DEPARTMENT OF ECONOMICS AND FINANCE

SCHOOL OF BUSINESS AND ECONOMICS

UNIVERSITY OF CANTERBURY

CHRISTCHURCH, NEW ZEALAND

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NOTE: This paper is a revision of University of Canterbury WP No. 2018/09

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WORKING PAPER

No. 3/2020

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Taxes and Economic Growth in OECD Countries: A Meta-Analysis

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January 2020

Abstract: A major difficulty with synthesizing estimates on taxes and economic growth is that they measure different things. This follows because studies differ in the government budget constraints implied by their regression specifications. To address this problem, we use a taxonomy from Gemmell, Kneller, and Sanz (2009) that predicts the growth effects from various tax-spending-deficit combinations. We apply this taxonomy to 641 estimates from 42 studies of tax effects in OECD countries, categorizing them based on the tax-spending-deficit combinations implied by their regression specifications. We then apply meta-analysis to this sample of estimates to calculate the effect of the following, revenue-neutral tax policy: a one-percentage point decrease in distortionary taxes as part of a negative-growth fiscal policy, accompanied by a one-percentage point increase in non-distortionary taxes as part of a positive-growth fiscal policy. Our headline result is that the associated 95% confidence interval implies an average increase in annual economic growth between 0.05 to 0.25 percent a year. This compares to an average annual growth rate of approximately 2.50 percent for the countries in our study. Another result from our analysis is that we find evidence of publication bias favoring negative estimates in the tax and growth literature. On the other hand, our results do not find any evidence to support the conventional wisdom that taxes on labor and capital are more distortionary than other types of taxes.

Keywords: Meta-analysis, Taxes, Economic growth, OECD

JEL Classifications: H2, H5, H6, O47, O50

Acknowledgments: W. Robert Reed acknowledges financial support from the Czech Science Foundation, Grant 18-02513S.

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I. INTRODUCTION

A multitude of studies have estimated the effect of taxes on economic growth. With so many studies working over a limited number of datasets, one would think that something resembling a consensus would have arisen. Not so. In their review of the literature, Kneller and Misch (2017, page 165) conclude "that at least the direction of the short-run and long-run growth effects can be predicted with a reasonable degree of certainty, but there is disagreement with respect to the magnitude."

We use meta-analysis to synthesize estimated tax effects in the growth literature. Meta-analysis is a statistical tool for averaging estimates from studies that measure the same or a similar thing (Stanley and Doucouliagos 2012). An alternative to meta-analysis is to find one or more studies that carefully address the subject of taxes and economic growth and focus on their estimates.

A problem with the latter approach is that it ignores publication bias. It is now well-known that many areas of empirical research are affected by the desire of researchers and journals to produce significant results and/or results that confirm theoretical and ideological beliefs (cf. Ioannidis, 2005; Doucouliagos and Stanley, 2009; Stanley and Doucouliagos, 2012; Franco, Malhotra, and Simonovits, 2014; Ioannidis, Stanley, and Doucouliagos, 2017). One would be surprised if these biases did not also affect the tax literature. For this reason, relying on one or a few studies is problematic.

This is not the first study to use meta-analysis to synthesize results from the literature on taxes and economic growth. Phillips and Goss (1995) aggregated estimates of tax effects on economic growth for U.S. states. Later, Nijkamp and Poot (2004) studied the effects of fiscal policy more generally on economic growth across countries. However, these initial attempts did not incorporate modern procedures to address publication bias. More recently, Gechert (2015) used meta-analysis to study the literature on fiscal multipliers. However, his study was hampered by the failure of the original studies to report standard errors for the associated multiplier effects, which is a key variable in addressing publication bias.

Our meta-analysis has three goals. Most importantly, we want our analysis to produce useful estimates of the magnitude of tax effects on economic growth. Secondly, we want to investigate whether publication bias exists, and whether it constitutes a significant feature of the empirical tax literature. Finally, we want to create a database of estimated tax coefficients that can be used by other researchers. As part of this database, we will record data, estimation, and study characteristics that may cause estimates to differ across studies.

We focus on estimated tax effects from national-level studies of OECD countries. Expanding the set of countries beyond the OECD raises concerns of noncomparability. Our final sample consists of 641 estimates from 42 studies. We find evidence of publication bias indicating that the empirical literature favors negative tax coefficients. However, even after adjusting for publication bias, our estimates indicate that tax policy can have a meaningful impact on economic growth.

Our analysis proceeds as follows. Section II reports how we collected our sample of estimates. Section III discusses some of the reasons why studies of tax effects can produce different estimates. Section IV presents our empirical results, addressing each of the three goals above.[1] Section V summarizes the main findings of our research.

II. SELECTION OF STUDIES AND CONSTRUCTION OF DATASET

This meta-analysis collects estimated tax effects for studies that estimate a variation of the following specification:

(1) $$growth = \alpha_0 + \alpha_1 tr + \boldsymbol{X\beta} + error,$$

[1] All the data and code necessary to replicate the results of this paper are publicly available at *Harvard Dataverse*: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/7CR6FE.

where $growth$ is a measure of economic growth, tr is a measure of the tax rate, $\boldsymbol{X}$ is a vector of control variables.[2] To do that, we conducted a comprehensive search including both electronic and manual search procedures.

The electronic search used three categories of keywords: (i) “TAX” keywords, (ii) “ECONOMIC GROWTH” keywords, and (iii) “OECD” keywords in the following combination: “TAX” *and* “ECONOMIC GROWTH” *and* “OECD”. A variety of keywords were substituted for each of the three categories. These are reported in APPENDIX 1. Keyword combinations were searched using the following search engines: EconLit, Google Scholar, JSTOR, Web of Science, Scopus, RePEc, EBSCO, and ProQuest. A total of 303 studies were identified in this manner.

The abstracts and conclusions of these studies were then read to eliminate any studies that did not estimate a growth equation with a tax variable, and/or included countries other than OECD countries. The dependent variable had to be a measure of GDP growth.[3] The growth equation had to include a tax variable that was measured in percentage points of income.[4] The countries included in a given regression equation had to consist entirely of OECD countries, though they could be restricted to a subset of OECD countries such as the G7, EU-15 or a larger set of EU member nations. Further, all estimates had to include multiple countries.[5] All estimated tax effects had to report a standard error or associated t-statistic. Finally, only studies written in English were included.[6] Backwards and forwards citation searches were used to locate additional studies. This produced a list of 54 studies, some of which were multiple

[2] We did not include studies that estimate nonlinear tax effects, such as the “growth hills” of Bania, Gray and Stone (2007).
[3] Alternatively, the dependent variable could be the level of income, as long as the explanatory variables included its lag.
[4] Studies where the “tax variable” consisted of all revenues, such as the ratio of total revenues to GDP, were not included.
[5] We eliminated single country studies because the combination of short data ranges with a large number of potential confounders makes estimates unreliable.
[6] We closed our search on 13 January 2016.

versions of the same study.[7] It included journal articles, conference proceedings, studies from think tanks and research firms, theses and dissertations, working papers and other unpublished research.

This list was emailed to 64 researchers who had published on the topic of taxes and economic growth. The researchers were asked for help in identifying additional research, including working papers or unpublished studies from PhD students. Based on their responses, a revised list was compiled, and all the studies were then re-read carefully to make sure they satisfied our criteria for eligibility. This resulted in a final sample of 42 studies. APPENDIX 2 lists the individual studies used in our analysis, and APPENDIX 3 provides a PRISMA flow chart of our search process.[8]

Once the studies were selected, we then went through each equation/estimate within those studies and coded relevant data, estimation, and study characteristics (see next section). Each estimate was independently coded by at least two coders, including both authors of this study, with a careful reconciliation of any discrepancies or inconsistencies. All search and coding procedures followed the MAER-NET protocols (Stanley et al., 2013).

III. USING THE GOVERNMENT BUDGET CONSTRAINT TO INTERPRET ESTIMATED TAX EFFECTS

In order for tax estimates to be correctly interpreted, they need to be placed in the context of the government budget constraint. As is apparent from Equation (2) below, no change in taxes takes place in isolation. It is accompanied by a change in one or more other fiscal categories: other revenues, expenditures, and/or the budget deficit.

(2) $$0 = Taxes + OtherRevenues - Expenditures + Deficit.$$

[7] When multiple versions of the same paper included different estimates, we pooled the estimates across versions.
[8] PRISMA stands for "Preferred Reporting Items for Systematic Reviews and Meta-Analyses". For more information, see the PRISMA website: http://prisma-statement.org/.

In empirical work, these variables often appear as effective rates, as ratios over some measure of income, such as GDP:

(3) $$0 = tr + \left(\frac{OtherRevenues}{Income}\right) - \left(\frac{Expenditures}{Income}\right) + \left(\frac{Deficit}{Income}\right),$$

where tr here represents the effective tax rate, $tr = \left(\frac{Taxes}{Income}\right)$. To avoid perfect multicollinearity, one or more of these variables must be omitted from a regression specification. This has an important implication for empirical work.

