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The Effect of Personal Income Tax Progressivity on Output Volatility: the Role of Non-linearity

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Abstract

The paper examines the relationship between personal income tax (PIT) progressivity index and real gross domestic product (GDP) growth volatility, focusing on the potential non-linear relationship. The economic theory suggests that automatic stabilizers are mechanisms that reduce the fluctuations of business cycle. While tax progressivity has stabilizing properties, it is also associated with economic efficiency loss which points to the possible non-linear link between PIT progressivity and output fluctuations. The two main conclusions we make based on the empirical analysis: no non-linear relationship between PIT progressivity and output volatility can be observed in the period from 2000 to 2012 in a sample of OECD countries; and the negative effect of PIT progressivity index and output volatility persists and can be observed in a data sample including after-crisis period.

Keywords: tax progressivity index, personal income tax, automatic stabilizers, output volatility, non-linearity

1. Introduction

We examine the relationship between personal income tax (PIT) progressivity index and real gross domestic product (GDP) growth volatility. Output volatility is an important indicator of the strength of economy. Therefore, as one of the long-term goals for policy makers in any country is to be less exposed to global economic and/or financial shocks and maintain a stable growth level. The economic theory suggests that automatic stabilizers are mechanisms that reduce the fluctuations of business cycle.

Government size and the progressivity of tax structure are two measures known for having strong stabilizing characteristics. The relationship between government size and economic stability has been widely examined in the literature and points to the stabilizing properties of government size on the economy. We focus our research on the progressivity of tax schedule and its effect on economic fluctuations. More specifically, it is suggested that the optimal tax structure, that is stabilizing and growth promoting, should be shifted towards the least distorting taxes and as personal income taxes have the most distortionary characteristics, we look at the personal income tax progressivity. In a progressive taxation schedule, the highest-earning population pays bigger fraction of their incomes in taxes, while people in lower-income brackets are facing a lower tax rate. The stabilizing effect comes from people shifting from one income bracket to another during the business cycles. When economy is booming, more people fall into a higher tax bracket and pay bigger fraction of their income in taxes, thus, constraining the increase of their disposable income. This automatic, built-in mechanism bounds the aggregate demand by not allowing it to increase excessively in times of economic boom; in a similar way, recession does not cause a sharp drop in the aggregate demand. Consequently, it produces a smoothing effect on output volatility.

While helping to smoothen fluctuations of the business cycle via automatic stabilization, progressive taxation is mainly used as a tool for improving income inequality. However, there is an extensive line of evidence showing that progressive taxation also lowers the economic efficiency by slowing down GDP growth and adjustments to economic shocks. This creates a trade-off between improved stabilization and income distribution and increased economic efficiency. Since 1980s, progressive taxation has been disregarded due to its negative effect on efficiency, be that as it may, the beginning of 2000s showed its importance in the discussion among policy makers as a tool in solving income inequality. Moreover, after the Great Recession, progressive taxation regained topicality with many countries shifting their tax structures towards being more progressive (Godar & Truger, 2017). Also, today the relevance of progressive taxation has not diminished as one of the more recent OECD member states Latvia, has increased the progressivity of its personal income tax structure as of January 2018.

The initial influence of this paper is the research done by Rieth, Checherita-Westphal, & Attinasi (2011). They employ the difference between average and marginal tax rates to estimate the effect of PIT progressivity on output volatility in OECD countries. The authors conclude that, *ceteris paribus*, output volatility decreases as tax system becomes more progressive. Our research aims to extend the study done by Rieth et al. (2011) exploring the potential non-linearity associated with this relationship which serves as the novelty of our paper. More specifically, we set out to test if there is a level of progressivity at which the effect of the index on output volatility diminishes or even reverts.

The motivation behind exploring the potential non-linear effect in the relationship between PIT progressivity and output volatility is based on the contradicting evidence in the literature related to this link. While much of the economic theory suggests that increasing tax progressivity implies a trade-off between economic efficiency and stability, Martinez-Mongay and Sekkat (2005) argue that this may not necessarily be the case. Using a theoretical AS-AD two-country model, the authors explain that the effect of tax reduction on output volatility can be either positive or negative and the effect is dependent on the structure of the taxation system. Their results suggest that there exists a robust non-linear relationship between taxation (tax cuts/increases) and output volatility, however this relationship depends on the tax structure in the country. Martinez-Mongay and Sekkat (2005) also have provided an explanation from the economic theory perspective. They describe an example for how PIT progressivity slows down the speed of supply adjustment during economic shocks.

In addition, the overall effect in the relationship of interest is ambiguous due to the different channels involved in directing this link. Padovano and Galli (2002) elaborate on the inefficiencies caused by progressive taxation, finding that there is a negative relationship between tax progressivity and economic growth. Rieth et al. (2011), on the other hand, described a negative link between progressivity and output volatility.

According to the above-mentioned findings, an increase in tax progressivity should contract both output growth and volatility, while Lin and Kim (2013) provide evidence of a negative link between output volatility and growth.

Furthermore, we contribute to the current literature by extending the empirical analysis of the linear relationship between PIT progressivity and output volatility discovered by Rieth et al. (2011). We include the crisis years in the sample period, which might give meaningful insights about the relationship due to the high exposure of the dependent variable to economic crisis. Also, we expand their work across more geographies, by including more countries in the sample, such as the new OECD members, adding to the novelty of our paper.

We define our research questions:

RQ1: Can the negative relationship between personal income tax progressivity and output volatility be observed in a sample including after-crisis data?

RQ2: Is there a non-linear relationship between personal income tax progressivity and output volatility?

The remainder of the paper is structured as follows. The Section 2 presents a summary of the relevant literature on automatic stabilizers and their measures and functions in relation with economic stabilization and efficiency. Section 3 turns to detailed description on the variables used and analyzes of the specifics of the data sample. Section 4 presents the empirical analysis of the models. Section 5 describes the results, connects our research with the existing literature, and elaborates on the limitations. Section 6 concludes.

2. Literature Review

We begin our literature review by explaining the economic mechanisms behind automatic stabilizers and look at one of the main determinants of their size - the size of general government sector. The following section provides a comparison between the distortionary effects among different tax types and introduces to the literature available on the relation between tax progressivity and output volatility. The last section describes the implications of tax progressivity on economic efficiency.

2.1. Automatic stabilization and government size

Automatic stabilizers are monetary or fiscal mechanisms that stabilize the fluctuations of business cycles. These mechanisms are said to function automatically because they do not require specific government initiation decisions. The primary goal of automatic stabilizers is to prevent an economy from overheating due to excessively high growth rates in times of economic expansion and to foster the economic activity in times of recession by smoothening the aggregate demand. Personal and corporate income taxes and government size are the most common proxies of the size of automatic stabilizers. By construction, progressive taxation provides larger stabilizing properties than flat tax structure. When incomes are decreasing, people find themselves in a lower tax bracket which prevents their disposable income from decreasing faster. The opposite effect is in place when the economy is growing - faced with higher tax rates, households lower their consumption which bounds the aggregate demand.

The current empirical literature has mostly looked at two major determinants of size of automatic stabilizers. One of the determinants of the size of automatic stabilizers is the size of government spending. According to OECD (1999), the size of government sector is the most important determinant of the economic stability. Several authors have consistently documented negative relationship between these variables.

Debrun, Sapir, and Pisani-Ferry (2008) explain that it has long been argued by economists that according to the Keynesian tradition, larger governments have had a positive impact on economic stability due to the close relation of the size of government expenditures to the size of automatic stabilizers. They refer to the contribution by Blinder and Solow (1974) who argue that this stabilization effect is achieved by reduced liquidity constraints to households during exogenous economic shocks which, hence, reduce the impact on the aggregate consumption and output.

The seminal paper by Gali (1994) uses a sample of OECD countries and applies the data to a real business cycle model to test the predictions of the traditional Keynesian view on automatic stabilizers. The author finds that government size is inversely related to output volatility - for countries such as Japan, Portugal, and Spain, the output fluctuations are higher than for countries with larger governments (e.g. Norway, the Netherlands, Sweden).

Fatás and Mihov (2001) in their paper "Government size and automatic stabilizers: international and intranational evidence" replicate and extend the work done by Gali (1994) to a sample of OECD countries and across the US states. They also introduce a large set of control variables and alternative methods of estimation to reaffirm the strong negative relation between government size and output volatility. By using two datasets, the authors both increase the robustness of the results and address the issue raised by Rodrik (1998) who pointed to the potential reverse causality issue between government size and volatility.

An important contribution to this topic has been made by Silgoner, Reitschuler, Crespo-Cuaresma (2003) who examined the possibility of non-linear relationship between government size and output volatility. The authors find supporting evidence of non-linear relationship and report that the smoothing effect of government size on output volatility even reverts at very high government expenditure levels.

2.2. Tax structure and economic stability

Since the economic crisis there has been wide debate on the mechanisms that could correct the inefficiencies in the economy in terms of its stability and exposure to economic shocks. Many academics have expressed the need to exploit the stabilizing functions of tax structure with a consensus that within the optimal tax structure the tax revenues are shifted towards taxes that produce least distortions to the economic growth. The discussions are continuing, however, an overlapping conclusion across the literature is that taxing income has the most distorting effects on economic growth. Some of the findings include that income taxes disregard the individual preferences for savings, reduce the risk-taking activities of entrepreneurs and shrink GDP per capita (Xing, J., 2011, Arnold, 2008). Taking this into account, our research focuses specifically on personal income taxes and its effect on economic stability.

