The Growth Effects of Corporate and Personal Tax Rates in the OECD

by

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Abstract

Recent aggregate tests of the impact of taxes on long-run growth rates in OECD countries remain vulnerable to two criticisms. First, they typically use '*an aggregate average rate, or constructed marginal rate, that probably does not affect the rate that any particular economic decision maker is facing' (Myles, 2007, p.89).* Second, despite increased testing of corporate tax effects, the models examined are essentially 'closed economy' in nature, yet corporate tax effects appear increasingly to operate via international competition for firms, profits and investment. Based on an open economy model, we propose a method for testing how far both domestic corporate tax settings, and those in competitor countries, affect individual countries' aggregate long-run growth rates. This predicts asymmetric effects between 'high tax' and 'low tax' competitor countries. We then use annual panel data on statutory tax rates (both personal and corporate), and effective average and marginal corporate tax rates, to test for these tax-growth effects in a sample of OECD countries. We find robust evidence that (i) marginal rates of personal income tax (as measured by the top personal rate); and (ii) both domestic *and* foreign corporate tax rates (statutory and/or effective), have affected OECD growth rates as predicted by theory. (iii) The predicted asymmetric effects find strong empirical support. Our evidence suggests that 'bucking the OECD trend' towards lower corporate tax rates is likely to be growth-retarding, but joining it is likely to be growth-neutral. The evidence also suggests that tax effects on growth operate through both factor accumulation and factor productivity.

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1. Introduction

Theory suggests taxes should have an effect on economic growth. Following Barro (1990), these can be 'permanent', as in the recent endogenous growth models of Kaas (2003), Kalyvitis (2003), Zagler and Durnecker (2003), Park and Philippopoulos (2003) and Ho and Wang (2005), or apply only to 'transitions', which Barro, *et al* (1995) and Turnovsky (2004) demonstrate could nevertheless be up to several decades.[1] The key characteristic of most of these models is that growth effects depend on the *form* of taxation (and the *type* of public expenditure that is tax-financed).

Recognising the weak theoretical case, and limited evidence, supporting *total tax* effects on growth, recent studies have begun to focus on particular aspects of the tax system, in particular whether taxes that distort individual, corporate and entrepreneurial decisions affect long-run growth rates though factor accumulation or productivity. Lee and Gordon (2005) for example, lay out a number of arguments why high corporate marginal tax rates, and personal-corporate tax rate differences, might be expected to affect entrepreneurial activity, with long-run growth consequences.

For personal income taxes, the well-known arguments regarding the efficiency costs of progressivity have recently been formalised within an endogenous growth model by Li and Sarte (2004). Their model captures the impact of incentives for individuals to increase their pre-tax incomes when personal income taxes are less progressive. This essentially captures tax-induced saving choices. In a similar vein, Gentry and Hubbard (2004a, b) argue that 'entrepreneurial responses' to personal taxes may also be important: progressive personal taxation affects entrepreneurs' savings decisions and appears to have discouraged entrepreneurial entry in the US.

Recent attempts to provide empirical tests some of these hypotheses on OECD countries have made a number of methodological improvements in recent years but remain vulnerable to two important criticisms. (i) Tax-growth hypotheses, typically derived in closed economy settings, are tested on economies that are increasingly open, especially with respect to capital flows and corporate choices. (ii) Empirical tax rate proxies are based on endogenous tax revenue measures that do not reflect the tax rates facing any economic decision-makers. This paper attempts to deal with both of these issues by considering how hypotheses derived from open-economy growth models can be tested empirically at the aggregate level. It also uses relevant statutory and

[1] Turnovsky (2004) demonstrates this within the context of a neoclassical model. Similar 'transitional effects' are found in recent 'semi-endogenous' growth models such as Dalgaard and Kreiner (2003).

effective average and marginal tax rates that various economic agents might be expected to face. We discuss these aspects in section 2 below.

