0.17)	-0.04*** (0.01)
Tax Burden	8.16 (9.78)	0.66* (0.37)	-1.20 (5.37)	-4.01*** (0.71)	5.60 (6.59)	55.88* (29.48)	1.03 (3.87)	-4.62*** (0.69)	1.28 (3.93)	0.53* (0.31)
IT & SSC	27.41 (32.13)	-0.61*** (0.21)								
PIT & SSC			-4.08 (4.71)	-5.13*** (0.76)						
CIT			12.43 (8.88)	-1.43* (0.85)						
CT					-13.85 (19.89)	-15.70* (8.96)				
VAT							3.17 (2.36)	-0.17 (0.35)		
OCT							-0.70 (3.16)	-5.43*** (0.46)		
PT							-5.53 (14.99)	-24.15*** (2.20)	-7.42 (15.19)	4.12*** (0.96)
VATOCT									-1.33 (2.24)	-0.07 (0.21)
Hausman test (MG vs PMG)	$\chi^2(5) = 2.51$ Prob > $\chi^2 = 0.77$		$\chi^2(6) = 1.44$ Prob > $\chi^2 = 0.96$		$\chi^2(5) = -6.20$ Prob > $\chi^2 = 0$		$\chi^2(7) = 1.89$ Prob > $\chi^2 = 0.97$		$\chi^2(6) = 0.77$ Prob > $\chi^2 = 0.99$	

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets.

IT & SSC - Income Taxes & Social Security Contributions;

PIT & SSC - Private Income Taxes & Social Security Contributions;

CIT - Corporate Income Taxes;

CT - Consumption Taxes;

VAT - VAT Type Taxes;

OCT - Other Consumption taxes;

PT - Property Taxes;

VATOCT - Consumption Taxes (excl. Property Taxes).

Table 8  
Hausman test of homogeneity restriction on the long-run coefficients. EU13(New).

LR coefficients	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG
Physical Capital	2.11*	0.47***	-1.89	1.22***	2.49	0.50***	0.31	-0.41***	-0.18	0.49***
	(1.10)	(0.08)	(3.00)	(0.15)	(1.58)	(0.09)	(1.67)	(0.14)	(1.51)	(0.09)
Human Capital	140.23	9.15***	1.69	5.34***	90.8	9.26***	4.25	1.53	4.56	9.38***
	(127.65)	(0.44)	(21.88)	(1.35)	(78.81)	(0.46)	(13.59)	(0.99)	(12.74)	(0.55)
Pop. growth	0.70	0.03**	-0.42	-0.09**	0.71	0.03**	0.48	0.09***	0.32	0.05***
	(0.52)	(0.01)	(0.37)	(0.04)	(0.54)	(0.01)	(0.44)	(0.02)	(0.33)	(0.02)
Tax Burden	20.35	-1.95***	-14.33*	-6.69***	14.18	-2.09***	5.58	-6.53***	4.42	-1.70***
	(22.06)	(0.45)	(7.77)	(1.47)	(14.53)	(0.45)	(8.01)	(1.17)	(8.90)	(0.56)
IT & SSC	70.15	-0.84***								
	(74.01)	(0.32)								
PIT & SSC			-1.39	-4.84***						
			(9.21)	(1.30)						
CIT			24.34	-3.18***						
			(16.38)	(1.23)						
CT					-39.05	0.95***				
					(45.84)	(0.36)				
VAT							0.83	5.16***		
							(4.49)	(1.25)		
OCT							-1.85	-8.98***		
							(6.13)	(1.29)		
PT							12.77	1.18	1.02	-1.95
							(30.55)	(3.79)	(30.51)	(2.52)
VATOCT									-2.63	1.18***
									(4.67)	(0.42)
Hausman test (MG vs PMG)	$\chi^2(5) = 1.38$ Prob > $\chi^2 = 0.93$		$\chi^2(5) = 5.95$ Prob > $\chi^2 = 0.43$		$\chi^2(5) = 1.35$ Prob > $\chi^2 = 0.93$		$\chi^2(5) = 8.71$ Prob > $\chi^2 = 0.27$		$\chi^2(5) = 0.71$ Prob > $\chi^2 = 0.99$	

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets.

IT & SSC - Income Taxes & Social Security Contributions;

PIT & SSC - Private Income Taxes & Social Security Contributions;

CIT - Corporate Income Taxes;

CT - Consumption Taxes;

VAT - VAT Type Taxes;

OCT - Other Consumption taxes;

PT - Property Taxes;

VATOCT - Consumption Taxes (excl. Property Taxes).