A paper by Ismael (2011) examines the relationship between progressive taxation and macroeconomic stability using the overlapping generations (OLG) model. The model assumes that in the first of two periods agents split their income between savings and consumption, and they spend the entire savings-generated income in the second period. The basic finding is that progressive labor-income taxation at high levels has destabilizing properties, because it increases the possibility of endogenous fluctuations created by the divergent effects of interest rates and wages on savings. This conclusion, however, goes against the results documented by Dromel and Pintus (2006) who find stabilizing properties of taxation policy. Ismael (2011) claims that such differences are explained by the different assumptions used in the OLG model, namely, Dromel and Pintus (2006) assume that income is spent only in the second period, and tax is imposed on capital income, instead of labor income.

Andrés and Doménech (2006) conclude that distortionary income taxes (proportional wage-income taxes) are negatively related to output volatility given that economic frictions such as price stickiness and capital adjustment costs are present. They stress that these frictions must be in place for the effect to be observed, otherwise the distortionary taxes have the opposite effect on output volatility.

This negative relationship is also supported by Moldovan (2010). She studies the impact of countercyclical taxation on aggregate variables such as output, investment, and consumption. While the results indicate that countercyclical taxes stabilize aggregate output, they also have smoothing effect on investment and consumption. Nevertheless, the author points out to the negative long-run consumption effects caused by the decreased volatility, which may overshadow the stabilization effect.

Martinez-Mongay and Sekkat (2005) further test the theoretical predictions on a sample of 25 OECD countries. The question proposed is whether countries with identical GDP, government sizes, and production structures, but a different tax-mix, could experience different stabilizing/destabilizing effects. The authors use two approaches to estimate stabilization effects of distorting taxes - first, using several time periods characterized by different distortionary tax levels; second, using an interaction term between government size and labor effective tax rate (indicator for distortionary taxes). Both approaches affirm the predictions of the theoretical model, namely that higher distortionary effect of taxes lead to a lower stabilizing effect of government size on output.

Rieth et al. (2011) explain that one of the major channels through which automatic stabilizers diminish the output fluctuations is the reaction of government revenues and expenditures to the business cycle which provide a smoothening effect on private disposable income. The size of this channel is driven by the level of progressivity of the taxation system. While completely flat tax system causes the tax revenue to move proportionally with the changes in income, in a progressive tax system a marginal increase in income will lead to a higher average tax rate. Their findings support the stabilizing properties of progressive taxation. More progressive the tax system, the stronger automatic stabilizers and, hence, lower output volatility.

Weller and Rao (2008), discuss different channels through which progressive taxation may lead to lower output volatility. One of such channels is through reduced income inequality - ensuring provision of more equal distribution of disposable income to households, progressive taxation can reduce output volatility. Another channel that might affect economic stability is economic growth, however, the authors mention that its effect cannot be easily deducted. Growth may be hindered or promoted by skill formation, yet this factor is dependent on labor elasticity of low wage workers or individual preferences. Also, the effect of progressive taxation on capital formation is ambiguous. Employing univariate and multivariate analysis, the authors conclude that both short-run and long-run output fluctuations are reduced with higher levels of progressivity.

2.3. Tax progressivity and economic efficiency

As mentioned earlier, the existing literature points to the potential trade-off between achieving higher economic stability and income equality and improving economic efficiency as a result of increased tax progressivity. Apart from having stabilizing properties on output discussed above, another positive aspect of tax progressivity also touched upon above is that it is known to reduce income inequality.

Several authors have documented this relationship - Carroll and Young (2011) examine the long-run effect of tax progressivity on income inequality. They employ a framework that models an economy with three sectors - households, government, and firm and make assumption of heterogeneity of households and absence of idiosyncratic risk. The authors conclude that income inequality is decreased by increasing tax progressivity. However, there are additional implications, some of which relate to economic efficiency, - higher tax progressivity also increases wealth inequality and reduces labor supply. Moreover, Echevarría (2014) adds to this line of evidence by approving progressive tax system's ability to correct the unequal income distribution. Additionally, the author shows that due to the downward pressure on aggregate savings, tax progressivity negatively affects the growth rate of the economy. As opposed to Echevarría (2014), Weller and Rao (2008) conclude that besides correcting income inequality, progressive income taxation also strengthens financial development, economic growth and domestic fixed capital formation by ensuring "more stable, long-term financial resources and a greater ability of policymakers to engage in countercyclical fiscal policies" (Weller & Rao, 2008).

Additionally, there is evidence that the inefficiency problems may be caused through decreased volatility. Bakas, Chortareas, and Magkonis (2017), emphasize that there is a line of research providing evidence that economic growth may be slowed down with lower volatility. The authors refer to Fountas and Karanasos (2006) who use Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model to examine the relationship between uncertainty about output growth (proxied by the variance of shocks to output growth) and output growth in Japan, USA, and Germany. They conclude that higher uncertainty about output growth positively relates to output growth. Similar conclusions are made by Kormendi and Meguire (1985) and Caporale and McKiernan (1996).

Ramey and Ramey (1995) studies the effect of output volatility on long-term growth and provides opposing evidence. In a sample of 92 countries as well as a sample of OECD countries, controlling for time and country-fixed effects, they find that countries with higher output volatility experience lower growth. This finding is supported by Philippe Martin, Carol Ann Rogers (2000) and Lin and Kim (2013), who find that countries and regions that have a higher standard deviation of output have lower growth rates.

Padovano and Galli (2002) contribute to this line of research and find a direct link between tax progressivity and output growth. They report a negative relationship between tax progressivity and economic growth. More specifically, the authors show that by increasing marginal tax rates and/or tax progressivity by 10 percent, the annual economic growth rate decreases by 0.23 percent with this effect diminishing if estimated within a time window that exceeds ten years.

Furthermore, in a simple AS-AD two-country model Martinez-Mongay and Sekkat (2005) have explored how tax structure of a tax system can influence the effect between tax cuts and output growth volatility. They have provided an explanation from the economic theory perspective. According to the authors, the existence of automatic stabilizers such as countercyclical taxes makes incumbents less responsive to economic shocks. In a situation of a sudden increase in inflation, the demand for goods exceeds supply as people lose incentive to save. In response to this, producers willing to increase supply are constrained. They need to hire more workers and pay higher wages due to inflation, on top of that the workers end up in higher income brackets, hence, the higher personal income tax is applicable to them. Because of additional production expenses, supply cannot adjust to increased demand as fast and reaches a new equilibrium much slower.

3. *Methodology*

3.1. Data description

The data compiled for the analysis is an unbalanced panel of 35 OECD member countries for the time period from 2000-2016. We obtain most of our data from OECD database (see *Appendix A* for the list of variable description and sources).

There is no publicly available data for output volatility or personal income tax progressivity index - we calculate them for the purpose of this research. Following Rieth et al. (2011) and other studies (Fatas and Mihov (2001) and Carmignani, Colombo, and Tirelli (2011)), output volatility - dependent variable in our model - is measured as the standard deviation of log changes of real GDP (*vola*). We calculate output volatility over 4-year fixed windows[1] to keep the number of observations high enough, to ensure the efficiency of our regression estimates, and to account for cyclical factors (we recognize the fact that a four-year window does not reflect a full business cycle).

Regarding the PIT progressivity index - different authors have presented various approaches to obtain this measure. As suggested by Musgrave and Thin (1948), a tax system is assumed to be progressive if the average tax rate increases as incomes rise. This means that the marginal tax rate is bigger than the average rate as incomes have an incremental increase. The authors have described four ways to calculate the index along with arguments favoring and opposing the use of them. These methods are popular and have been used in the academic literature. However, akin to the research done by Rieth et al. (2011), these measures are not applicable in our case due to their demand for accurate microdata. This particular data is not available for multiple countries and/or years, therefore, would significantly reduce the sample size. Another widely used measure was estimated by Slitor (1948). This measure again is not applicable in our case because it is used for calculation of tax progression at a specific income level and is aimed at calculation of progressivity index for a toll tax schedule. All the previously mentioned measures have later been regarded by Kakwani (1977) as weak. He then presents his own measure that, based on data from four countries (Australia, Canada, United Kingdom, USA), is assumed to be superior at accounting for the average tax rate. There is still

[1] Sub-periods: 2001-2004; 2005-2008; 2009-2012; 2013-2016.

uncertainty regarding the measures and the search for the undisputed one is ongoing. In this study, we follow the approach used by Rieth et al. (2011) and for PIT progressivity index calculation employ the formula estimated by Arnold (2008) that is considered a direct measure of personal income tax progressivity. We use the following formula:

$$Progressivity\ index = 1 - \frac{100-MTR}{100-ATR} \qquad (1)$$

Equation (1). PIT progressivity index (Rieth et al., 2011; Arnold, 2008).

where, *MTR*[2] and *ATR*[3] are marginal and average tax rates, respectively. Higher progressivity index value implies more progressive tax structure (Rieth et al., 2011)[4]. In 2005 OECD broadened the definition of Average production wage (APW) on which *MTR* and *ATR* calculations are based. The updated definition includes additional industry sectors and both manual and non-manual workers, which would overestimate the index after year 2005 meaning that additional data manipulations are required (Rieth et al., 2011). However, OECD has adjusted the pre-2005 data for the new definition, hence the data is comparable and does not require additional adjustments (Benefits and Wages: OECD Indicators, 2007). We calculate average values of PIT progressivity index over the determined 4-year fixed window sub-periods.