The paper focuses specifically on the contribution of corporate and personal income taxes to long-run growth in OECD countries. This reflects both availability of suitable tax rate data for those taxes and the ongoing debate over their respective growth contributions. As Myles (2007) notes: 'there is mixed evidence from regression analysis on whether it is personal income taxes or corporate income taxes that are responsible for the negative relation', and 'it is not clear whether it is the level of taxation or the progressivity of taxation that matters'. Our evidence supports the thrust of recent contributions that both personal tax progressivity and high corporate tax rates are associated with lower growth. However, to identify these latter effects robustly requires recognition of the impact of both domestic and relevant 'foreign' tax rates.

The remainder of the paper is organised as follows. Section 2 discusses the relevance of open-economy growth models, and the recent literature on international corporate mobility, for tests of aggregate tax-growth effect. It also considers the choice of suitable tax rates. Section 3 describes our data and methodologies for testing tax-growth impacts in OECD countries. Section 4 presents our results and section 5 concludes.

2. Taxes and Growth in Closed and Open Economies

2.1 Testing models of taxes and growth

To the extent that aggregate-level empirical tests of the 'taxes and growth' relationship have been based on rigorous growth models, these have generally been closed economy models such as Barro (1990).[2] Arguably, where international mobility of labour or human capital is not an issue, the main growth responses to *personal* taxes may be suitably analysed and tested in such a setting.[3]

For corporate taxes however, international dimensions in general, and the globalization of companies and capital flows in particular, are increasingly recognized as important. The recent literature on behavioural responses of multinational corporations to international differences in corporate tax rates has begun to address these aspects. Increasingly, evidence supports the view that multinationals' profits and investment are attracted to countries offering lower statutory or effective corporate tax rates (see, for example, Grubert and Slemrod 1998; Bartelsman and

[2] See, for example, Devarajan *et al* (1996), Kneller *et al* (1999), Bleaney *et al* (2001), Adam and Bevan (2005).

[3] Even in this context, attempts to tax (increasingly mobile) capital income via personal tax schedules raises doubts over the closed economy assumption. With *foreign-sourced* capital income typically harder to tax than its domestically-sourced equivalent, there is a greater incentive for individuals in high-tax economies to earn capital income abroad.

Beetsma, 2003; Devereux and Hubbard, 2003; Huizinga and Laeven, 2008; Devereux, *et al*, 2008).

A second important issue, highlighted in the *Introduction*, concerns the use of suitable tax rates to measure tax-growth effects. Following an extensive literature review, Myles (2007, p 89) neatly characterized the problem as follows.

"What should matter for the economic outcome is the distortion caused by the tax (how much it changes decisions). An aggregate measure of the tax rate can never capture the varying degrees of distortion that individuals or firms with different incomes will face. … it still remains the case that all of the regressions are limited by the fact that they are unable to work with the rate of tax that affects individual decisions. For decisions at the margin we would think of the marginal rate of tax as being important. But there are discrete choices (such as choice of location) for which the average rate matters. What the regressions end up using is an aggregate average rate, or constructed marginal rate, that probably does not affect the rate that any particular economic decision maker is facing."

As Myles (2007) notes, previous regression studies have mostly relied on implicit average tax rates measured using tax revenue data either as a share of GDP (e.g. Kneller *et al*, 1999; Bleaney *et al*, 2001) or as ratios of a tax base measure such as personal incomes or corporate profits. These latter tax rates have sometimes been labelled as 'effective' rates (see Martinez-Mongay, 2000; Angelopoulos, *et al*, 2007; Romero-Ávila & Strauch, 2008; Arnold, 2008) but they retain the problems mentioned by Myles.[4] The few studies that have reported tax-growth effects using statutory tax rates (e.g. Wildmalm, 2001; Lee and Gordon, 2005; Angelopoulos, *et al*, 2007) have found non-robust evidence for corporate taxes but generally negative growth effects associated with the top rate of personal income tax.[5]