The interpretation of the estimate of α_1 in Equation (1) will differ depending on which variable(s) are omitted from Equation (3). If $\left(\frac{Expenditures}{Income}\right)$ is omitted, then α_1 measures the effect of an increase in taxes to fund expenditures. Alternatively, if $\left(\frac{Deficit}{Income}\right)$ is omitted and expenditures are held constant, then α_1 measures the combined effect of increasing taxes and cutting the deficit (or increasing the surplus) by equal amounts.

In practice, it is generally more complicated than that. Not all taxes are expected to have the same effect. For example, it is commonly claimed that taxes on labor and capital are relatively "distortionary", while taxes on consumption are relatively "non-distortionary".[9] Likewise with expenditures. Expenditures on health and public infrastructure are generally regarded as relatively "productive", while income transfers such as welfare and social security are generally regarded as relatively "unproductive". Incorporating these subcategories into Equation (3) produces:

[9] Distortionary taxes are those that distort the private sector's allocation of resources. Proportional wage-income taxes are commonly viewed as being distortionary. A non-distortionary tax leaves the allocation of resources unchanged. A lump sum tax is commonly given as an example of a non-distortionary tax. In practice, no tax is truly non-distortionary, so the distinction hinges on the degree to which the allocation of resources is affected. In a similar fashion, government expenditures are divided into productive versus unproductive expenditures. A productive expenditure is one which increases private sector production. Investment in education and infrastructure are examples of productive expenditures. Welfare expenditures and other income transfers are commonly classified as unproductive (Kneller, Bleaney, and Gemmell, 1999).

$$(4) \qquad 0 = tr(Non - distortionary) + tr(Distortionary) + \left(\frac{OtherRevenues}{Income}\right) - \left(\frac{Productive\ Expenditures}{Income}\right) - \left(\frac{Unproductive\ Expenditures}{Income}\right) + \left(\frac{Deficit}{Income}\right).$$

If Equation (4) is estimated with $\left(\frac{Productive\ Expenditures}{Income}\right)$ omitted, the coefficient on the non-distortionary tax rate variable would measure the combined effect of an increase in non-distortionary taxes to fund productive expenditures. On the other hand, if $\left(\frac{Unproductive\ Expenditures}{Income}\right)$ were omitted, the coefficient on the distortionary tax rate variable would measure the combined effect of an increase in distortionary taxes to fund unproductive expenditures. Accordingly, estimates from two different studies using the exact same data could estimate very different tax effects, even opposite-signed estimates, depending on the specification of the regression equation.

Studies frequently incorporate even finer detail. Within the sub-categories of distortionary taxes and non-distortionary taxes, and productive expenditures and unproductive expenditures, are sub-sub-categories. TABLE 1 gives a flavour of just how quickly the number of sub-categories can grow. It lists eight categories of revenues (taxation on income and profit, social security contributions, taxation on payroll and manpower, etc.) and ten categories of expenditures (general public services, defence, education, etc.). Thus, even if there existed a perfectly conducted, bias-free study that estimated the effect of say, an increase in payroll taxes to fund an increase in social security benefits, the associated tax effect estimates would not be very useful for policymakers if they were considering an increase in value-added taxes to fund investments in public infrastructure.

This is where meta-analysis can be helpful. By combining estimated tax effects from many different studies and controlling for the associated tax-spending-deficit specifications employed by those studies, it allows estimated tax effects to be more closely matched to actual fiscal policies. This could be done, say, by estimating a meta-regression equation with the estimated tax effects as the dependent variable, and a series of dummy variables as explanatory variables identifying different tax-spending-deficit combinations. This would allow the policymaker to calculate a predicted tax effect for the specific policy being considered. The challenge is how best to do this.

As there is no standard specification of the government budget constraint in studies of taxes and economic growth, a great variety of tax-spending-deficit combinations have been employed. TABLE 2 illustrates this situation by presenting a sampling of tax-spending-deficit specifications used by different studies. All of the five studies cover similar time periods and countries and measure fiscal variables as effective rates, but they differ in the number and types of fiscal categories they include in their regression equations.

The Colombier (2009) study simply includes an average tax rate with nothing else. The Romero-Avila and Strauch (2008) study includes a complete set of tax and spending categories, so that the omitted fiscal variable is the budget deficit. The Bleaney et al. (2001) study also includes exhaustive, though somewhat different, tax and spending categories, but the omitted fiscal variable is non-distortionary taxes. The Afonso and Fuceri (2010) and Muinelo-Gallo and Roca-Sagalés (2013) papers provide still two alternative specifications. Our argument is that all of these studies have useful information to provide to policy-makers. The challenge is how best to aggregate their findings.

It should be clear from TABLE 2 that there are too many different tax-spending-deficit specifications to represent each with a unique dummy variable and therefore, some degree of aggregation is required. What we need is a taxonomy that classifies tax-spending-deficit specifications with respect to their combined effect on economic growth. Such a taxonomy would need to be both applicable to empirical research; and exhaustive, so that it would cover the full range of tax-spending-deficit possibilities encountered in actual research. We are aware of only one such taxonomy, the classification presented in Gemmell, Kneller, and Sanz (2009), which draws heavily from Barro (1990). TABLE 3 applies their taxonomy to define three types of fiscal policies.[10]

TaxNegative Fiscal Policies are policies where an increase in the tax rate is predicted to produce negative economic growth. Gemmell, Kneller, and Sanz, 2009 (henceforth, GKS) identify two corresponding tax-spending-deficit combinations. The first is an increase in distortionary taxes to fund unproductive expenditures. The second is an increase in distortionary taxes accompanied by a decrease in non-distortionary taxes. According to GKS, there are three tax-spending-deficit combinations that are predicted to produce positive economic growth (*TaxPositive Fiscal Policies*): An increase in non-distortionary taxes to fund productive expenditures. An increase in non-distortionary taxes accompanied by a decrease in distortionary taxes. And an increase in non-distortionary taxes to decrease the deficit. Every other combination of taxes-spending-deficits is predicted to have "ambiguous" (or zero) growth effects (*TaxAmbiguous Fiscal Policies*). GKS classify a fiscal policy as "ambiguous" when the individual components have conflicting effects and it is unclear which effect is stronger.

In lieu of developing our own classification system, we use GKS's taxonomy to categorize tax-spending-deficit specifications. For each of the hundreds of estimated tax effects in our meta-analysis sample, we identify both the operative tax type and the use of the tax revenues implied by respective regression specification. Tax types and expenditures are classified as non-distortionary/distortionary, productive/unproductive, or other according to the taxonomy in TABLE 1. We then use TABLE 3 to code the respective tax-spending-deficit specification as belonging to one of the three fiscal policy categories. We note that the fiscal policy categories in TABLES 1 and 3 have been widely employed in the tax and growth

[10] See APPENDIX 4 for the source table from Gemmell, Kneller, and Sanz (2009).

literature.[11] Later, we expand our categories to separately analyze the effects of taxes on labor and capital.

IV. EMPIRICAL ANALYSIS

A note on units of measurement. Any interpretation of estimated tax effects depends on the units of measurement employed for the $growth$ and tr variables (cf. Equation 1) in the original study. Each of these variables can be measured in percentage points (e.g., 2%) or in decimals (0.02). This will obviously affect the size of the tax coefficient, α_1. If a one-percentage point increase in the tax rate lowers growth by 0.1%, and if both $growth$ and tr are measured in percentage points, or both are measured in decimals, then the corresponding value of α_1 will be -0.1. However, if $growth$ is measured in percentage points, and tr is measured in decimals, then the corresponding value of α_1 will be -10. And if $growth$ is measured in decimals, and tr is measured in percentage points, then the value of α_1 will be -0.001. Accordingly, we adjust all estimated effects so that $\alpha_1 = X$ means that a one-percentage point increase in the tax rate is associated with an *X*-percent increase in economic growth.[12]

Setting the final sample. Our literature search produced a dataset consisting of 713 estimated tax coefficients. Columns (1) through (3) of TABLE 4 reports descriptive statistics for the full sample, grouped by type of fiscal policy. The values represent the growth effects associated with a one-percentage point increase in the tax rate for a given fiscal policy. For example, the mean of estimated tax coefficients for tax-spending-deficit combinations categorized as *TaxNegative* suggests that a one-percentage point increase in the tax rate for this type of fiscal policy — i.e., a one-percentage point increase in distortionary taxes accompanied

[11] Examples include Angelopoulos et al. (2007), Arin (2004), Benos (2009), Bassanini et al. (2001), Blankenau et al. (2007), Bleaney et al. (2001), Gemmell et al. (2015), Kneller et al. (1999), Paparas et al. (2015), Gemmell et al. (2014), Muinelo-Gallo and Roca-Sagalés (2013), and Romero-Avila and Strauch (2008).