Table 9

Hausman test of homogeneity restriction on the long-run coefficients. EU15+2(Old)

LR coefficients	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG
Physical Capital	-0.74 (1.08)	0.53*** (0.04)	-1.28 (1.62)	0.34*** (0.04)	-0.74 (1.11)	0.50*** (0.05)	0.84 (0.59)	0.72*** (0.04)	0.43 (0.29)	0.71*** (0.04)
Human Capital	2.53 (2.48)	3.99*** (0.18)	0.28 (3.31)	4.38*** (0.12)	2.20 (2.25)	3.85*** (0.19)	4.35 (3.11)	4.00*** (0.16)	4.75 (4.22)	4.13*** (0.15)
Pop. growth	-0.14 (0.09)	-0.04*** (0.01)	0.17 (0.21)	-0.03*** (0.01)	-0.15 (0.10)	-0.03*** (0.01)	-0.06 (0.12)	-0.04*** (0.00)	-0.04 (0.18)	-0.04*** (0.01)
Tax Burden	-1.17 (3.76)	0.93** (0.39)	8.85 (6.57)	-0.40 (0.30)	-0.96 (3.41)	0.79* (0.41)	-2.38 (3.18)	0.92*** (0.29)	-1.07 (2.08)	0.73** (0.32)
IT & SSC	-5.28** (2.27)	-0.57*** (0.22)								
PIT & SSC			-6.14 (4.65)	-1.21*** (0.17)						
CIT			3.32 (9.29)	0.88*** (0.28)						
CT					5.41** (2.51)	0.61*** (0.21)				
VAT							4.93** (2.43)	0.91** (0.40)		
OCT							0.17 (3.28)	-0.56** (0.26)		
PT							-19.25 (12.84)	3.83*** (0.98)	-13.76 (14.43)	4.15*** (1.08)
VATOCT									-0.35 (1.92)	-0.12 (0.22)
Hausman test (MG vs PMG)	$\chi^2(5) = 4.12$ Prob > $\chi^2 = 0.53$		$\chi^2(5) = 0.59$ Prob > $\chi^2 = 0.99$		$\chi^2(5) = 5.85$ Prob > $\chi^2 = 0.32$		$\chi^2(5) = 0.94$ Prob > $\chi^2 = 0.99$		$\chi^2(5) = 1.49$ Prob > $\chi^2 = 0.96$	

Note: \*: significant at 10% level; \*\* at 5% level; \*\*\* at 1% level. Standard errors are in brackets.

IT &amp; SSC - Income Taxes &amp; Social Security Contributions;

PIT &amp; SSC - Private Income Taxes &amp; Social Security Contributions;

CIT - Corporate Income Taxes;

CT - Consumption Taxes;

VAT - VAT Type Taxes;

OCT - Other Consumption taxes;

PT - Property Taxes;

VATOCT - Consumption Taxes (excl. Property Taxes).

## Appendix B: Descriptive statistics, definitions and data sources

### Descriptive statistics

<b>Variable</b>	<b>Observations</b>	<b>Mean</b>	<b>Standard deviation</b>	<b>Minimum</b>	<b>Maximum</b>
Country ID	660	15.50	8.66	1	30
Year	660	2005.50	6.35	1995	2016
Log GDP per capita	660	9.915	0.526	8.434	11.257
Log Physical Capital	660	3.090	0.186	1.686	3.622
Log Human Capital	653	2.472	0.059	2.262	2.567
Working Population Growth Rate	653	0.216	0.947	-3.585	3.738
Log Trade Openness	660	4.564	0.464	3.614	6.017
Expenditure on Research & Development	637	1.406	0.861	0.150	3.910
Tax Burden	653	0.360	0.061	0.236	0.497
<b>Tax Categories</b>					
Consumption Taxes	653	0.372	0.068	0.215	0.561
Property Taxes	609	0.017	0.013	0.000	0.062
VAT type taxes	649	0.204	0.046	0.112	0.349
Other Consumption taxes	653	0.153	0.046	0.081	0.409
Consumption Taxes (excl. Property Taxes)	653	0.356	0.068	0.212	0.556
Corporate Income Taxes	653	0.085	0.043	0.013	0.293
Private Income Taxes & Social Security Contributions	653	0.521	0.071	0.327	0.679
Income Taxes & Social Security Contributions	653	0.626	0.068	0.425	0.784

Definitions of variables used in regressions:

- Log GDP per capita ( $\ln_y$ ): Gross domestic product per capita in purchasing power standards. (EUROSTAT National Accounts);
- Log Physical Capital ( $\ln_s^k$ ): Total gross fixed capital formation, as a share of gross domestic product GDP. (EUROSTAT National Accounts);
- Log Human Capital ( $\ln_h$ ): proxied by the average years of schooling of the population from 25 to 64 years of age. (EUROSTAT Education and Training). Calculated using formula:

$$\text{Average years of schooling}_{i,t} = I_{i,t} * 9 + II_{i,t} * 12 + III_{i,t} * 15$$