In this paper we use annual data on top statutory tax rates in OECD countries from the Office of Tax Policy Research at the University of Michigan, and the statutory, effective average and marginal tax rates (ETRs) calculated by Devereux *et al* (2002). While top personal statutory rates are, at best, able to capture the marginal rates relevant to higher income earners, they are likely to be close to the personal rates most relevant to many human capital accumulation, personal equity investment and entrepreneurial decisions. It is these decisions that might be expected to have greatest impact on GDP growth rates in OECD countries. Likewise, effective tax rates (ETRs), such as those calculated by Devereux *et al* (2002), have been calculated to reflect the tax rates

[4] Padovano and Galli (2002) construct 'effective' average and marginal tax rates using regression methods applied to annual tax revenue and GDP data.

[5] For example, to interpret an estimated *positive* impact of higher (domestic) corporate tax rates on GDP growth, Angelopoulos *et al* (2007) argue that the increasing international mobility of corporate investment and/or profits that cause countries to compete over corporate tax rates, can generate an outcome where the observed revenue-maximising tax rate is below the growth-maximising rate.

relevant to corporate investment decisions under a variety of assumptions and, as Devereux *et al* (2008) emphasise, the *statutory* corporate tax rate is the relevant rate applicable to corporate profit-shifting decisions. These latter decisions may not directly affect real economic activity (to the extent that they represent pure accounting effects via transfer pricing). However, as Grubert and Slemrod (1998) argue, real resource transfers by multinationals are often complimentary to profit-shifting strategies. In addition, countries' *measured* GDP will be affected, even if real activity is unchanged, to the extent that shifted profits are captured in National Accounting profit measures.

Further, the recent evidence of Devereux *et al* (2008) provides strong support for the view that, since the early 1980s, OECD countries have increasingly competed over corporate tax rates (statutory and effective) to attract mobile capital. If this has spillover effects onto aggregate economic growth, any reduced-form relationship between domestic tax rates and GDP growth rates will miss out on a key determinant, namely the interaction between domestic, and competing foreign, tax rates. In section 3 we discuss further how we incorporate those 'foreign' rates.

2.2 Tax-growth effects in open economies

This sub-section outlines the key implications of the Barro (1990) closed-economy, and the Barro, Mankiw and Sala-i-Martin (hereafter BMS, 1995) open-economy, tax-growth models; see the Appendix for details. Endogenous growth models since Barro (1990) predict that taxes which distort accumulation decisions can affect long run growth. In practical applications or tests of these simplified models, this has generally been interpreted to suggest that taxes on income, capital and property assets are potentially 'distortionary'.[6] To the extent that these taxes affect the drivers of total factor productivity growth (innovation/R&D, entrepreneurship, etc), there may be further channels to long-run growth.

In the Barro (1990) model, the marginal tax rate has two effects – a growth-retarding effect via reductions in the after-tax return on capital, and a positive effect via enabling higher (growth-enhancing) public expenditure. Though Barro assumes a proportional income tax, Li and Sarte's (2004) extension to allow for heterogeneous individuals and progressivity (marginal/average tax rate differences) shows that raising tax progressivity has a negative growth impact since this raises adverse marginal impacts relative to positive public spending impacts.

[6] As Mendoza *et al* (1997) demonstrated, consumption taxes can also be distortionary (in the growth sense) to the extent that labour supply/education choices are affected.

BMS (1995) amend the 'closed' neoclassical model to allow for internationally mobile physical capital but immobile human capital. The key insight from that small open economy model for present purposes is that the transition from an initial stock of human capital to a steady-state equilibrium is affected both by the domestic tax rate, τ, and world rate of return on physical capital (see Appendix). In the latter case, this reflects the fact that a lower world interest rate, r^w (= rate of return abroad) increases the optimal foreign borrowing to fund a higher physical capital-output ratio. This, in turn, raises the marginal productivity of human capital and hence growth.