[12] Sometimes it was difficult to determine the units of measurement of the respective variables from the original study so as to properly interpret the coefficient. When this happened, we would contact the original author(s). When there was substantial uncertainty about the interpretation of the coefficient, the estimate was dropped from our analysis.

by a one-percentage point increase in either unproductive spending or non-distortionary taxes (see TABLE 3) — would lower annual economic growth by 0.18 percentage points. This compares to an average, annual growth rate for OECD countries of approximately 2.50 per cent over the period 1970-2000[13], a period which roughly corresponds to the "average" sample period of the studies included in this meta-analysis.[14]

GKS's taxonomy suggests that fiscal policies can be ordered in terms of their effects on economic growth by *TaxNegative* ≤ *TaxAmbiguous* ≤ *TaxPositive*. This is reflected in TABLE 4 in both the mean and median values of the estimated tax coefficients. However, it is important to note that the values in TABLE 4 represent naïve estimates of tax effects, because they do not control for data, estimation and study characteristics that may be correlated with types of fiscal policies.

TABLE 4 also alerts us to potential data problems. For example, the minimum and maximum estimated tax coefficients from *TaxAmbiguous* specifications are -3.52 and 12.72. These estimates imply that a one-percentage point increase in the tax rate would, respectively, lower annual economic growth by over 3 percentage points and increase it by more than 12 percentage points. These numbers are outside the bounds of what is reasonable. Accordingly, the subsequent analysis works with a truncated sample of estimates that deletes the top and bottom 5 percent of estimated tax coefficients. Nevertheless, we note that we obtain similar results if we use the full sample, with estimated tax effects that lie within the confidence intervals we report below.

[13] Growth rate is the average, annual rate over the period 1970-2000 for the 22 countries that belonged to the OECD in 1970.
[14] This is calculated by taking the average beginning and average ending dates for the sample ranges of the respective studies.

Our final sample consists of 641 estimated tax coefficients.[15] The descriptive statistics for this truncated sample are reported in Columns (4) – (6) in TABLE 4. The truncated sample preserves the growth effects ordering of *TaxNegative* ≤ *TaxAmbiguous* ≤ *TaxPositive*, which is now evident not only for the mean and median, but also at the respective quantile points.

The estimation strategy. Our estimation strategy is built around the following specification:

(5) $\hat{\alpha}_{1i} = \beta_0 + \beta_1 TaxNegative_i + \beta_2 TaxPositive_i + \sum_k \delta_k X_{ki} + \varepsilon_i,$

where the dependent variable, $\hat{\alpha}_{1i}$, is the estimated tax effect from a regression in primary study *i*; $TaxNegative$ ($TaxPositive$) are dummy variables indicating that the estimated tax coefficient is part of a tax-spending-deficit specification where taxes are predicted to have a negative (positive) impact on economic growth; and the X_k are data, estimation, and study characteristics that may influence the size of the estimated tax effect.

The coefficients β_1 and β_2 can be interpreted as the estimated growth effects of a one-percentage point increase in taxes associated with a *TaxNegative* and *TaxPositive* fiscal policy, respectively, compared to a one-percentage point increase in taxes associated with a *TaxAmbiguous* fiscal policy.

Rather than having two measures of the growth effect of taxes (β_1 and β_2), it would be convenient to have one summary measure. Accordingly, we focus on the difference, $\beta_2 - \beta_1$. This corresponds to a revenue neutral tax change of one-percentage point whereby a *TaxNegative* fiscal policy is replaced with a *TaxPositive* fiscal policy. An example would be reducing distortionary taxes/unproductive expenditures by one percentage point as a share of income while increasing non-distortionary taxes/productive expenditures by the same amount.

[15] "Trimming", as here, and "winsorising", not applied here, where extreme values are set equal to fixed percentile values, are the two most common procedures for handling suspect outlier values. 5% and 95% are commonly chosen as cut-off percentile values for both approaches.

Four estimation procedures. Equation (5) can be estimated with Ordinary Least Squares (OLS). However, while the corresponding estimates of β_1 and β_2 will be unbiased and consistent, they will not be efficient. This is because the tax coefficients in our sample are estimated with different precisions, as reflected in their different standard errors.

Let $SE(\hat{\alpha}_i)$ be the standard error of the *i*th estimated tax coefficient. If all estimates come from a population with a single, true tax effect for each of the three categories, so that the only source of variation in ε_i is proportional to sampling error — i.e., $\text{var}(\varepsilon_i) = SE(\hat{\alpha}_i)^2\sigma^2$ — then Weighted Least Squares (WLS) estimation of Equation (5) will produce asymptotically unbiased, consistent, and efficient estimates of β_1 and β_2, with the appropriate weight being the inverse of $(SE_i)^2$.[16] This model is known in the meta-analysis literature as the inverse variance or "Fixed Effects" model (Borenstein et al. 2010).[17]

The assumption that there exists a single, true tax effect within each fiscal policy category is obviously unrealistic, as tax effects can be expected to vary across time periods and economies, among other reasons. Let τ^2 represent the component of the variance of ε_i that is due to these differences in true tax effects. If we can assume that sampling error and variation in true effects are independent, and that the variance of ε_i is proportional to these two components, then $\text{var}(\varepsilon_i) = [SE(\hat{\alpha}_i)^2 + \tau^2]\sigma^2$.

This leads to an alternative version of WLS, known in the meta-analysis literature as the "Random Effects" model, with the appropriate weight now being the inverse of $[SE(\hat{\alpha}_i)^2 + \tau^2]$ (Borenstein et al. 2010).[18] We thus have two WLS estimators that we can use, depending on whether the assumptions of the "Fixed Effects" or the "Random Effects" model

[16] Strictly speaking, WLS will be unbiased only if the estimates of $\text{var}(\varepsilon_i)$ are equal to their population values.
[17] This nomenclature is unfortunate, given the association of these same terms with panel data estimation. Nevertheless, given their ubiquitousness in the meta-analysis literature, we will perpetuate the practice of using "Fixed" and "Random Effects" to refer to models of homogeneous and heterogeneous effects, respectively.
[18] Borenstein et al. (2010) discuss two main procedures for estimating τ^2: DerSimonian and Laird's method of moments, and restricted maximum likelihood. The Stata program that we employ ("metareg") allows both methods. The default is D&L and that is the method we use in our analysis.

are appropriate. While researchers generally agree that the "Random Effects" model most closely matches reality, there is some debate about which works best in practice (Doucouliagos and Paldam 2013; Reed 2015).[19] Accordingly, our analysis employs both "Fixed Effects" and "Random Effects".[20]

The two WLS models can be easily related to Equation (5) by multiplying each term by the square root of the respective weight, $\frac{1}{\omega_i}$:

$$\text{(6.a)} \quad \frac{\hat{\alpha}_{1i}}{\omega_i} = \frac{\beta_0}{\omega_i} + \beta_1 \frac{TaxNegative}{\omega_i} + \beta_2 \frac{TaxPositive}{\omega_i} + \sum_k \delta_k \frac{X_{ki}}{\omega_i} + \frac{\varepsilon_i}{\omega_i}, \quad i = 1,2,\ldots,N,$$

where

$$\text{(6.b)} \quad \omega_i = \begin{cases} SE(\hat{\alpha}_i), & \textit{(FixedEffects1)} \\ \sqrt{SE(\hat{\alpha}_i)^2 + \tau^2} & \textit{(RandomEffects1)} \end{cases}.$$

OLS estimation of this transformed equation produces estimates equivalent to WLS. Additionally, when the meta-analysis sample consists of multiple estimates from the same study, it is standard practice to correct for non-independence of the error terms by using cluster robust standard errors (Stanley and Doucouliagos, 2012).

A related issue concerns the weighting of estimates versus studies. The number of estimates per study can vary widely. In our sample, the number of estimates per study ranges from 2 to 80, with a mean of 15.3.[21] The WLS estimators discussed above implicitly give greater weight to studies with more estimates. Accordingly, we employ an alternative

[19] Our sample of estimated tax coefficients evidences a significant amount of variation beyond sampling error. Even with all the explanatory variables included in a meta-regression, the associated estimate of *I-squared*, a measure of effect heterogeneity based on τ^2, is 68.6%, which is quite substantial (Borenstein et al., 2010).

[20] Fixed Effects is the most common estimation procedure in the economics meta-analysis literature. However, in our sample, the weights from Fixed Effects are heavily skewed towards a very few studies. Under Fixed Effects, the 3 most heavily weighted studies account for 92.4% of the total weight. The Random Effects model arguably overcompensates in the opposite direction, with the 3 most heavily weighted studies accounting for 8.3% of the total weight (see APPENDIX 5).

[21] This is explained by the fact that studies often use multiple tax variables in the same regression, as well as estimating multiple regression equations.

weighting system that, ceteris paribus, gives equal weight to studies rather than individual estimates:

$$\text{(6.c)} \quad \omega_i = \begin{cases} SE(\hat{\alpha}_i) \cdot \sqrt{n_{i \in S}} & \textit{(FixedEffects2)} \\ \sqrt{SE(\hat{\alpha}_i)^2 + \tau^2} \cdot \sqrt{n_{i \in S}}, & \textit{(RandomEffects2)} \end{cases}$$

where $n_{i \in S}$ is the number of estimates in study *S* from which estimate *i* was taken, and SE_i and τ^2 are defined as above. We estimate Equation (5) using all four estimation procedures as a way of checking for robustness.