Where:

- $I_{i,t}$  – share of population attained less than primary, primary and lower secondary education (ISCED11<sup>21</sup> levels 0-2);
- $II_{i,t}$  - share of population attained upper secondary and post-secondary non-tertiary education (ISCED11 levels 3 and 4);
- $III_{i,t}$  - share of population attained tertiary education (ISCED11 levels 5-8);
- 9;12;15<sup>22</sup> represent average years of schooling in each category accordingly.
- Working Population Growth Rate ( $n$ ): annual growth rate of population aged 15-64 years in percent. (EUROSTAT Population and Social Conditions);
- Tax Burden: total tax revenue as a ratio of GDP. (EUROSTAT Government Statistics);
- Log Trade Openness: sum of imports and exports as a share of GDP in percent. (EUROSTAT National Accounts);
- Expenditure on Research & Development: gross domestic expenditure on R&D as a share of GDP in percent. (EUROSTAT Government Statistics);

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<sup>21</sup> International Standard Classification of Education 2011

<sup>22</sup> ISCED 1+2 typical cumulative duration is 9 years; ISCED 3+4 typical cumulative duration is 12 years; ISCED 5 on average is additional 3 years of schooling. As ISCED 5 to ISCED 8 is additional 2-10 years, author assumed minimal years of schooling necessary to obtain tertiary education (15).

Tax indicators expressed as respective tax category revenue as a ratio of total tax revenue. Tax categories are based on EUROSTAT tax classification (reference in brackets). (EUROSTAT Government Statistics);

- Income Taxes & Social Security Contributions: Current taxes on income, wealth, etc. (D5) and Net social contributions (D61);
- Private Income Taxes & Social Security Contributions: Taxes on individual or household income including holding gains (D51A\_C1) and Net social contributions (D61);
- Corporate Income Taxes: Taxes on the income or profits of corporations including holding gains (D51B\_C2);
- Consumption Taxes: Taxes on production and imports (D2);
- VAT Type Taxes: Value added type taxes (D211);
- Other Consumption taxes: Other taxes on production (excl. Property Taxes) (D29 excl. D29A);
- Property Taxes: Taxes on land, buildings and other structures (D29A);
- Consumption Taxes (excl. Property Taxes): Taxes on production and imports (excl. Property Taxes) (D2 excl. D29A)

## Appendix C: Estimation results from Arnold et al. (2011)

Estimated Cross-country Effects of the Tax Mix on Long-run GDP per Capita from Arnold et al. (2011)

Dependent variable: log GDP p.c.	(1)	(2)	(3)	(4)	(5)
<b>Baseline model</b>					
Physical Capital	0.18*** (0.05)	0.25*** (0.14)	0.18*** (0.05)	0.16*** (0.05)	0.21*** (0.45)
Human Capital	1.19*** (0.13)	1.30*** (0.12)	1.18*** (0.13)	1.40*** (0.11)	1.57*** (0.11)
Population Growth	-0.08*** (0.01)	-0.08*** (0.01)	-0.07*** (0.01)	-0.07*** (0.01)	-0.07*** (0.01)
<b>Control variable</b>					
Overall tax burden (Total revenues/GDP)	-0.27*** (0.05)	-0.24*** (0.05)	-0.26*** (0.05)	-0.22*** (0.04)	-0.14*** (0.04)
<b>Tax structure variables</b>					
Income taxes	-0.98*** (0.20)				
Personal income taxes		-1.13*** (0.19)			
Corporate income taxes		-2.01*** (0.32)			
Consumption and property taxes			0.93*** (0.20)		
Consumption taxes (excl. property taxes)				0.74*** (0.18)	0.72*** (0.19)
Property taxes				1.45*** (0.43)	
Property Taxes: recurrent taxes on immovable property					2.47*** (0.84)
Property Taxes: other property taxes					-0.34 (0.51)
Observations	696	675	696	696	698
Omitted tax variable	Consumption Taxes		Income Taxes & Social Security Contributions		

Notes. \* Significant at 10 % level; \*\* at 5% level; \*\*\* at 1 % level. All equations include short-run dynamics, country-specific intercepts and country-specific time controls. Standard errors are in brackets.

Source: Arnold, Jens, Bert Brys, Christopher Heady, Asa Johansson, Cyrille Schwellnus and Laura Vartia. 2011. Tax policy for economic recovery and growth. The Economic Journal 121: 59-80.

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