3.1.1. Control variables

For the control variables we follow the two sets of variables chosen by Rieth et al. (2011). We calculate average values of all control variables over the determined 4-

[2] *MTR* is calculated as the combined central and sub-central government income tax plus employee social security contribution for a single person without dependent at 100% of the (Average Wage)/ (Average Production Wage) multiple.

[3] *ATR* is calculated as the combined central and sub-central government income tax plus employee social security contribution for a single person without dependent at 100% of the AW/APW multiple.

[4] OECD offers multiple specifications for *MTR* and *ATR* calculations the difference being in the percentage of the AW/APW multiple that is applied. We tested progressivity indices calculated with other fractions of the multiple applied to *MTR* and *ATR*, however, 100% percent of the multiple shows the highest significance in relation to the dependent variable.

year fixed window sub-periods.

First set consists of variables that are included to capture the part of changes in output volatility due to openness of economy. Rodrik (1998) finds empirically sound evidence to the argument that countries that are more exposed to external shocks (most open economies) have larger governments compared to closed economies. Hence, the first set of controls accounts for this relationship. *Set 1* includes three variables: trade openness (*Open*) - the sum of total exports and imports over GDP; the standard deviation of log changes in purchasing power parity (*PPP*); percentage of people employed in the industry (*Industry*).

Second set of variables control for the size of the government that have been used in the existing literature by Fatas and Mihov (2001) and Crespo, Reitschuler & Silgoner, (2011). *Set 2* includes: two GDP ratios as proxies for government size - total government expenditures over GDP (*Expend*) and total revenues over GDP (*RevTot*)[5]; credit to private sector over GDP (*Credit*) as proxy for the development of the financial sector; total real GDP adjusted for PPP (*GDP*) and GDP per capita adjusted for PPP (*GDPpc*), and growth rate of real GDP (*Growth*)[6] to account for the economy size.

3.1.2. Basic statistics

The summary statistics of the PIT index across countries is presented in *Appendix B*. The table indicates that the countries with the highest mean PIT progressivity index over our sample period are Hungary, Luxembourg, and Germany equaling 0.294, 0.274, and 0.245, respectively. The lowest progressivity indices in the sample are 0.00 (Chile)[7],

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[5] As both Expend and RevTot are measures of government size and different authors have argued in favor of both variables to be used as proxies for government size, we test them as controls in the regressions by adding each of them separately and assessing the effect on the main variables.

[6] Even though previous studies have used GDP growth as an explanatory variable of output volatility, there is evidence that output volatility might affect economic growth, not vice-versa (see Ramey & Ramey, 1995). However, it is important to keep in mind that in our study we do not consider the potential reverse causality issue.

[7] The values of MTR and ATR remain constant at 7 across all sample period.

0.032 (Poland), 0.041 (Latvia), and 0.048 (Estonia), while Australia, Spain, and United States with index values of 0.131, 0,135, and 0.143 are positioned around the middle of the list. The differences in country rankings based on PIT index used for this research and those of previous studies are mainly because of the sample period and included countries. Rieth et al. (2011), for example, uses a sample that does not cover the after-crisis years and does not include countries joining OECD more recently, such as Latvia and Estonia that also show low progressivity index values.

As mentioned before, PIT progressivity index can range from 0 to 1. We believe that when progressivity index values increase to a certain level, the magnitude of its effect on output volatility may diminish or even revert. In our sample, the mean value of the index is 0.145 and the biggest fraction of observations are distributed between the values from 0 to 0.3, some are between 0.3 and 0.6 with none being above 0.6 (see Figure 1).

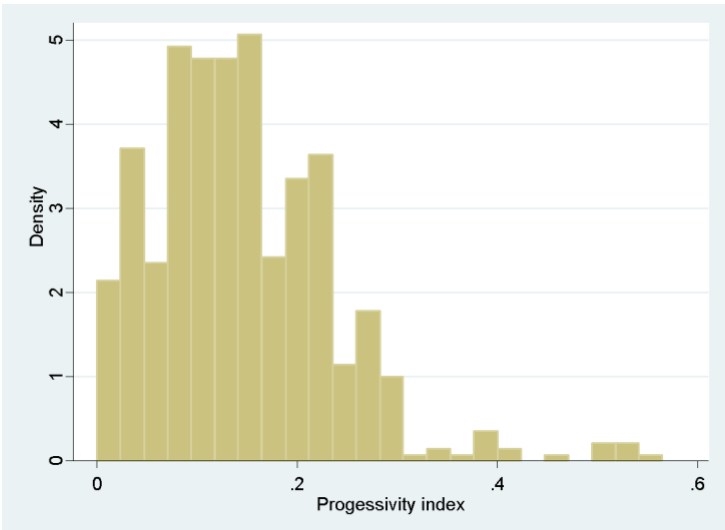

Figure 1. PIT progressivity index histogram. Made by the authors.

Figure 2 below presents the mean PIT progressivity index in our sample across countries and over years. The graph depicts that tax reform policy makers have faced a trade-off between efficiency (such as efficient allocation of capital) and correcting income inequality (distribution via progressive taxation). The stabilizing function had been disregarded since 1980s - the policy makers' preferences shifted towards economic efficiency improvement and the top income rates together with progressivity index started to decline in both OECD and EU countries (Rieth et al., 2011, Godar & Truger, 2017). In the beginning of 2000s, the income inequality was considered to be a more important issue, therefore tax reforms were aimed at correcting it via the distribution functions of tax structure. After the Great Recession, it was recognized again that tax progressivity is stalling efficiency, hence the decline in progressivity index after year 2008. In 2011, however, the stabilization function was again brought back into the light, and progressive taxation became increasingly topical. Since 2013, the mean progressivity index has been declining, in line with the literature - several European Union countries have been shifting away from distribution functions of tax structure and prefer tax structures that are oriented towards more efficient allocation of capital (Godar & Truger, 2017).

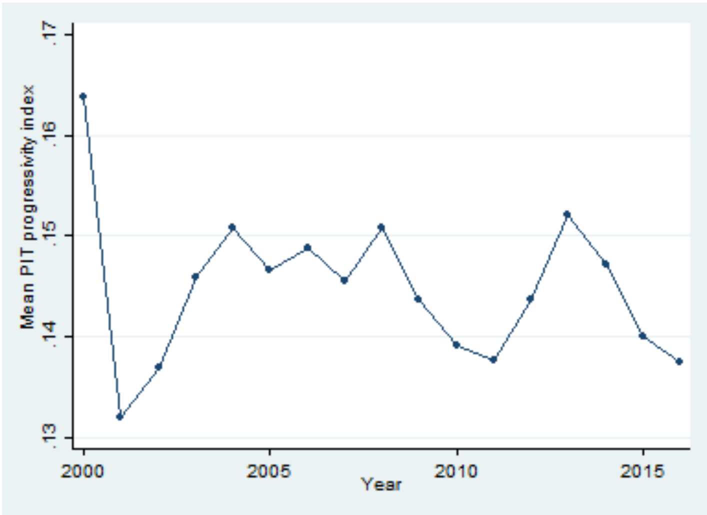

Figure 2. Mean of PIT progressivity index across countries, over time. Made by the authors.

Summary statistics on GDP growth across countries is included in *Appendix C*. As expected, the larger developed economies such as United States, Australia, bigger European countries and Scandinavian countries have had less fluctuations in GDP growth over the sample period. Greece, Ireland and smaller economies, such as the recent members of OECD - Latvia, Estonia - have experienced larger business cycle fluctuations. As mentioned before, we split our sample in four fixed window sub-periods, calculating output volatility as the 4-year standard deviation of log changes of real GDP. The length of our sample period does not allow us to capture a full business cycle as the number of observations would be too small. From this manipulation we get that the average output volatility in our sub-periods across all countries are 1.34 for years 2001-2004, 2.11 for 2005-2008, 3.50 for 2009-2012 and 1.01 for 2013-2016. These values coincide with the Figure 3, which shows the mean of GDP growth across countries over time. The last four years (2013-2016) are the least volatile, while sub-period 2009-2012 includes years with noticeably larger changes in the mean GDP growth.

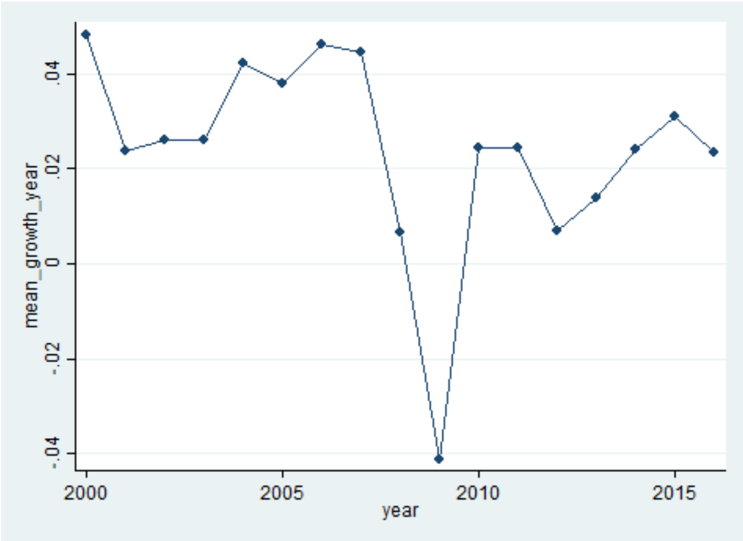

Figure 3. Mean of GDP growth rate across countries, over time. Made by the authors.