Estimates of Equation (5) without control variables and without correcting for publication bias. Panel A of TABLE 5 reports estimates of Equation (5) where the specification includes the two fiscal policy dummy variables and no control variables. If this were OLS, the estimates would equal the respective differences in mean values in TABLE 4. For example, $\hat{\beta}_1^{OLS} \equiv \bar{\hat{\alpha}}_1^{TaxNegative} - \bar{\hat{\alpha}}_1^{TaxAmbiguous} = -0.17 + 0.10 = -0.07$. Since WLS applies different weights, the associated estimates for β_1 are similar but not the same (-0.038, -0.048, -0.024, -0.068). Note that all the signs for $\hat{\beta}_1$ and $\hat{\beta}_2$ are consistent with the growth effect ordering, *TaxNegative* ≤ *TaxAmbiguous* ≤ *TaxPositive* and six of the eight estimates are significant at the 5 percent level.

The next row in the table calculates the difference in the two tax variables, $\beta_2 - \beta_1$, along with the corresponding 95% confidence interval. This provides an estimate of the scope that tax policy has to influence economic growth. Using the *FixedEffects1* estimates, we estimate $\beta_2 - \beta_1$ to be 0.066, with a 95% confidence interval of 0.042 to 0.090. This implies that a revenue neutral, one-percentage point change in the tax rate such that *TaxNegative* taxes/expenditures are replaced by a *TaxPositive* fiscal policy of the same amount would increase annual economic growth between 0.04 and 0.09 percentage points (rounded to two digits). This compares to an annual growth rate of approximately 2.50 percent for the countries in our sample. All of the 95% confidence intervals are positive. Across all four estimation procedures, the estimates of $\beta_2 - \beta_1$ range from 0.07 to 0.14. The minimum and maximum values of the respective 95% confidence intervals are 0.00 and 0.23.

Estimates of Equation (5) without control variables and with correction for publication bias. Publication bias arises when the estimates reported by researchers comprise a biased sample of the population of all estimates. This can happen when researchers/journals have preferences for estimates that are statistically significant and/or whose signs match theoretical expectations or personal beliefs (Christensen and Miguel, 2018). It can occur even in unpublished working papers if researchers only write up results that they think can get published.[22] Publication bias represents a serious challenge to the validity of meta-analysis. If the estimates in the literature are disproportionately large and significant, then averaging them will preserve this bias, producing a distorted estimate of the mean true effect.

The most common test for publication bias in the economics literature is the Funnel Asymmetry Test (FAT). The FAT is carried out by adding the standard error variable, $SE(\hat{\alpha}_i)$, to the specification of Equation (5) (Card and Krueger, 1995; Egger et al., 1997; Stanley, 2008). Evidence of publication bias is given by statistical significance of the *SE* variable. The addition of the *SE* variable to Equation (5) has a further benefit. It adjusts the estimates of the other variables for publication bias in much the same way that including an inverse Mills ratio adjusts for sample selection (Stanley and Doucouliagos, 2012, 2014).

Panel B of TABLE 5 reports our estimates of the tax effects correcting for publication bias. The first row reports the estimated coefficient on the publication bias term, *SE*. Across all four columns, we reject $H_0: \beta_{SE} = 0$ at the 1 percent level of significance, indicating the existence of publication bias. The sign of the estimate identifies negative publication bias. This suggests that the literature discriminates in favor of negative tax coefficients.

[22] Franco et al. (2014) report that the main source of publication bias is failure of researchers to write up results that are not significant or interesting.

The second and thirds rows of Panel B report the "corrected" estimates of β_1 and β_2. These are not very different from the uncorrected estimates of Panel A. Thus, while the effect of publication bias is sufficiently large to be statistically significant, it is not large enough to be economically significant on average, though it may be important in individual studies. The subsequent empirical analysis will include the variable *SE* in order to correct for possible publication bias in the expanded specifications we consider below.

Control variables. The preceding analysis has ignored the role of other variables that may influence estimates of tax effects that appear in the literature. TABLE 6 describes various data, estimation, and study characteristics that we recorded as we assembled our sample. The variables are grouped by categories such as Country Group, Economic Growth Measure, Tax Variable Measure, Duration of Tax Effect, among others.

Most of the estimated tax coefficients in our sample come from studies that estimate tax effects for the full set of OECD countries (78.8%), as opposed to smaller groupings such as the G-7 countries (11.7%) or EU countries (6.4% and 3.1%). In most cases, economic growth is measured in per capita terms (74.1%). Most taxes are measured as average rates, rather than marginal (91.0% versus 9.0%); are specified in level rather than differenced form (82.8% versus 17.2%); and are effective rather than statutory tax rates (90.6% versus 9.4%). Most estimated tax effects measure the short-run effect of a tax change (70.2%), versus a medium- or long-run effect (5.3% and 24.5%).[23]

Two thirds of the estimated tax coefficients in our sample come from peer-reviewed journal articles and the mean year of publication is 2007. Almost all of the original studies used panel data to estimate tax effects (99.1%). The average sample length in the original studies was 31.4 years, and the average mid-point was 1985. About two-thirds of the estimated tax coefficients were estimated using OLS or a related procedure that assumed errors to be

[23] See APPENDIX 6 for an explanation of how we classified tax effects as Short-, Medium-, and Long-Run.

independently and identically distributed across observations (such as mean group or pooled mean group procedures). Of the remainder, 15.4 percent used GLS, and 16.8 percent attempted to correct for endogeneity using a procedure such as TSLS or GMM.

Because the standard error plays such a significant role in meta-analysis, we categorized standard errors into three groupings: *SEOLS* (58.7%); *SEHET* (24.5%), where standard errors were estimated using a heteroskedastic-robust estimator; and *SEHAC* (16.8%), whenever allowance was made for off-diagonal terms in the error variance-covariance matrix to be nonzero. Lastly, dummy variables were used to indicate the presence of important control variables such as country fixed effects (83.3%), and measures of investment (58.5%), initial income (55.9%), human capital, such as educational achievement (44.0%), employment growth (37.8%), and population growth (24.3%).

Estimates of Equation (5) with control variables. Our analysis introduces control variables in two ways. First, we include the full set of control variables in the same regression with the two tax variables and the publication bias variable, *SE.* However, because of concerns with multicollinearity from including so many variables, we also use a stepwise selection algorithm that chooses control variables to minimize the regression model's Schwarz Information Criterion.[24]

We force the selection algorithm to include the variables *TaxNegative, TaxPositive, SE,* and *Endogeneity* in the final model. We keep the tax variables because this is the focus of our study. We keep the *SE* variable so as to correct for publication bias if it exists. We also keep *Endogeneity* because we want to know if studies that correct for endogeneity produce different estimates.[25] Forcing these variables to remain in the regression has the advantage of preserving

[24] We use a backwards stepwise regression procedure that selects variables so as to minimize the Schwarz Information Criterion. We employed the user-written, Stata program *vselect* to implement the stepwise procedure.
[25] For example, if tax systems are progressive, then economies that grow faster should see their effective tax rates increase, inducing a positive bias. Correcting that bias would cause estimated tax coefficients to be more negative. This would be evidenced by a negative coefficient on the *Endogeneity* variable.

their inferential validity. In contrast, statistical inference is invalidated for the other variables whose selection depends on their regression performance.

TABLE 7 reports the results of estimating Equation (5) with control variables. The top and bottom panels report the estimates when all the control variables are included, and when a selection algorithm chooses the control variables to include. We only show the estimates for *SE, Endogeneity, TaxNegative,* and *TaxPositive* since these are the variables of most interest to us. Interested readers can find the full set of estimates in the supplementary files we have posted at *Harvard Dataverse*, a public data archive.[26]

Summarizing the results from the table, we continue to find strong evidence of negative publication bias. All eight coefficient estimates for the *SE* variable are statistically significant at the 1 percent level. In contrast, we find no evidence that studies that correct for endogeneity produce different tax estimates than studies that don't. *Endogeneity* is statistically insignificant at the 5 percent level in all eight regressions with estimated coefficients close to zero. One could find this reassuring given that most of the estimates in the tax literature do not correct for endogeneity. It suggests that these still provide useful information. Alternatively, it could mean that the instruments used in the literature are not very effective at reducing endogeneity bias.

Finally, we see that the addition of control variables, if anything, has made the estimates of tax effects a little stronger. *TaxNegative* is now generally significant in the Random Effects regressions. The size of the *TaxNegative* estimates are somewhat larger in absolute value compared to the regressions without control variables, while the *TaxPositive* estimates are about the same. The net effect is to produce slightly larger estimates of $\beta_2 - \beta_1$. The associated

[26] The results are reported in the Stata .smcl output files for TABLE 7 ("Part2 Results-20200102") posted at *Harvard Dataverse*. The output files corresponding to the other tables are posted there, as well.

point estimates range from 0.08 to 0.16, with 95% confidence intervals that range from a minimum of 0.05 to a maximum of 0.25.