Since the model describes the behaviour of a representative consumer-producer, we can think of a representative firm borrowing from abroad to fund physical capital investment. This could involve borrowing from a foreign subsidiary or unrelated party at rate, r^w. In either case, in practice the tax liability associated with such borrowing typically depends on country-specific tax rules governing foreign interest/income. For example, interest payments abroad may be tax-deductable, different tax rates may be applicable to foreign-sourced income such as interest and dividends, and country-specific double tax agreements may be relevant. Below we discuss some of the relevant tax rules. In general the value of r^w for a domestic investor in practice can be expected to depend on a mixture of domestic and foreign tax rates.

The recent literature on tax-induced profit shifting by multinational firms has begun to examine the tax liabilities associated with different locations for investment or taxable profits. Huizinga and Laeven (2008) discuss a number of mechanisms by which taxable profits can be 'shifted' across countries in response to differences in tax rates. For investment decisions involving location choices, the appropriate tax rate is the effective average tax rate (EATR), whereas the effective marginal rate (EMTR) is relevant for investment decisions conditional on prior location choice; see Devereux and Griffith (2003). Both these effective rates take into account the capital allowance deductions available against investment, methods of financing (e.g. debt versus equity), etc. Devereux and Griffith (2003) provide evidence on these EATRs and EMTRs across OECD countries since 1980.

For international profit-shifting decisions, top statutory rates on corporate income in different locales are more relevant. Even here however, as Huizinga and Laeven (2008) point out, given the variety of country-specific tax rules, it is the 'effective' tax rates on reported income in each country that determine these locational choices. This effective rate is a function of the various statutory rates and tax rules. In particular, different tax regimes treat tax paid in other countries by domestically-resident firms in different ways. The three most common are:

1. **Tax credits**: foreign taxes paid may be deducted from domestic tax liabilities.
2. **Tax exemptions**: foreign-sourced income is tax exempt or is taxed only on repatriation.
3. **Tax deductions**: foreign taxes paid are treated as a 'business cost' to be deducted from domestic *profit* (rather than from domestic *tax liability*).

Huizinga and Laeven (2008) show that the relevant effective tax rates on different profit sources vary across these three regimes. This is illustrated below for a domestic parent firm (*p*) with a foreign subsidiary (*s*) – or set of subsidiaries – where τ (*t*) is the effective marginal (statutory) tax rate applicable in the 'home' country, where 'home' is defined as the country of residence of the parent firm.

Tax credit	**Tax exemption**	**Tax deduction**
$\tau_p = t_p$ $\tau_s = max.[t_p, t_s]$	$\tau_p = t_p$ $\tau_s = t_s$	$\tau_p = t_p$ $\tau_s = t_s + t_p(1 - t_s)$

This shows that, while the effective tax rate on parent firms' profits earned at home is always the domestic statutory rate, the rate payable (at 'home') on foreign subsidiaries' profits differs across the three cases. The most common regime in the OECD is the tax credit system such that profits earned by foreign subsidiaries are taxed at the maximum of the home or foreign statutory rates.[7]

There is an incentive to shift profits to the subsidiary if $\tau_s < \tau_p$. In the *exemption* case, this condition is equivalent to $t_s < t_p$, with profits shifted *from* the subsidiary if $t_s > t_p$. Thus, profit-shifting is symmetric with respect to statutory tax rate differences. With a tax *credit* system there is an asymmetry. There is an incentive to stream profits from subsidiaries in 'high statutory rate' countries towards the parent (i.e. when $t_s > t_p$), but no incentive to stream profits to/from subsidiaries in countries where $t_s < t_p$ (because the 'final' tax rate is t_p). In practice some incentives to shift profits to subsidiaries in low-tax countries may remain even in this case; for example, where subsidiaries' profits face additional tax of $t_p - t_s$ only on repatriation to the parent. In the *deduction* case, it is always worth shifting profits from subsidiaries to the parent to the maximum extent possible to minimise 'double taxation'.