From the Figure 4 we see one observation set far apart from the main cluster of observations. For Ireland (which is associated with this observation) the standard deviation of output volatility in the period from 2013 to 2016 is over 10 percent. This strong movement comes from the GDP growth in 2015 which reached 26.3%. This rapid expansion was due to the openness of Ireland's economy and the low tax on corporate profits which both attracted large corporations with valuable assets. Many international companies acquired smaller players in Ireland, thus creating an influx of funds. More importantly, they relocated their main operations and brought high value assets (mostly intellectual property products (IPP)) to Ireland. Therefore, all revenues created using this IPP suddenly contributed to Ireland's GDP. Although the value coming from IPPs is included in the GDP and does reflect the real economy, we believe that this is a highly unlikely event and exclude this observation when performing empirical analysis to avoid the results being influenced by this obvious outlier (Irish GDP up by 26.3% in 2015?, 2016).

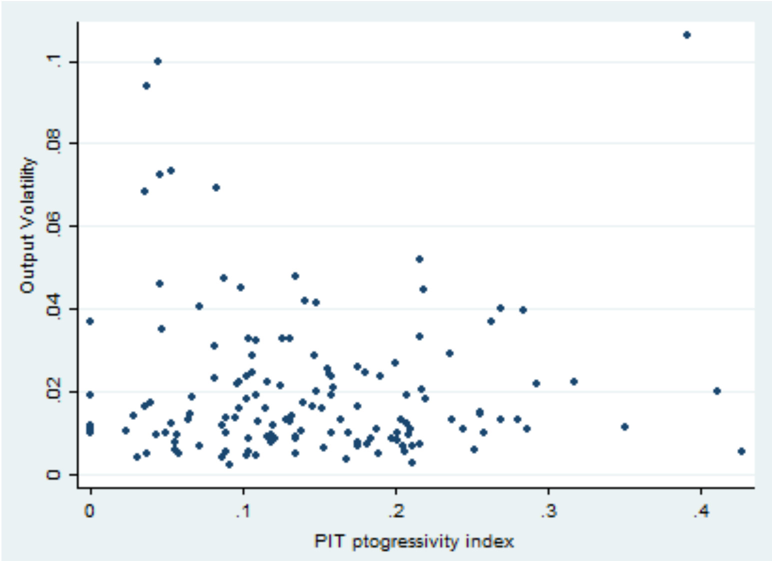

Figure 4. Scatter plot of output volatility and PIT progressivity index. Made by the authors.

3.2. Research design

The *longitudinal research design* is used to answer the research questions since it allows to observe changes of multiple variables among OECD countries over extended period of time. As our research question involves observing the changes in output, income tax progressivity, and other variables for different countries over the period of several years, the longitudinal research design will accommodate the use of multidimensional panel data. This research design has been used by authors who have examined similar topics, for example, the presence of non-linear effect of government size on output volatility (Silgoner et al., 2003), as well as by Rieth et al. (2011) who quantified the effect of tax progressivity on output volatility.

3.2.1. Empirical model

Our empirical approach will be based on the one used by Rieth et al. (2011). In the first empirical model, we attempt to estimate the effect of tax progressivity on output volatility. Following the Rieth et al. (2011) approach, we will obtain our estimates from OLS, random-effects (RE), and fixed-effects (FE) regressions. Our second model extends the first model by introducing the quadratic form of PIT progressivity index variable to test for the potential non-linear effect. In both models we account for various factors using to sets of control variables mentioned earlier.

We develop the following empirical models:

Model 1:

$$Volatility_{i,t} = \beta_0 + \beta_1(Progressivity_{i,t}) + \beta_3(Controls_{i,t}) + u_{i,t} \qquad (2)$$

Model 2:

$$Volatility_{i,t} = \beta_0 + \beta_1(Progressivity_{i,t}) + \beta_2(Progressivity_{i,t}) * (Progressivity_{i,t}) +$$

$$+\beta_3(Controls_{i,t}) + u_{i,t} \qquad (3)$$

where i = 1…35 (countries), t = time (4-year fixed windows), *Volatility* is the measure of output volatility, *Progressivity* is the progressivity index, *Progressivity*Progressivity* is quadratic form of progressivity index, *Controls* is control variables (described in Data description section), and u is error term.

3.2.2. OLS, fixed- and random- effects estimation

We begin by estimating our empirical model with *ordinary least squares* (OLS) regression. By using a set of control variables, we account for factors that also have a potential of affecting output volatility. We follow the approach used by Rieth et al. (2011) and firstly introduce only the set of controls associated with the openness of economies. We proceed by adding the other control variables to the regression associated with output volatility one by one. Moreover, the presence of heteroskedasticity in the residuals is accounted for using the robust standard errors function.

To assess the robustness of the estimates obtained by OLS regression, we re-estimate our model using *fixed-effects* (FE) regression. FE estimation allows to capture the unobserved country-specific institutional factors, that our independent variables do not take into consideration, but that are important in explaining the given relationship. Additionally, we estimate the results using *random-effects* (RE) estimation that assumes no fixed effects. We also introduce the Hausman specification test which allows to choose the model that provides the most appropriate and efficient estimates.

3.2.3. Instrumental variables estimation

Instrumental variables (IV) estimation is going to be used to address the endogeneity problems. One potential endogeneity problem was raised by Rodrik (1998) who finds that more volatile economies tend to have larger governments. The underlying argument is that in countries with more open economies voters consciously choose to have larger governments to better absorb the economic shocks, thus creating a simultaneity problem. As previously noted by Rieth et al. (2011), the evidence about the endogeneity problem of the government size in the literature is contrasting. Fatás and Mihov (2001) address the endogeneity of government size and are able to improve their OLS estimates by instrumentation. Debrun et al. (2008), on the other hand, are not able to detect differences between OLS and IV estimates by instrumenting government size variable. The instruments used by the mentioned authors have attempted to capture structural and institutional characteristics of the countries, while being exogenous from output volatility. For instrumenting the revenue and expenditure ratios, we use the instrument set initially chosen by Rieth et al. (2011) - a dummy for the type of political system (presidential or parliamentary), an index of checks and balances of the executive authority, the rate of urbanization, and a dummy identifying Anglo-American countries. According to Persson and Tabellini (1998), countries with presidential regimes tend to have smaller governments. They show that larger competition among politicians along with a more direct accountability induces less government spending. The index of checks and balances reflects the degree of competitiveness with which the executive power is elected. Fatas and Mihov (2001) argue that rate of urbanization is one of the standard determinants of the size of government. The underlying argument is that the provision of public goods requires more government spending in countries where more people live in non-urban areas.

Moreover, Debrun and Kapoor (2010) argue that credit-to-GDP-ratio could also be subject to problem of endogeneity since agents within inherently more volatile economies might utilize more financial tools to protect themselves against economic fluctuations. Following the aforementioned literature, we use share of employment in agriculture and the investment share in GDP are used as instruments for credit-to-GDP-ratio.

Regarding the PIT progressivity index, to our knowledge, literature has not yet estimated appropriate instrumental variables that are relevant and efficient for instrumenting PIT progressivity index. Although in one case PIT progressivity has previously been instrumented by Rieth et al. (2011), they use a set of instruments that is fitted for a government size measure rather than for PIT progressivity index. What is more, the same authors suggest that the variable might in fact not be endogenous. Their argument is that policy decisions about PIT progressivity are mostly aimed at social issue solving (such as income inequality) and backed by political and philosophical arguments, while higher stability of economic aggregates, in most cases, is not an argument for PIT progressivity. Still, the authors perform the tests and conclude that the variable, indeed is not endogenous. However, the authors argue that the endogeneity of government size and credit variables might affect the estimates of progressivity coefficients and thus they instrument progressivity anyway. As we demonstrate in the empirical analysis part of our paper, several measures point to the validity of the argument that PIT progressivity does not suffer from endogeneity issue.

4. *Empirical analysis*

4.1. Model 1

In the first stage of our empirical analysis we attempt to answer the first proposed research question. We examine if the linear negative relationship between PIT progressivity and output volatility discovered by Rieth et al. (2011) can also be observed in our data sample that includes the crisis and the aftermath of it[8]. This data is meaningful because during this period large scale fluctuations in the dependent variable (GDP growth volatility) can be observed across the sample countries. We also change the time window over which output volatility is calculated and include more countries.

Following the steps of the empirical analysis by the authors, we start by testing the model using ordinary least squares (OLS) estimation accounting for heteroskedasticity in residuals in all regressions.

4.1.1. OLS estimation

Table 1 reports the results obtained from OLS estimation. We begin by running the model on the complete data sample. The obtained results indicate that the expected negative relationship between PIT progressivity and output volatility is borderline significant. The coefficient on *Prog* has the expected negative sign but is significant at the 10% level in both reported model specifications where the full set of control variables is included (columns (1) and (2)).