In summary, using the tools of meta-analysis, we are able to combine the estimated tax coefficients from the empirical literature to calculate an average effect of taxes on economic growth for OECD countries. We estimate that a revenue neutral, one-percentage point switch in tax policy from a *TaxNegative* fiscal policy to a *TaxPositive* fiscal policy would, on average, increase annual economic growth within a range of 0.05 to 0.25 percent a year. This compares to an annual growth rate of approximately 2.50 percent for the countries in our study.

A closer look at taxes on labor and capital. The preceding analysis aggregated the tax-spending-deficit specifications in the literature into three fiscal categories. In this section, we further subdivide the fiscal policies categories to focus on taxes on labor and capital.

All *TaxNegative* fiscal policies rely on distortionary taxes. Distortionary taxes can be divided into taxes on labor, taxes on capital, and other (primarily taxes on property). We subdivide the *TaxNegative* dummy variable into three separate dummy variables by type of distortionary tax: *TaxNegative(Labor), TaxNegative(Capital),* and *TaxNegative(Other)* and replace the *TaxNegative* dummy variable in the previous regressions with these three dummy variables.[27] By comparing the relative sizes of the respective estimated coefficients, we can determine whether taxes on labor and capital are more distortionary than other types of distortionary taxes. This would be reflected by the labor and capital coefficients being more negative than the *TaxNegative(Other).*

We can do the same with the *TaxAmbiguous* dummy variable. We subdivide this into *TaxAmbiguous(Labor), TaxAmbiguous(Capital),* and *TaxAmbiguous(Other).* Note that the

[27] We follow the OECD classification system in categorizing taxes. If the original study used personal income taxes, payroll taxes, or social security contributions, we categorized that tax as a *Labor* tax. Corporate income taxes or capital taxes (taxes on dividends) were categorized as a *Capital* tax. All other types of taxes were categorized as *Other*.

latter category includes both distortionary and non-distortionary taxes (cf. TABLE 3). We replace *TaxNegative* with these three dummy variables in the previous regressions. If labor and capital taxes are more distortionary than other types of taxes, the labor and capital coefficients should be smaller than the estimated coefficient for *TaxAmbiguous(Other).*

TABLE 8 reports the results. There are now four panels. As before, we estimate regressions that (i) include the full set of control variables, and (ii) use a selection algorithm to choose control variables for the regression. In each case, we run two sets of regressions. One where the *TaxNegative* variable is replaced with *TaxNegative(Labor), TaxNegative(Capital),* and *TaxNegative(Other).* And one where *TaxNegative* is replaced with *TaxAmbiguous(Labor), TaxAmbiguous(Capital),* and *TaxAmbiguous(Other).* Note that the latter replacement changes the implied comparison group from *TaxAmbiguous* to *TaxNegative.* For each regression, we test the hypothesis that the three tax variables have identical coefficients.

We proceed by testing for differences in the tax coefficients associated with labor, capital, and other taxes within the same fiscal policy. We then check whether labor and capital taxes are more distortionary than other taxes. There are a total of 11 regressions in TABLE 8 where the hypothesis of identical coefficients is rejected at the 5 percent level. The tax on labor coefficient is less than the *Other* tax coefficient in only four of these.[28] The tax on capital coefficient is less than the *Other* tax in none of them.

These results suggest that tax effects can differ even within fiscal policy categories. In other words, while we have grouped taxes on labor and capital with other types of distortionary taxes, we reject the hypothesis of identical tax coefficients in 11 of 16 regressions. We also do not find any support for the conventional wisdom that labor and capital taxes are more distortionary than other types of taxes. However, one needs to interpret this finding with caution. Every tax effect is embedded within a particular fiscal policy. The finer the tax sub-

[28] See Panels B and D.

categories, the more likely the associated fiscal policies will not "average out". Thus, our results may reflect the fact that labor and capital taxes are associated with fiscal policies that differ systematically from other types of taxes. As we discuss in our conclusion, this is a subject that lies beyond the ability of our dataset to explore but that could be explored in further research.

V. CONCLUSION

Judging by the number of studies dedicated to the subject, there is much interest in identifying the effect of taxes on economic growth. Unfortunately, there is no consensus on the magnitude of this effect, as the literature has produced a wide range of effects. An underappreciated problem is that these studies are actually estimating different things, despite all claiming to provide estimates of "the effect" of taxes on growth. This follows from the fact that studies differ in the government budget constraints implied by their regression specifications. This greatly impacts the interpretation of the estimated tax coefficients.

We address this problem by categorizing estimated tax coefficients according to their implied government budget constraints using the taxonomy of fiscal policies presented in Gemmell, Kneller, and Sanz (2009). We then use meta-analysis to synthesize 641 estimates from 42 studies and calculate an average tax effect on economic growth. To do that, we define a measure of the growth effect of taxes that depends on a revenue neutral, one-percentage point change in tax policy: We estimate the effect of a one-percentage point decrease in distortionary taxes as part of a negative-growth fiscal policy, accompanied by a one-percentage point increase in non-distortionary taxes as part of a positive-growth fiscal policy. The associated 95% confidence interval implies that this would, on average, increase annual economic growth between 0.05 to 0.25 percent a year. This compares to an annual growth rate of approximately 2.50 percent for the countries in our study.

Several other findings arise from our study. We find strong evidence of publication bias. The results are consistent with researchers and journals discriminating in favor of negative estimated tax coefficients. While the bias is sufficiently large to be statistically significant, it is not large enough to be economically significant on average, though it may be important in individual studies. The existence of publication bias suggests that it is unwise to rely on one or a few individual studies of tax effects, as the associated estimates may not be representative of the population of estimated tax effects.

We also do not find any support for the conventional wisdom that labor and capital taxes are more distortionary than other types of taxes. However, one needs to interpret this finding with caution. These results may reflect the fact that labor and capital taxes are associated with fiscal policies that differ systematically from other types of taxes. To investigate this further requires more detailed investigation by primary studies that distinguish labor and capital taxes from other types of taxes. Relatedly, our sample of estimated tax coefficients shows substantial heterogeneity even within the same fiscal policy categories (cf. TABLE 4). Having a better understanding of the factors that influence the effectiveness of tax policy is key to making the results of the literature more useful to policymakers. These are topics for further research.

A final contribution of our study is that we make all our data and code available on the public data archive *Harvard Dataverse*. In particular, the database of estimated tax coefficients, including the corresponding data, estimation, and study characteristics associated with those estimates, will allow other researchers to further investigate the relationship between taxes and economic growth.

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TABLE 1
Matching of Functional and Theoretical Classifications

Functional classification	*Theoretical classification*
Taxation on income and profit Social security contributions Taxation on payroll and manpower Taxation on property	Distortionary taxation
Taxation on domestic goods and services	Non-distortionary taxations
Taxation on international trade Non-tax revenues Other tax revenues	Other revenues
General public services expenditure Defense expenditure Educational expenditure Health expenditure Housing expenditure Transport and communication expenditure	Productive expenditures
Social security and welfare expenditure Expenditure on recreation Expenditure on economic services	Unproductive expenditures
Other expenditures (unclassified)	Other expenditures

SOURCE: Kneller, Bleaney, and Gemmell (1999).

TABLE 2
Different Tax-Spending-Deficit Specifications Used by Studies

Study	Colombier (2009)	Romero-Ávila & Strauch (2008)	Bleaney et al. (2001)	Afonso & Fuceri (2010)	Muinelo-Gallo and Roca-Sagalés (2013)
Regression	Table 1, Column 1	Table 5, Column 5	Table 1, Column 1	Table 5, Column 1	Table 3, Column 1
Dep. Variable	Real GDP per capita growth	Real GDP per capita growth	Real GDP per capita growth	Real GDP per capita growth	Real GDP per capita growth
Tax variable(s)	- Average tax rate	- Direct taxes - Indirect taxes - Social contributions	- Distortionary taxes	- Direct taxes - Indirect taxes - Social contributions	- Direct taxes - Indirect taxes
Other Fiscal Variable(s)	-None	- Govt. consumption - Govt. transfers - Govt. investment	- Other revenues - Other expenditures - Budget surplus - Productive expenditures - Non-productive expenditures	-None	- Non-distributive expenditures
Omitted Fiscal Categories	- All expenditures - Deficit	- Deficit	- Non-distortionary taxes	- All Expenditures - Deficit	- Distributive expenditures - Deficit
Countries	21 OECD countries	15 EU countries	22 OECD countries	28 OECD countries	21 OECD countries
Time Period	1970-2001	1960-2001	1970-1995	1970-2004	1972-2006

TABLE 3
Classification of Tax and Expenditure Combinations
by Their Predicted Growth Effects

TYPE OF TAX	***OMITTED FISCAL CATEGORY***	***PREDICTED EFFECT***
	A. TaxNegative Fiscal Policies	
Distortionary	Unproductive Expenditures	Negative
Distortionary	Non-distortionary Taxes	Negative
	B. TaxPositive Fiscal Policies	
Non-distortionary	Productive Expenditures	Positive
Non-distortionary	Distortionary Taxes	Positive
Non-distortionary	Deficit/Surplus	Positive
	C. TaxAmbiguous Fiscal Policies	
Distortionary	Productive Expenditures	Ambiguous
Distortionary	All Expenditures (Prod. & Unprod.)	Ambiguous
Distortionary	Other Expenditures	Ambiguous
Distortionary	Deficit/Surplus	Ambiguous
Distortionary	Other Revenue	Ambiguous
Distortionary	Distortionary Taxes	Ambiguous
Distortionary	Intergovernmental Revenue	Ambiguous
Distortionary	Net Utility Expenditures	Ambiguous
Non-distortionary	Unproductive Expenditures	Ambiguous
Non-distortionary	Productive & Unproductive Expenditures	Ambiguous
Non-distortionary	Other Expenditures	Ambiguous
Non-distortionary	Other Revenue	Ambiguous
Non-distortionary	Non-distortionary Taxes	Ambiguous
Non-distortionary	Intergovernmental Revenue	Ambiguous
Non-distortionary	Net Utility Expenditures	Ambiguous

SOURCE: Gemmell, Kneller, and Sanz (2009), where we combine the original categories of "zero" and "ambiguous" to "ambiguous" (see Appendix 4 for the source table).

TABLE 4
Descriptive Statistics for Estimated Tax Coefficients by Fiscal Policy

	FULL SAMPLE			***TRUNCATED SAMPLE***		
	TaxNegative (1)	***TaxAmbiguous (2)***	***TaxPositive (3)***	***TaxNegative (4)***	***TaxAmbiguous (5)***	***TaxPositive (6)***
Mean	-0.18	-0.08	0.03	-0.17	-0.10	-0.04
Median	-0.12	-0.06	0.03	-0.12	-0.06	-0.01
Minimum	-1.00	-3.52	-0.67	-0.52	-0.52	-0.37
Maximum	0.25	12.72	0.82	0.15	0.17	0.14
Std. Dev.	0.21	0.75	0.25	0.17	0.13	0.14
1%	-0.85	-1.91	-0.67	-0.52	-0.44	-0.37
5%	-0.52	-0.58	-0.36	-0.46	-0.37	-0.36
10%	-0.46	-0.37	-0.23	-0.45	-0.29	-0.25
90%	0.05	0.05	0.36	0.03	0.04	0.14
95%	0.12	0.14	0.38	0.08	0.08	0.14
99%	0.18	0.91	0.82	0.13	0.14	0.14
Obs	156	507	50	146	457	38

TABLE 5
Estimated Tax Effects without Control Variables

	Fixed Effects (Weight1) (1)	***Fixed Effects (Weight2) (2)***	***Random Effects (Weight1) (3)***	***Random Effects (Weight2) (4)***
A. WITHOUT CORRECTION FOR PUBLICATION BIAS				
TaxNegative $(\boldsymbol{\beta_1})$	-0.038*** *(0.009)*	-0.048** *(0.018)*	-0.024 *(0.052)*	-0.068 (0.046)
TaxPositive $(\boldsymbol{\beta_2})$	0.028*** *(0.009)*	0.032*** *(0.008)*	0.084*** *(0.026)*	0.069*** *(0.024)*
$\boldsymbol{\beta_2 - \beta_1}$	0.066 *(0.042, 0.090)*	0.080 *(0.043, 0.118)*	0.108 *(0.004, 0.212)*	0.137 *(0.042, 0.232)*
B. WITH CORRECTION FOR PUBLICATION BIAS				
SE	-1.556*** *(0.311)*	-1.500*** *(0.266)*	-0.904*** *(0.281)*	-0.990*** *(0.212)*
TaxNegative $(\boldsymbol{\beta_1})$	-0.023*** *(0.005)*	-0.029*** *(0.010)*	-0.032 *(0.041)*	-0.056 *(0.038)*
TaxPositive $(\boldsymbol{\beta_2})$	0.038*** *(0.005)*	0.038*** *(0.004)*	0.083*** *(0.029)*	0.064*** *(0.021)*
$\boldsymbol{\beta_2 - \beta_1}$	0.060 *(0.048, 0.073)*	0.067 *(0.046, 0.0.088)*	0.115 *(0.029, 0.200)*	0.120 *(0.042, 0.198)*
Observations	641	641	641	641

NOTE: The top value is the coefficient estimate, and the bottom value in parentheses is the associated cluster robust standard errors. *, **, and *** indicate statistical significance at the 10-, 5-, and 1-percent level, respectively. The last row of the top panel (Panel A) and the row before the last row in the bottom panel (Panel B) calculates the difference in the two tax variables, $\beta_2 - \beta_1$. The corresponding 95% confidence interval is reported in parenthesis. The four WLS estimators (*Fixed Effects-Weight1, Fixed Effects-Weight2, Random Effects-Weight1,* and *Random Effects-Weight2*) are described in the “Four estimation procedures” subsection of Section IV in the text.

TABLE 6
Summary Statistics of Study Characteristics

Variable	*Description*	*Mean*	*Min*	*Max*
	COUNTRY GROUP			
G7	=1, if G7 countries	0.117	0	1
EU15	=1, if EU15 countries	0.064	0	1
EU	=1, if EU countries but not EU-15	0.031	0	1
*OECD**	=1, if OECD countries but not G7, EU-15, or EU	0.788	0	1
	ECONOMIC GROWTH MEASURE			
GDP	=1, if dependent variable is GDP growth	0.259	0	1
*PCGDP**	=1, if dependent variable is per capita GDP growth	0.741	0	1
	TAX VARIABLE MEASURE			
Marginal	=1, if marginal tax rate (as opposed to average tax rate)	0.090	0	1
Differenced	=1, if change in tax rate (as opposed to level of tax rate)	0.172	0	1
ETR	=1, if effective tax rate (as opposed to statutory tax rate)	0.906	0	1
	DURATION OF TAX EFFECT			
*ShortRun**	=1, if tax variable measures immediate/short-run effect	0.702	0	1
MediumRun	=1, if tax variable measures cumulative/medium-run effect	0.053	0	1
LongRun	=1, if tax variable measures long-run, steady-state effect	0.245	0	1
	STUDY TYPE			
PeerReviewed	=1, if study published in peer-reviewed journal	0.661	0	1
PublicationYear	Year in which the last version of study was "published."	2007	1993	2015
	DATA TYPE			
CrossSection	=1, if data are cross-sectional.	0.009	0	1
*Panel**	=1, if data are panel	0.991	0	1
Length	Length of sample time period	31.4	5	40
MidYear	Midpoint of the sample time period	1985	1970.5	2004.5

Variable	*Description*	*Mean*	*Min*	*Max*
	ESTIMATION TYPE			
*OLS**	=1, if OLS estimator is used.	0.677	0	1
GLS	=1, if Generalized Least Squares estimator is used.	0.154	0	1
Endogeneity	=1, if estimator corrects for endogeneity, e.g. 2SLS, 3SLS, or GMM.	0.168	0	1
	STANDARD ERROR TYPE			
*SEOLS**	=1, if OLS standard error is considered.	0.587	0	1
SEHET	=1, if heteroskedasticity standard error is considered.	0.245	0	1
SEHAC	=1, if both heteroskedasticity and autocorrelation standard error are considered.	0.168	0	1
	INCLUDED VARIABLES			
InitialIncome	=1, if initial level of income included	0.559	0	1
LaggedDV	=1, if lagged dependent variable included	0.167	0	1
CountryFE	=1, if the country fixed effects are included	0.833	0	1
Investment	=1, if investment included	0.585	0	1
TradeOpenness	=1, if trade openness included	0.170	0	1
HumanCapital	=1, if human capital included	0.440	0	1
PopulationGrowth	=1, if population growth included	0.243	0	1
EmploymentGrowth	=1, if employment growth included	0.378	0	1
Unemployment	=1, if unemployment rate included	0.090	0	1
Inflation	=1, if inflation rate included	0.131	0	1

NOTE: The grouped variables include all possible categories, where the categories omitted in the subsequent analysis are indicated by an asterisk, where applicable.