Based on the observations made in the earlier *Basic statistics* section, further, we perform the OLS regressions excluding the last sub-period which notably alters the estimation results. The exclusion of the sub-period 2013-2016 improves the significance of the coefficient on *Prog* and it remains highly significant when including the control variables. These results reaffirm our initial observation that the most recent period in our sample reflects low output volatility. Thus, we report the results obtained from the estimation excluding the last sub-period as the final OLS results and treat the last sub-

[8] The sample used for this research is different from that of Rieth et al (2011) in several aspects - our sample constitutes of observations for 35 countries (versus 30) from 2000-2016 (versus 1982-2009), we use 4-year fixed window sub-periods (versus 7-year fixed windows).

period similarly in the following robustness checks and non-linear model. In columns (3) and (4), we run the model controlling only for the openness of economy and introduce control variables for government size. As explained earlier, both revenue- and expenditure-to-GDP ratios have been used in the relevant literature to account for the effect of government size on output volatility. Thus, we include both measures as control variables one at the time - revenue-to-GDP in column (3) and expenditures-to-GDP in column (4). In column (3), we can see that the effect of government size on output volatility is statistically insignificant and the effect of *Prog* on output volatility is significant only at the 10% level. Including expenditures-to-GDP ratio in column (4), the absolute value of *Prog* coefficient increases and improves its significance to 1% level. Still, the coefficient on *Expend* is insignificant similar to that of *RevTot*. In further model specifications we follow the existing literature that mainly uses expenditures-to-GDP ratio as a control for government size (also, it improves the significance of the coefficient on *Prog*). The coefficients on openness control variables - openness and log changes of PPP - are highly significant at the 1% level and positive indicating that more open economies indeed tend to be more volatile. The coefficients on *PPP* and *Open* remain highly significant across all model specifications.

We proceed by adding the rest of the control variables one by one in the subsequent regressions. Adding the control for financial development *Credit* does not noticeably affect the significance of *Prog* coefficient nor its absolute value. Moreover, financial development does not appear to have a statistically significant effect on output volatility. In columns (6), (7), and (8), we introduce measures controlling for the general size (GDP) and wealth (GDP per capita) of the economy, and the rate of economic growth (*Growth*). In all three specifications the significance of *Prog* coefficients drops to 5% level. All three measures have statistically significant effect on output volatility at least at 5% level.

The results indicate that the basic negative relationship between PIT progressivity and output volatility holds across all model specifications and remains statistically significant at least at 5% level.

Table 1. Progressivity and output volatility: OLS, 2000-2016 and -2012, fixed-windows of 4 years. Dependent variable: Sd. log changes of real GDP. Made by the authors.

	Full period		2013-2016 sub-period excluded					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Prog	-2.758*	-2.555*	-3.855*	-5.51***	-5.59***	-4.872**	-4.555**	-4.165**
	(1.653)	(1.485)	(2.084)	(2.001)	(2.050)	(1.978)	(1.979)	(1.722)
Open	0.449***	0.443***	0.228***	0.220***	0.234***	0.449***	0.523***	0.509***
	(0.118)	(0.110)	(0.064)	(0.060)	(0.066)	(0.102)	(0.114)	(0.114)
PPP	0.815***	0.731***	0.512***	0.867***	0.900***	0.768***	0.959***	0.867***
	(0.267)	(0.236)	(0.145)	(0.215)	(0.260)	(0.265)	(0.259)	(0.222)
Industry	4.355	5.194	2.542	1.996	4.017	1.706	2.312	3.789
	(3.317)	(3.337)	(2.905)	(2.831)	(3.808)	(3.993)	(3.984)	(4.006)
RevTot			-0.588					
			(2.262)					
Expend	2.962	-0.211		2.758	2.509	2.802	3.587	-0.396
	(1.895)	(2.057)		(2.332)	(2.391)	(2.254)	(2.247)	(2.205)
Credit	0.604*	0.402			0.223	0.573	0.411	0.195
	(0.351)	(0.399)			(0.417)	(0.382)	(0.388)	(0.438)
GDPpc	-0.47***	-0.432**				-0.462**	-0.528**	-0.486**
	(0.176)	(0.173)				(0.195)	(0.207)	(0.206)
GDP	11.785**	9.346**					16.562***	13.389***
	(4.754)	(4.493)					(4.948)	(4.748)
Growth		-22.168**						-24.437**
		(9.550)						(10.228)
Constant	-1.022	0.814	1.196	-0.345	-1.009	0.566	-0.194	1.871
	(1.765)	(1.870)	(1.058)	(1.265)	(1.886)	(2.084)	(2.050)	(2.068)
Observations	124	124	103	97	93	93	93	93
R-squared	0.271	0.320	0.271	0.300	0.287	0.313	0.351	0.412

(1) Robust standard errors in parentheses

(2) *** p<0.01, ** p<0.05, * p<0.1

4.1.2. FE and RE estimation

Further, we compare the results among OLS, fixed-effects (FE) and random-effects (RE) models as the first robustness check. FE estimation helps us to take into account different country-specific institutional factors that are constant over time and cannot be observed or controlled for in OLS estimation. RE estimates are also reported. Similar to the OLS estimation we account for possible heteroskedasticity in residuals across all regressions and exclude the last sub-period reflecting uncharacteristically low output volatility described in section *4.1.1. OLS estimation*. The results are reported in Table 2.

To compare the estimates, we return to the baseline model where openness is controlled for (*Open*, *PPP*). Additionally, we add control to account for wealth (*GDPpc*), and the government size (*RevTot* or *Expend)*. In column (1) OLS estimates are reported - the coefficients on *Prog*, *Open* and *PPP* are highly significant. In order to assess the appropriateness of the obtained coefficients from RE and FE estimations, we run the

Hausman test that is based on columns (2) and (4). With the p-value of 0, we can reject the null hypothesis that the difference in FE and RE coefficients are not systematic, hence, the estimates of FE are more appropriate and efficient (see *Appendix D*). In columns (2) - (7) RE and FE results are reported.

When running the model from column (1) using RE (column (2)) estimation, the *Prog* coefficient remains significant at 1 percent level, however, the absolute value of the it increases from -5.6 to -8.0. When *RevTot* is used (column (3)) instead of *Expend* the coefficient on *Prog* losses significance and decreases in absolute value (from -8.0 to -3.8). In both cases *Open* and *PPP* coefficients are positive and significant with at least 5% confidence level. This strengthens the conclusions from OLS estimation that more open economies are more exposed to global markets and, hence, more volatile.

In columns (4) to (7) FE estimation results are reported. We present multiple sensitivity checks. In column (4) we replicate model from column (1). In column (5) we replace *Expend* with *RevTot*, then in columns (6) and (7) we again insert expenditure ratio and add credit ratio and real GDP, respectively. Across all specifications, the basic negative relationship between PIT progressivity index and output volatility holds; coefficients on *Prog*, *Expend,* and *GDPpc* increase in absolute value and are significant at least at 5% confidence level. According to Rieth et al. (2011), the coefficients may increase due to the larger stabilizing role that might have been attributed to the control variables. The authors explain that by controlling for the unobservable country-specific factors in FE estimates, the potential for endogeneity bias in the equations becomes lower.

Table 2. Progressivity and output volatility: OLS, RE, FE 2000-2012, fixed-windows of 4 years. Dependent variable: Sd. log changes of real GDP. Made by the authors.

	OLS	RE		FE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Prog	-5.286***	-8.011***	-3.845*	-10.506***	-6.537**	-9.579***	-9.849***
	(1.949)	(2.198)	(2.005)	(2.780)	(2.463)	(2.837)	(2.756)
Open	0.317***	0.379***	0.350***	0.036	0.186	0.184	-0.008
	(0.098)	(0.119)	(0.113)	(0.234)	(0.207)	(0.229)	(0.250)
PPP	0.787***	0.802**	0.436***	0.353	0.265***	0.104	0.343
	(0.216)	(0.312)	(0.163)	(0.284)	(0.089)	(0.244)	(0.276)
GDPpc	-0.224	-0.178	-0.274	3.665***	3.608***	3.199**	3.896***
	(0.173)	(0.237)	(0.187)	(1.047)	(1.170)	(1.251)	(1.143)
Expend	2.908	6.895***		24.034***		22.734***	24.727***
	(2.242)	(2.638)		(5.932)		(7.301)	(6.452)
RevTot			0.499		5.560		
			(2.245)		(15.714)		
Credit						-0.203	
						(1.126)	
GDP							-67.038
							(82.997)
Constant	0.868	-0.667	2.411***	-20.132***	-11.718	-17.848***	-20.463***
	(1.166)	(1.564)	(0.862)	(5.048)	(8.017)	(5.911)	(5.229)
Observations	97	97	103	97	103	93	97
R-squared overall	0.307	0.291	0.281				
R-squared within				0.566	0.349	0.493	0.570
Number of country	34	34	35	34	35	34	34

(1) Robust standard errors in parentheses

(2) *** p<0.01, ** p<0.05, * p<0.1

4.1.3. Instrumental variables estimation

We continue assessing the robustness of the results using instrumental variables (IV) regression. Table 3 reports the results of IV estimation of *Model 1*. In columns (1) to (4) we report the specifications of the model instrumenting *RevTot* and *Credit* variables. We include the relevant statistics to evaluate the appropriateness of the instruments at the bottom of the table. As in the earlier estimations, we exclude the last sub-period reflecting uncharacteristically low output volatility.

The choice of instrumenting revenue-to-GDP instead of expenditure ratio is motivated by running a test of weak instruments. The rule of thumb suggests that if the first stage F-statistic is larger than 10, the model does not suffer from weak instruments problem. The test yields F-statistic of 13.52 using *president, checks, Urban,* and *Anglo_American* as instruments for *RevTot* while it is only 3.32 for instrumenting *Expend.* What is more, when testing weak endogeneity, the p-values using Wu-Hausman test are 0.15 and 0.57 for *RevTot* and *Expend*, respectively. Meaning that we can reject the endogeneity bias in *Expend* variable. Instrumenting *Credit* with *Agriculture* and *Investments* yields first stage F-statistic of 22.61. The p-value of Wu-Hausman test is very high (0.92), however, if *Credit* and *RevTot* are combined and instrumented together with their relevant instruments, the p-value decreases which confirms the use of the combination of potentially endogenous variables instrumented and validates the instrumental variables.