TABLE 7
Estimated Tax Effects with Control Variables

	Fixed Effects (Weight1) (1)	*Fixed Effects (Weight2) (2)*	*Random Effects (Weight1) (3)*	*Random Effects (Weight2) (4)*
A. FULL SET OF CONTROL VARIABLES INCLUDED				
SE	-1.150***	-1.172***	-0.673***	-0.656***
	(0.263)	*(0.223)*	*(0.156)*	*(0.192)*
Endogeneity	-0.001*	-0.001	-0.009	0.015
	(0.000)	*(0.001)*	*(0.021)*	*(0.021)*
TaxNegative	-0.046**	-0.037**	-0.080**	-0.090**
	(0.017)	*(0.015)*	*(0.031)*	*(0.033)*
TaxPositive	0.039***	0.041***	0.065**	0.059***
	(0.009)	*(0.007)*	*(0.028)*	*(0.026)*
$\boldsymbol{\beta_2 - \beta_1}$	0.084	0.078	0.146	0.148
	(0.049, 0.120)	*(0.046, 0.110)*	*(0.078, 0.214)*	*(0.077, 0.220)*
B. CONTROL VARIABLES CHOSEN BY SELECTION ALGORITHM				
SE	-1.090***	-1.144***	-0.804***	-0.860***
	(0.259)	*(0.241)*	*(0.157)*	*(0.182)*
Endogeneity	-0.000	-0.001	-0.004	0.011
	(0.001)	*(0.001)*	*(0.021)*	*(0.018)*
TaxNegative	-0.044***	-0.042***	-0.080**	-0.068*
	(0.012)	*(0.010)*	*(0.030)*	*(0.038)*
TaxPositive	0.039***	0.042***	0.063***	0.095***
	(0.009)	*(0.007)*	*(0.026)*	*(0.026)*
$\boldsymbol{\beta_2 - \beta_1}$	0.083	0.084	0.143	0.163
	(0.053, 0.113)	*(0.063, 0.104)*	*(0.071, 0.215)*	*(0.077, 0.249)*
Observations	641	641	641	641

NOTE: The top value in each cell is the coefficient estimate, and the bottom value in parentheses is the associated cluster robust standard errors. *, **, and *** indicate statistical significance at the 10-, 5-, and 1-percent level, respectively. The last row of the top panel (Panel A) and the row before the last row in the bottom panel (Panel B) calculates the difference in the two tax variables, $\beta_2 - \beta_1$. The corresponding 95% confidence interval is reported in parenthesis. The four WLS estimators (*Fixed Effects-Weight1, Fixed Effects-Weight2, Random Effects-Weight1,* and *Random Effects-Weight2*) are described in the "Four estimation procedures" subsection of Section IV in the text.

TABLE 8
Estimated Tax Effects by Type of Tax

	Fixed Effects (Weight1) (1)	***Fixed Effects (Weight2) (2)***	***Random Effects (Weight1) (3)***	***Random Effects (Weight2) (4)***
A. FULL SET OF CONTROL VARIABLES INCLUDED (Omitted Tax Category = *TaxAmbiguous*)				
TaxNegative (Labor)	-0.017** *(0.021)*	0.008 *(0.024)*	-0.019 *(0.029)*	0.003 *(0.036)*
TaxNegative (Capital)	0.004 *(0.018)*	0.017 *(0.018)*	0.005 *(0.026)*	-0.012 *(0.031)*
TaxNegative (Other)	-0.102*** *(0.037)*	-0.077** *(0.029)*	-0.174*** *(0.040)*	-0.151*** *(0.039)*
TaxPositive	0.038*** *(0.009)*	0.040*** *(0.007)*	0.057** *(0.026)*	0.055** *(0.025)*
***Test:* Labor=Capital=Other**	F = 17.64 *(p = 0.000)*	F = 4.94 *(p=0.012)*	F = 17.14 *(p = 0.000)*	F = 7.11 *(p = 0.002)*
B. FULL SET OF CONTROL VARIABLES INCLUDED (Omitted Tax Category = *TaxNegative*)				
TaxAmbiguous (Labor)	0.043** *(0.019)*	0.031 *(0.020)*	0.044 *(0.041)*	0.055 *(0.042)*
TaxAmbiguous (Capital)	0.066*** *(0.018)*	0.060*** *(0.016)*	0.094*** *(0.032)*	0.107*** *(0.038)*
TaxAmbiguous (Other)	0.044** *(0.018)*	0.037** *(0.016)*	0.088** *(0.032)*	0.094*** *(0.034)*
TaxPositive	0.083*** *(0.018)*	0.078*** *(0.017)*	0.144*** *(0.036)*	0.148*** *(0.037)*
***Test:* Labor=Capital=Other**	F = 5.80 *(p = 0.006)*	F = 6.20 *(p = 0.004)*	F = 1.23 *(p = 0.303)*	F = 1.29 *(p = 0.286)*
C. CONTROL VARIABLES CHOSEN BY SELECTION ALGORITHM (Omitted Tax Category = *TaxAmbiguous*)				
TaxNegative (Labor)	-0.048*** *(0.012)*	-0.041*** *(0.013)*	-0.041 *(0.031)*	0.010 *(0.045)*
TaxNegative (Capital)	-0.025** *(0.012)*	-0.026*** *(0.010)*	-0.016 *(0.025)*	-0.014 *(0.027)*
TaxNegative (Other)	-0.086** (0.035)	-0.068** *(0.029)*	-0.151*** *(0.037)*	-0.121*** *(0.038)*
TaxPositive	0.039*** *(0.008)*	0.042*** *(0.007)*	0.065** *(0.028)*	0.095*** *(0.027)*
***Test:* Labor=Capital=Other**	F = 255.81 *(p = 0.000)*	F = 1.54 *(p = 0.227)*	F = 10.23 *(p = 0.000)*	F = 7.79 *(p = 0.001)*

	Fixed Effects (Weight1) (1)	*Fixed Effects (Weight2) (2)*	*Random Effects (Weight1) (3)*	*Random Effects (Weight2) (4)*
D. CONTROL VARIABLES CHOSEN BY SELECTION ALGORITHM (Omitted Tax Category = *TaxNegative*)				
TaxAmbiguous (Labor)	0.035** *(0.015)*	0.034** *(0.017)*	0.053 *(0.042)*	0.054 *(0.047)*
TaxAmbiguous (Capital)	*0.061**** *(0.012)*	*0.063**** *(0.012)*	0.093*** *(0.027)*	0.077** *(0.036)*
TaxAmbiguous (Other)	0.038** *(0.014)*	0.041*** *(0.010)*	0.085** *(0.031)*	0.069* *(0.039)*
TaxPositive	0.078*** *(0.017)*	0.083*** *(0.011)*	0.141*** *(0.037)*	0.163*** *(0.043)*
***Test:* Labor=Capital=Other**	F = 7.95 *(p = 0.001)*	F = 5.54 *(p = 0.007)*	F = 0.69 *(p = 0.507)*	F = 0.41 *(p = 0.665)*
Observations	641	641	641	641

NOTE: The top value in each cell is the coefficient estimate, and the bottom value in parentheses is the associated cluster robust standard errors. *, **, and *** indicate statistical significance at the 10-, 5-, and 1-percent level, respectively. The last row of panel A, B, C and the row before the last row in panel D report the F-test (the null hypothesis is that the three tax variables have identical coefficients).The four WLS estimators (*Fixed Effects-Weight1, Fixed Effects-Weight2, Random Effects-Weight1,* and *Random Effects-Weight2*) are described in the “Four estimation procedures” subsection of Section IV in the text.

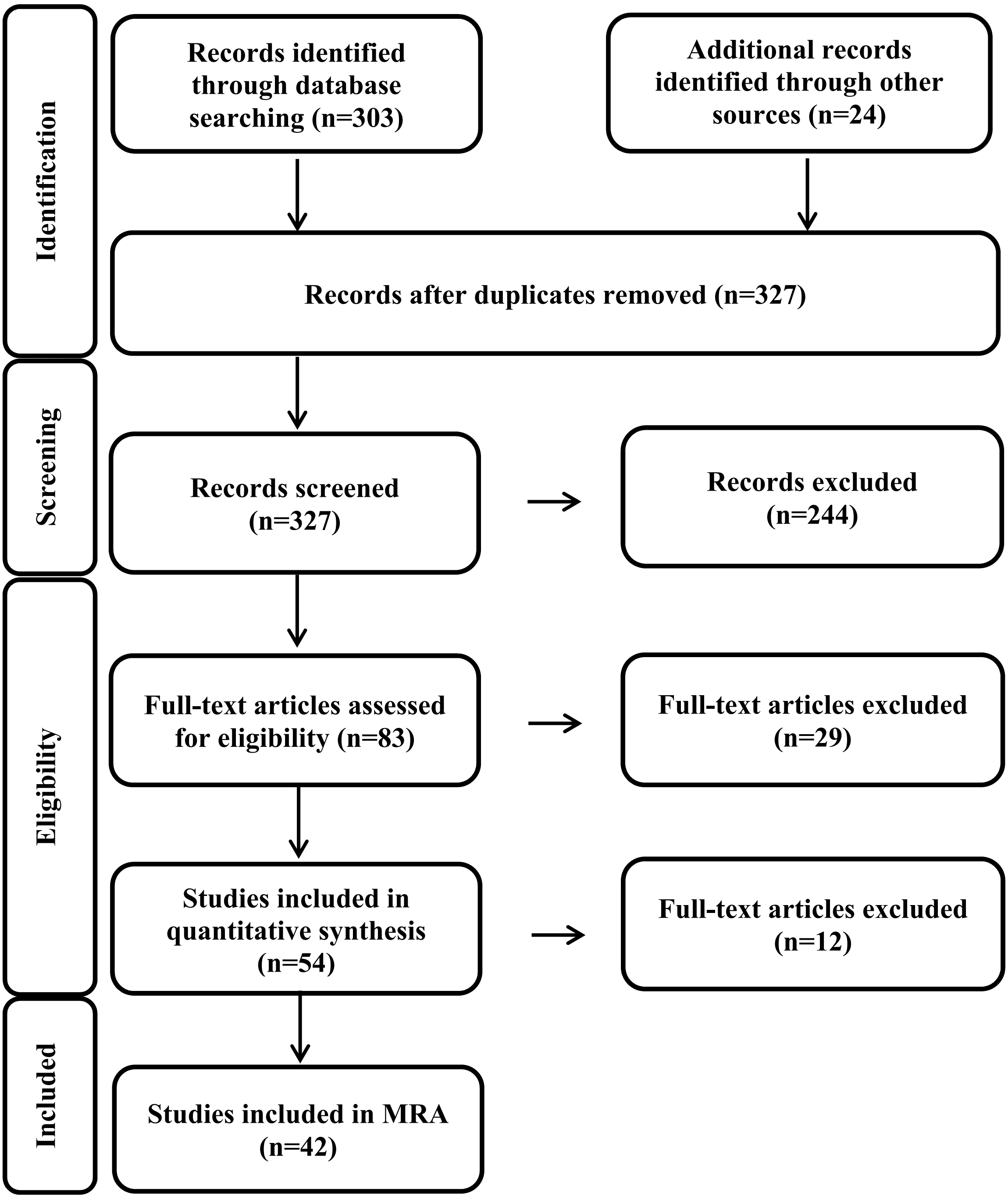
APPENDIX 1
List of Terms Used in Electronic Search by Category

TAX	ECONOMIC GROWTH	OECD
Tax(es) /Tax rate(s)/Taxation	Economic growth	OECD countries
Tax policy(policies)	Growth	EU countries
Tax ratios	Economic indicators	G-7 countries
Tax changes	Long-term growth	High income OECD countries
Tax rate change	Long-run growth	Industrial countries
Fiscal policy(policies)		Rich countries
Tax structures/Fiscal structures		Europe
Fiscal decentralization		Cross-national study
Public finances		

APPENDIX 2
Studies

ID	Study	Publication Status	Number of estimates
1	Afonso and Alegre (2008, 2011)	Working Paper + Journal	12
2	Afonso and Furceri (2010)	Journal	6
3	Afonso and Jalles (2013, 2014)	Working Paper + Journal	21
4	Agell et al. (1997)	Journal	3
5	Agell et al. (1999)	Journal	4
6	Agell et al. (2006)	Journal	4
7	Alesina and Ardagna (2010)	Journal	26
8	Angelopoulos et al. (2007)	Journal	36
9	Arin (2004)	Working Paper	80
10	Arnold et al. (2011)	Journal	5
11	Arnold (2008)	Working Paper	18
12	Baskaran and Feld (2013)	Journal	12
13	Bergh and Karlsson (2010)	Journal	3
14	Bergh and Ohrn (2011)	Working Paper	10
15	Bleaney et al. (2001)	Journal	19
16	Colombier (2009)	Journal	13
17	Daveri et al. (1997, 2000)	Working Paper + Journal	6
18	De La Fuente (1997)	Discussion Paper	15
19	Fölster and Henrekson (2001)	Journal	7
20	Fölster and Henrekson (1999)	Journal	7
21	Furceri and Karras (2009)	Working Paper	43
22	Gemmell et al. (2015)	Journal	10
23	Gemmell et al. (2008)	Working Paper	18
24	Gemmell et al. (2014)	Journal	53
25	Gemmell et al. (2011)	Journal	19
26	Hansson (2010)	Journal	23
27	Heitger (1993)	Journal	2
28	Karras and Furceri (2009)	Journal	32
29	Karras (1999)	Journal	28
30	Kneller et al. (1999)	Journal	35
31	Mendoza et al. (1997)	Journal	11
32	Miller and Russek (1997)	Journal	12
33	Muinelo-Gallo and Roca-Sagales (2013)	Journal	6
34	Padovano and Galli (2001)	Journal	2
35	Romero-Avila and Strauch (2008)	Journal	15
36	Volkerink et al. (2002)	Journal	26
37	Widmalm (2001)	Journal	6
38	Xing (2011)	Working Paper	34
39	Hakim et al. (2013)	Conference Paper	2
40	Arin et al. (2015)	Working Paper	6
41	Paparas et al. (2015)	Journal	16
42	Xing (2012)	Journal	7

APPENDIX 3
PRISMA Flow Diagram



APPENDIX 4
Copy of Table from Gemmell, Kneller, and Sanz (2009) Classifying Tax and Expenditure Combinations by their Growth Effects

Financed by:		Public Spending: Productive	Public Spending: Unproductive	Budget Surpluses
Taxes:	Distortionary	*positive/negative* (at *low/high* gov. size)	*negative*	*ambiguous*
	Non-distortionary	*positive*	*zero*	*positive*
Budget Deficits		*ambiguous*	*negative*	-

SOURCE: Gemmell, Kneller, and Sanz (2009), Table 1, page 19.

APPENDIX 5
Study Weights

	Fixed Effects	*Random Effects*
Mean	2.38%	2.38%
Median	0.10%	2.59%
5%	0.0009%	0.86%
10%	0.0046%	1.75%
90%	1.2%	2.7%
95%	4.0%	2.8%
Maximum	81.4%	2.8%
Top 3	92.4%	8.3%
Top 10	97.4%	27.5%
Studies	42	42

NOTE: Study weights were calculated by $w_i / \sum w_i$, where $w_i = 1/(SE_i)^2$ or $w_i = 1/[(SE_i)^2 + \tau^2]$ depending on whether Fixed Effects or Random Effects were being used (cf. Ringquist, 2013, page 128).

APPENDIX 6
Classification of Tax Coefficients into Short-, Medium, and Long-Run Effects

Let the estimated relationship between $growth$ and the tax rate variable, *tr*, be given by the finite distributed lag model,

(A1) $growth_t = \alpha_0 + \alpha_1 tr_t + \alpha_2 tr_{t-1} + \boldsymbol{X\beta} + \varepsilon_t$.

If this is the model estimated by the original study, then α_1 and α_2 represent the "short-run/immediate" effects of a one-percentage point increase in taxes in years *t* and *t-1* on economic growth in year *t*.

By adding and subtracting $\alpha_2 tr_t$ to the right hand side, one can rewrite the above as:

(A2) $growth_t = \alpha_0 + \tau\, tr_t - \alpha_2 \Delta tr_t + \boldsymbol{X\beta} + \varepsilon_t$,

where $\tau = (\alpha_1 + \alpha_2)$. If this is the model estimated in the original study, then the coefficient on the current tax rate, τ, represents the "cumulative/intermediate" effect of a one-percentage point increase in taxes in year *t* and *t-1* on economic growth in year *t*.

An alternative specification to Equation (A1) is the auto-regressive, distributed lag model,

(A3) $growth_t = \alpha_0 + \alpha_1 tr_t + \alpha_2 tr_{t-1} + \gamma growth_{t-1} + \boldsymbol{X\beta} + \varepsilon_t$.

Subtracting $growth_{t-1}$ from both sides gives:

(A4) $\Delta growth_t = \alpha_0 + \alpha_1 tr_t + \alpha_2 tr_{t-1} + (\gamma - 1) g_{t-1} + \boldsymbol{X\beta} + \varepsilon_t$,

which can be rewritten in error correction form as:

(A5) $\Delta growth_t = \alpha_0 + \delta(growth_{t-1} - \theta tr_t) - \alpha_2 \Delta tr_t + \boldsymbol{X\beta} + \varepsilon_t$,

where $\delta = (\gamma - 1)$ and $\theta = \frac{(\alpha_1 + \alpha_2)}{(1-\gamma)}$. This specification is common in recent mean group and pooled mean group studies of economic growth. In Equation (A5), the coefficient on tr_t in the cointegrating equation, θ, represents the total, long-run effect of a permanent, one-percentage point increase in the tax rate on steady-state economic growth.[29]

Specifications (A1), (A2), and (A5) lead to three different measures of the effect of taxes on economic growth. Our meta-analysis controls for this by noting the specification of the growth equation in the original study and categorizing the duration of the estimated tax effect as Short-, Medium-, or Long-run.

[29] We note that Equation (A5) is sometimes estimated using an equivalent, alternative specification: $\Delta growth_t = \alpha_0 + \delta(growth_{t-1} - \theta tr_{t-1}) + \alpha_1 \Delta tr_t + \boldsymbol{X\beta} + \varepsilon_t$, where δ and θ are defined as above.