Regarding the potential endogeneity problem of PIT progressivity index described earlier, we take several measures to assess if the conclusion that the index is not endogenous is prevalent in our data sample. Testing the relevance of instruments using F-statistic, we observe F value of 16.98 which indicates relevance of instruments. Nevertheless, testing for weak exogeneity of *Prog* variable (with the given instruments) using Wu-Hausman test, we obtain p-value of 0.64, which does not allow to reject the exogeneity of *Prog*. Moreover, running an instrumental variables estimation treating *Prog* variable as endogenous does not yield meaningful results. This coincides with the conclusion by Rieth et al. (2011) who also fail to observe endogeneity of progressivity variable. Based on the aforementioned evidence, we proceed by running the model instrumenting only *RevTot* and *Credit* variables in various specifications.

We start by controlling for *Open, PPP,* and *Industry* first and then add *GDPpc, GDP,* and *Growth* controls in columns (2), (3), and (4) respectively. The results show that the negative relationship between PIT progressivity and output volatility is statistically significant at 5 or 1% level across all specifications. Similarly, the openness control variables remain significant, except for column (2) where the coefficient on *Open* loses significance. Across all specifications, p-values of the Wu-Hausman tests are very low (0 - 0.015) which allows us to reject the null hypothesis about exogeneity of the instrumented variables. Also, the over-identification p-values larger than 0.1 indicate the model does not suffer from overidentification.

The instrumental variables estimation indicates that the negative relationship between PIT progressivity and output volatility withstands the robustness checks and remains statistically significant when treating the potentially endogenous variables.

Table 3. Progressivity and output volatility: Instrumental variables estimation, 2000-2012, fixed-windows of 4-years. Dependent variable: Sd. log changes real GDP. Made by the authors.

	RevTot & Credit instrumented			
	(1)	(2)	(3)	(4)
Prog	-7.532**	-7.214**	-8.783***	-7.584***
	(2.955)	(2.902)	(3.337)	(2.781)
Open	0.195**	0.359	0.755***	0.655**
	(0.076)	(0.223)	(0.264)	(0.255)
PPP	0.733**	0.611**	0.906***	0.833***
	(0.300)	(0.285)	(0.287)	(0.236)
Industry	0.575	-1.753	-1.911	1.607
	(5.215)	(4.604)	(5.045)	(4.255)
GDPpc		-0.369	-1.038**	-0.756
		(0.398)	(0.477)	(0.464)
GDP			36.738***	26.771***
			(11.141)	(10.357)
Growth				-23.941**
				(9.951)
RevTot	9.559	10.623	22.432**	14.164
	(5.819)	(7.471)	(9.976)	(9.494)
Credit	-0.479	-0.306	0.074	-0.049
	(0.710)	(0.945)	(1.064)	(0.962)
Constant	-1.030	0.276	-2.937	-1.238
	(3.088)	(2.709)	(3.575)	(3.325)
Observations	93	93	93	93
R-squared	0.104	0.114	.	0.255
Wu-Hausm. p-value	0.003	0.003	0.000	0.015
Overid. p-value	0.459	0.216	0.882	0.183

(1) Robust standard errors in parentheses.
(2) *** p<0.01, ** p<0.05, * p<0.1.

4.2. Model 2

We move a step further in exploring the link between PIT progressivity and output volatility to see whether the effect of progressivity index can in fact be non-linear. To test this, we add a quadratic form of Progressivity index (*Prog_sq*) variable to the previous model and follow similar steps in analyzing the model as in the previous section.

4.2.1. OLS, FE, and RE estimation

Similar to the empirical analysis in *Model 1* we account for possible heteroskedasticity in residuals across all regressions and exclude the last sub-period reflecting uncharacteristically low output volatility described in section *4.1.1. OLS estimation*. We begin with OLS model regressing *vola* on *Prog* and *Prog_sq* carefully controlling for the openness of economy and adding other control variables one by one in the subsequent regressions. The results reveal that the expected quadratic relationship between PIT progressivity and output volatility does not seem to hold. Even though the coefficients on *Prog* and *Prog_sq* across all specifications are with the expected signs, they are statistically insignificant. Therefore, in Table 4 we only report the OLS regressions (columns (1) - (3)) where most or all of the control variables are used.

Next, we run the model using FE and RE estimations to see if they produce notably different results. We perform the Hausman test with the base regression (*Prog, Prog_sq, Open, PPP* included) for both RE and FE to see which method is more appropriate and efficient. Like in the previous section, the test returns a p-value of 0.0014 indicating that the FE estimates are more appropriate (see *Appendix E*). Nevertheless, we move on to perform both methods. The results of RE estimation are similar to those obtained by OLS - coefficients on *Prog* and *Prog_sq* remain statistically insignificant (Table 4 columns (4) - (6) report the results). FE estimation does not provide meaningful results - the coefficients are statistically significant, and, in some cases, we do not observe the expected signs on *Prog* or *Prog_sq,* thus they are not reported. As in *Model 1*, openness controls (*Open, PPP*) remain highly significant across all specifications in OLS estimation and significant with at least 5% significance in RE. Conclusions from *Model 1* are reaffirmed again regarding the importance of trade openness in the model. *GDPpc, GDP* are at least 5% significant across all specifications but *GDP* loses its significance, when GDP *Growth* variable is added. In the specifications reported, *Growth* is a significant determinant in the equation. The significance of other controls' explanatory power in both OLS and RE vary depending on the specifications and does not seem stable.

Table 4. Progressivity squared and output volatility: OLS, RE, 2000-2012, fixed-windows of 4 years. Dependent variable: Sd. log changes of real GDP. Made by the authors.

	OLS			RE		
	(1)	(2)	(3)	(4)	(5)	(6)
Prog	-12.600	-9.916	-12.110*	-11.153	-10.068	-12.241
	(7.909)	(7.792)	(7.093)	(8.994)	(8.919)	(7.951)
Prog_sq	19.879	13.732	20.346	10.497	8.611	17.829
	(16.714)	(16.258)	(15.161)	(19.771)	(19.506)	(18.220)
Open	0.414***	0.495***	0.467***	0.590***	0.645***	0.584***
	(0.098)	(0.109)	(0.111)	(0.127)	(0.149)	(0.132)
PPP	0.768***	0.933***	0.824***	0.671**	0.771***	0.585**
	(0.245)	(0.235)	(0.193)	(0.281)	(0.283)	(0.244)
Expend	3.057	3.684	-0.259	6.418**	6.584**	0.059
	(2.287)	(2.266)	(2.239)	(2.711)	(2.608)	(2.380)
Credit	0.525*	0.345	0.082	0.947**	0.729*	0.418
	(0.312)	(0.327)	(0.384)	(0.461)	(0.437)	(0.410)
GDPpc	-0.411**	-0.512**	-0.470**	-0.647***	-0.714***	-0.623**
	(0.183)	(0.198)	(0.190)	(0.246)	(0.271)	(0.257)
GDP		15.313***	11.489**		14.594***	8.087
		(4.895)	(4.956)		(5.350)	(6.293)
Growth			-24.420**			-28.764***
			(10.556)			(10.485)
Constant	1.395	0.875	3.600***	0.394	0.247	4.182***
	(1.192)	(1.158)	(1.325)	(1.327)	(1.234)	(1.313)
Observations	93	93	93	93	93	93
R-squared overall	0.321	0.352	0.413	0.301	0.332	0.396
Number of country	34	34	34	34	34	34

(1) Robust standard errors in parentheses
(2) *** p<0.01, ** p<0.05, * p<0.1

4.2.2. Instrumental variables estimation

To test the robustness of the results, we turn to IV estimation. The variables of interest for instrumentation are, similar as in *Model 1 - RevTot* and *Credit.* The choice to instrument revenue-to-GDP ratio instead of expenditure ratio which both measure the government size is motivated by the same arguments as in Section *4.1.3. Instrumental variables estimation* (larger first stage F-statistic). Additionally, we refer to the same motivation of excluding progressivity index from the endogenous variables list as for *Model 1*. As in the earlier estimations, we exclude the last sub-period reflecting uncharacteristically low output volatility. Table 5 presents the results obtained. As can be seen from the specifications reported, instrumentation does not seem to improve the significance on the neither *Prog* nor *Prog_sq* coefficient.

Table 5. Progressivity squared and output volatility: Instrumental variables estimation, 2000-2012, fixed-windows of 4-years. Dependent variable: Sd. log changes real GDP. Made by the authors.

	RevTot & Credit instrumented			
	(1)	(2)	(3)	(4)
Prog	-15.091	-9.983	-8.662	-12.010*
	(9.912)	(7.750)	(7.975)	(6.799)
Prog_sq	19.192	7.963	0.573	11.130
	(18.816)	(14.451)	(15.095)	(12.949)
Open	0.193***	0.323	0.716***	0.594**
	(0.050)	(0.222)	(0.258)	(0.257)
PPP	0.720***	0.645**	0.933***	0.813***
	(0.274)	(0.269)	(0.266)	(0.216)
GDPpc		-0.256	-0.924*	-0.659
		(0.422)	(0.481)	(0.481)
GDP			35.577***	26.156**
			(10.943)	(10.623)
Growth				-25.389**
				(10.564)
RevTot	11.613	9.894	20.898**	14.072
	(7.484)	(8.077)	(10.190)	(9.834)
Credit	-0.307	-0.282	0.061	-0.314
	(0.539)	(0.839)	(0.941)	(0.895)
Constant	-1.167	-0.181	-3.309	-0.383
	(2.240)	(2.003)	(2.797)	(2.805)
Observations	93	93	93	93
R-squared	0.076	0.134	.	0.245

(1) Robust standard errors in parentheses
(2) *** p<0.01, ** p<0.05, * p<0.1

5. *Discussion of results*

The results from the empirical analysis allow us to answer both of the proposed research questions. The analysis of *Model 1* suggests that there exists a negative relationship between PIT progressivity and output volatility in a data sample that includes after-crisis period. This result appears to be statistically significant and robust across different methodological approaches and multiple model specifications including various controls. During our empirical analysis, we observed that this relationship does not seem to hold when we use the whole sample period until 2016. Based on the data analysis carried out in section *3.1.2. Basic statistics*, we decided to test the same relationship excluding the last sub-period that captures years 2013-2016 which experienced the lowest fluctuations in the GDP growth. While excluding the last sub-period may ignore the fact that several economies experienced double-dip in terms of negative economic growth, our data set does not indicate long-lasting crisis impact - only few countries have shown negative growth rates after 2013 (Finland, Greece). The regression results using the shortened sample yield coefficients on *Prog* negative and statistically significant, affirming the negative relationship between PIT progressivity and output volatility. These results remain significant when RE and FE models are employed with FE estimates being more appropriate according to the Hausman test. Additionally, after instrumenting the potentially endogenous variables, we conclude that the estimated results are robust as the coefficients do not lose significance.

Based on the evidence, we see that one standard deviation (0.091 in our sample) increase in progressivity index reduces the output volatility by 0.38 on average. Whether this reduction in volatility is substantial or not, highly depends on the GDP growth fluctuations for the country of interest over the period. For Latvia, for example, which experienced relatively large volatility over the period, it would mean that an increase of PIT progressivity index by one sample standard deviation would reduce output volatility from 6.49 to 6.11, a decrease by 6%. Increase in the PIT progressivity index by one standard deviation, could, for example, be achieved by increasing the marginal tax rate in Latvia from 32 to 38 percent. For a country with lower output volatility over the period, such as Germany, the impact would be more pronounced - a decrease from 2.27 to 1.89 or 16.7% decrease.

As the relationship is broken by the inclusion of the last sub-period, we consider that the last four years of our sample comprises data that reflects uncharacteristically low volatility comparing to the periods before. We want to emphasize this finding as it might be that the effect of PIT progressivity index on output volatility is observable only during periods of relatively high volatility. This leads us to think that the effect of PIT progressivity index on output volatility is not as pronounced and the stabilization function takes place through other channels when economic fluctuations are low. Nevertheless, it is difficult to speculate based on purely theoretical considerations.

The fact that the coefficients on the right-hand side variables vary after inclusion of different control variables, highlights the importance of the channels through which the impact of index is directed. For instance, in Table 2 both government size variables - *RevTot* and *Expend* - are used in RE and FE estimations and noticeably affect the coefficient on *Prog*. Also, other controls do not show as large shifts in the coefficient values. The coefficients on *Prog* decreases in absolute value when the revenue side (*RevTot)* is used. It might be because it is more directly related to taxation, therefore, partly absorbs fraction of the explanatory power that PIT progressivity index would have alone and reduces the significance of the *Prog* coefficient. If the expenditure side (*Expend*) is used as the government size measure, the coefficient on *Prog* remains larger as it is less related to taxation.

The results obtained from the *Model 2* empirical analysis part allow us to answer the second research question. With *Model 2* we test whether a non-linear relationship can be observed between PIT progressivity and output volatility. Considering the extensive literature on the negative effects of progressive tax structure on economic efficiency it is expected that with high levels of PIT progressivity index these effects will become more forceful and the negative linear relationship will diminish or even revert and become positive. In order to empirically test the effect, the quadratic form of the PIT progressivity index variable (*Prog_sq*) is included in *Model 2.* Although the index proves to have a significant role in *Model 1*, the empirical analysis of *Model 2* shows that, when *Prog_sq* is added, coefficients on neither *Prog* nor *Prog_sq* are statistically significant in none of the different models' specifications. The results are robust as the significance is also not improved after the possible endogenous variables are instrumented in IV regression.

We propose potential explanations of why the non-linear relationship is not observable using empirical analysis tools and explain the limitations of our research. First, if our theoretical considerations hold and the effect of PIT progressivity on output volatility is indeed smaller or even changes sign and reverts at very high levels of PIT progressivity index, the research data sample should exhibit higher variation and include relatively high index values. In the section *3.1.2. Basic statistics* we show that, on a scale from 0 to 1, the vast majority of the PIT progressivity index values are concentrated in the range from 0 to 0.3, very few values fall between 0.3 and 0.6, and there are no observations larger than 0.6 (see Figure 1). We believe that high concentration of the index values and the small representativeness of observations with higher index values might reduce the ability of the estimator to capture the effect of increased progressivity index values variable on the output volatility.

Second, it might not be a coincidence that across observations of 35 countries and 17 years, none of the progressivity index values is greater than 0.6. For comparison, in the summary statistics table provided by Rieth et al. (2011), none of the values exceeds 0.47 with the mean being 0.16 (0.15 in our data sample). It may be either that the non-linear relationship does not exist, or the required PIT progressivity index level is not observable or even reasonable enough to be considered by the policy makers for implementation in real economies.

In both *Model 1* and *Model 2* empirical analysis, it is noticeable that some variables tend to maintain their significance in equation across most specifications. According to the results, trade openness variables (*Open, PPP*), *GDP,* and the growth of real economy (*Growth*) have a significant role in explaining the output growth volatility. The mentioned control variables remain significant in *Model 1* and *Model 2* OLS and RE estimations as well as IV regressions. *GDPpc* also tends to have a significant explanatory power, indicating that the wealth of the economy is essential in the equation.

5.1. Contribution to the existing literature

Given the empirical evidence on the link between PIT progressivity and output volatility, several conclusions can be made based on the reviewed literature. Generally, our results are in line with the literature that documents stabilizing properties of progressive personal income taxation.

Our research extends the work done by Rieth et al. (2011), which was one of the initial influences to our research topic. First, we confirm findings by providing evidence on the previously observed relationship using after-crisis data. This data is meaningful since it covers major fluctuations in GDP growth. Second, we strengthen the evidence of the relationship by changing the time window over which the dependent variable is calculated. Third, we expand the findings on the relationship across more geographies by increasing the country selection. Lastly, there is not a consensus in the literature regarding the endogeneity of PIT progressivity index. Based on the relevant empirical tests, we reaffirm the findings of Rieth et al. (2011) that the progressivity index does not suffer from the endogeneity bias in the equation. This allows to support the argument that in most cases, PIT progressivity is motivated by political or social reasoning (such as targeting income inequality), not by its stabilizing properties.

To our knowledge, Martinez-Mongay and Sekkat (2005) are among the few who have tested a similar potential non-linear relationship. They found acceptably robust evidence of the non-linear relationship between taxation (tax cuts/increases) and output volatility for the period 1960-2000. However, they emphasize that the effect of taxation highly depends on the tax structure in a country. We contribute to this line of research by exploring specifically PIT progressivity, showing that progressive PIT taxation does not contribute to this relationship.

5.2. Limitations and suggestions

It is important to point out that the conclusions drawn from our empirical analysis are purely based on the data sample used. Our research, as any other, is exposed to certain limitations. One of the most important is the time period over which it is possible to obtain comparable data on *MTR* and *ATR* (marginal and average tax rate, respectively) for PIT progressivity index calculation. This data is only available starting from year 2000 which limits our research in multiple ways. First, it restricts the whole data sample to this period, including the output volatility variable which bounds the possible diversity in its values. As the crisis years and its impact extends over a relatively big part of our period, we believe that the values we obtain are uncommonly far from each other since the dependent variable is very exposed to economic crisis. Second, we take the standard deviation of log of changes in GDP over 4-year fixed windows admitting that this period does not reflect a full business cycle and calculating the standard deviation over a longer time period would greatly reduce the number of observations.

Another limitation is that we are focusing our research on OECD countries. As the Organization of Economic Cooperation and Development (OECD) it aims to "promote policies that will improve the economic and social well-being of people around the world" ("About the OECD - OECD", 2018). We believe that, while being separate, independent countries, as OECD member states, they tend to follow similar path in terms of considered and implemented economic policies, including but not limited to tax reforms. By restricting the data sample to OECD countries only, the conclusions we draw about the effect of PIT progressivity index refer to a sample of countries that supposedly have certain similarities in their decision-making process and policy development. It is important to mention that the inclusion of non-OECD countries, however, might be constrained by the availability of quality data. Furthermore, assuming that the information the policymakers consider might be similar, it could be an argument for why we observe PIT progressivity index values in the ranges discussed in the previous sections.

Finally, considering the limitations explained above, we present a few suggestions for the future academic papers aiming to examine the relationship between personal income tax progressivity index and GDP growth volatility. The following researches on this topic should aim to extend the length of sample. As it has been mentioned above, a long enough data sample period allows to capture full business cycles in output volatility calculations while maintaining a representative number of observations. Also, it benefits the estimations by presenting a larger variability in both dependent and independent variable values. Additionally, it makes other result robustness checks possible, such as testing the relationship with output volatility calculated over different time periods (5-, 7-, 10-years) or using lagged values of dependent variable and other variations. Lastly, it is worth including non-OECD member states in the sample since it might decrease the possibility that the results are biased due to assumed similarities among OECD countries.

6. Conclusion

The research presented in this paper has been motivated by the growing attention to the progressivity of the tax schedule. Mainly, the importance of the question recently has been driven by the ongoing tax reform in Latvia which, among other changes, implemented progressive personal income tax schedule. Progressive taxation, by shifting people from one tax bracket to another during business cycles, shows the properties of automatic stabilization. We investigate the effect of personal income tax progressivity index on GDP growth fluctuations and set out to enhance the understanding on the role of non-linearity. The reason behind exploring the potential non-linear effect in the relationship between PIT progressivity and output volatility is based on the contradicting evidence in the literature related to this link. The overall effect in the relationship of interest is ambiguous due to the different channels involved in determining the magnitude and direction of this link.

The two main conclusions we make based on the empirical analysis: no non-linear relationship between PIT progressivity and output volatility can be observed in the period from 2000 to 2012 in a sample of OECD countries; and the negative effect of PIT progressivity index and output volatility persists and can be observed in a data sample including after-crisis period. Based on the evidence, we conclude that one standard deviation (0.091 in our sample) increase in progressivity index reduces the output volatility by 0.38 on average.

As the progressive taxation regains relevance and the literature lacks consensus on the complete effect of progressive taxation, additional insights into the relationship between PIT progressivity index and output volatility are important to both academics and policymakers. This paper highlights the role of automatic stabilizers (measured by the PIT progressivity index) as a mechanism to reduce output fluctuations. The following researches on this topic should aim to extend the length of the data sample as it might give more flexibility in testing the robustness of the results.

7. References

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8. *Appendices*

Appendix A. Variable description and sources. Made by the authors.

Variable	Description	Source
vola	st.dev. of log changes in GDP	own calculations
MTR	marginal tax rate	OECD database
ATR	average tax rate	OECD database
Expend	government expenditures over GDP	OECD database
RevTot	total gov. tax revenues over GDP	OECD database
GDPpc	GDP per capita (constant PPP)	OECD database
GDP	real GDP (constant prices, constant PPP)	OECD database
Industry	employment in industry (% of total employment)	World Bank database
Credit	ratio of domestic credit to the private sector relative to GDP (Credit/GDP)	OECD database
Open	(exports plus imports)/GDP	OECD database, own calculations
PPP	national currency value of GDP over real GDP in USD	OECD database
Growth	Growth rate of GDP	OECD database
President	presidential vs parliamentary	Database of Political Institutions 2015: Codebook
Checks	index of checks and balances of the executive authority	Database of Political Institutions 2015: Codebook
Urban	rate of urbanization	OECD database
Anglo_American	Anglo American country	
Agriculture	employment in agriculture (% of total employment)	ILOSTAT database
Investments	Gross fixed capital formation (% of GDP)	World Bank database

Appendix B. Summary statistics by country, PIT progressivity index, 2000-2016. Made by the authors.

group1	mean	p50	sd	min	max
Hungary	0.294	0.327	0.216	0.000	0.540
Luxembourg	0.274	0.277	0.011	0.247	0.292
Germany	0.245	0.254	0.033	0.207	0.292
Belgium	0.234	0.220	0.029	0.211	0.292
Ireland	0.224	0.148	0.129	0.108	0.407
Norway	0.219	0.220	0.052	0.095	0.275
Netherlands	0.219	0.190	0.118	0.128	0.565
Israel	0.210	0.199	0.030	0.171	0.268
Austria	0.209	0.224	0.040	0.140	0.261
Finland	0.208	0.204	0.018	0.185	0.253
Greece	0.178	0.168	0.044	0.096	0.245
Portugal	0.175	0.166	0.021	0.153	0.217
Slovenia	0.174	0.152	0.032	0.146	0.217
Canada	0.162	0.162	0.016	0.137	0.207
Sweden	0.155	0.096	0.121	0.016	0.336
Italy	0.143	0.134	0.031	0.121	0.223
United States	0.143	0.181	0.062	0.061	0.200
Spain	0.135	0.139	0.024	0.105	0.167
Australia	0.131	0.117	0.042	0.096	0.244
New Zealand	0.128	0.157	0.063	0.019	0.194
Iceland	0.126	0.130	0.016	0.097	0.151
Denmark	0.121	0.135	0.034	0.081	0.166
France	0.120	0.128	0.073	0.034	0.214
Switzerland	0.106	0.122	0.021	0.076	0.126
Slovak Republic	0.102	0.099	0.014	0.086	0.129
Czech Republic	0.102	0.101	0.017	0.079	0.149
Mexico	0.097	0.097	0.018	0.068	0.135
Korea	0.093	0.095	0.029	0.037	0.141
United Kingdom	0.090	0.086	0.013	0.073	0.113
Japan	0.065	0.069	0.007	0.056	0.074
Turkey	0.064	0.074	0.033	0.030	0.157
Estonia	0.048	0.046	0.009	0.035	0.062
Latvia	0.041	0.038	0.010	0.029	0.063
Poland	0.032	0.033	0.007	0.022	0.040
Chile	0.000	0.000	0.000	0.000	0.000
Total	0.145	0.135	0.091	0.000	0.565

Appendix C. Summary statistics by country, GDP growth, 2000-2016. Made by the authors.

group	mean	p50	sd	min	max
Turkey	0.051	0.061	0.046	-0.060	0.111
Ireland	0.050	0.052	0.066	-0.046	0.256
Korea	0.042	0.037	0.020	0.007	0.089
Chile	0.041	0.041	0.022	-0.016	0.072
Slovak Republic	0.039	0.039	0.035	-0.054	0.108
Estonia	0.039	0.061	0.062	-0.147	0.106
Latvia	0.039	0.054	0.065	-0.144	0.119
Israel	0.037	0.040	0.023	-0.002	0.088
Poland	0.036	0.036	0.016	0.012	0.070
Luxembourg	0.031	0.032	0.032	-0.044	0.084
Iceland	0.031	0.038	0.041	-0.069	0.094
Australia	0.029	0.028	0.008	0.019	0.040
Czech Republic	0.028	0.027	0.029	-0.048	0.069
New Zealand	0.027	0.031	0.015	-0.015	0.051
Mexico	0.025	0.026	0.025	-0.047	0.066
Sweden	0.024	0.027	0.026	-0.052	0.060
Hungary	0.022	0.034	0.029	-0.066	0.050
Slovenia	0.022	0.030	0.035	-0.078	0.069
Canada	0.021	0.025	0.017	-0.029	0.052
United States	0.019	0.022	0.016	-0.028	0.041
Switzerland	0.019	0.019	0.016	-0.022	0.041
United Kingdom	0.019	0.024	0.018	-0.042	0.037
Spain	0.018	0.032	0.027	-0.036	0.053
Norway	0.017	0.020	0.013	-0.017	0.040
Belgium	0.016	0.015	0.015	-0.023	0.036
Austria	0.015	0.015	0.017	-0.038	0.036
Finland	0.015	0.020	0.032	-0.083	0.056
Netherlands	0.014	0.017	0.019	-0.038	0.042
Germany	0.013	0.017	0.023	-0.056	0.041
France	0.013	0.012	0.015	-0.029	0.039
Denmark	0.011	0.013	0.020	-0.049	0.039
Japan	0.009	0.014	0.020	-0.054	0.042
Portugal	0.005	0.009	0.021	-0.040	0.038
Italy	0.003	0.009	0.021	-0.055	0.037
Greece	0.002	0.006	0.047	-0.091	0.058
Total	0.024	0.025	0.032	-0.147	0.256

Appendix D. Hausman test for Model 1. Made by the authors.

	Coefficients (b) Consistent	(B) Efficient	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
Prog	-10.50569	-8.01062	-2.49507	2.112094
Open	.0355848	.3785166	-.3429319	.3011327
PPP	.3532773	.8021594	-.4488821	.1210632
GDPpc	3.665177	-.1784133	3.84359	.7467144
Expend	24.03393	6.894567	17.13936	3.449426

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 55.16
Prob>chi2 = 0.0000

Appendix E. Hausman test for Model 2. Made by the authors.

	Coefficients (b) Consistent	(B) Efficient	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
Prog	6.25223	-7.924698	14.17693	11.62252
Prog_sq	-29.72487	10.77192	-40.49679	26.42497
Open	1.17649	.2039573	.972533	.3696586
PPP	.2398449	.494606	-.2547611	.0808243

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 17.68
Prob>chi2 = 0.0014

Appendix F. Summary statistics by variables, 2000-2016. Made by the authors.

Variable	Obs	Mean	Std. Dev.	Min	Max
vola	139	2.000068	1.712601	.2554922	9.968355
Prog	140	.1434968	.0844484	0	.4272037
Open	138	1.300585	1.866375	.2265574	13.31767
PPP	140	1.78727	1.415111	0	14.35882
Industry	140	.2500536	.0570078	.10875	.40075
RevTot	140	.3331658	.0733089	.1250425	.4657925
Expend	133	.431309	.078245	.0977785	.5707864
Credit	134	1.008015	.4708374	.1491657	2.5058
GDPpc	140	3.498858	1.371415	1.326847	8.711408
GDP	140	.0123883	.0256646	.000102	.1640118
Growth	140	.0225245	.0218535	-.0655309	.1016647