In testing for these international tax aspects in the context of an empirical growth model, the relevant question is how far *changes* in relevant domestic and/or foreign tax rates might affect

[7] Huizinga and Laeven (2008) examine 32 European countries of which 25 have a tax credit system, 4 have an exemption system and only 2 have a deduction system (1 offers no double tax relief).

investment and profit flows that could impact on aggregate GDP growth. In a world of fully open economies it might be argued that multinational investors will optimise their allocations across all locations at all points in time, given the existing and expected set of tax rates, and other determinants of the expected profitability of investment in each location. An (unanticipated) reduction in a relevant tax rate in country *i* would therefore induce a reallocation of the investment portfolio towards country *i*. That is, even if country *i*'s tax rate is higher than country *j*'s, *ceteris paribus*, there would be an incentive to shift resources from *j* to *i* when the latter's tax rate falls.

This is clearly not the situation that best describes OECD countries over recent decades. Rather, as Devereux *et al* (2008) show, those economies have generally experienced increasing openness of their capital markets such that resources that were optimally invested within a high-tax country when it is 'closed' can be expected to shift towards a lower-tax country, *ceteris paribus*, when international flows become possible. This is reinforced by most OECD countries use of the tax credit system described above. As economies become 'open', global tax liability can be reduced by moving parent firms to lower tax jurisdictions and by shifting investment/profits from subsidiaries in jurisdictions with tax rates above the 'home' country rate, to the home jurisdiction and/or those with tax rates below the 'home' rate. The asymmetry in this system ensures that there is no (or a smaller) tax incentive to shift resources 'up the chain' of tax rates.

In section 4 we examine those arguments empirically within the context of a growth model in which international capital flows become possible. Open economy tax-growth models, such as BMS (1995), have not formally modelled the *process* of globalization in the sense of moving from being 'less open' to 'more open'. Rather BMS (1995) compare tax-growth effects in 'closed' with 'open' economies where *physical* capital is perfectly immobile and mobile respectively. Nevertheless, the insight from such models is that when capital markets become open, growth during the transition towards the steady-state becomes sensitive to the tax rates on both domestic output *and* foreign borrowing or income. Ignoring foreign taxes in an open economy context could lead to erroneous conclusions with respect to domestic tax effects; for example, where downward co-movement in all countries tax rates is misinterpreted as downward movement in only the domestic rate.

3. Data and Methodology

We argued earlier that tests of the impact of taxes on economic growth need to be improved in two ways: by (i) using suitable tax rates that can better approximate those that affect agents' decisions; and (ii) accommodating open-economy dimensions. A third issue concerns the appropriate set of control variables when testing for aggregate tax-growth effects. We consider each in turn below.

3.1 Tax rate data

As noted above, Myles (2007) rightly argues that the tax rates used in regression analyses should, to the extent possible, reflect the actual effective rates that relevant economic agents face. In the context of the kind of growth models we are seeking to test this implies using tax rates that affect physical and human capital investment decisions and those that might impact on other drivers of productivity growth such as R&D and entrepreneurship. For tax rates relevant to corporate investment decisions we use *annual* panel data on the statutory tax rate, and effective marginal and effective average tax rates from the Office of Tax Policy Research at the University of Michigan, and the Institute for Fiscal Studies (IFS) respectively. Since observed growth impacts from investment or profit-shifting may reflect location choices and/or marginal decisions, we are agnostic regarding which of these is likely to best capture relevant growth effects.

Lee and Gordon (2005) argue that statutory corporate rates also capture the relevant incentives facing entrepreneurs. While this would apply to incorporated businesses, many entrepreneurs are likely to be unincorporated in which case the top personal rate is likely to be more relevant. This rate can also be expected to approximate the marginal rate facing individual portfolio investors, at least where this reflect the rate applicable to capital income. In some countries – such as Scandinavian countries with dual income tax systems - the tax rate applicable to capital income may be lower than the top statutory rate. The form in which capital income is earned (interest, dividend, capital gains) can also affect the applicable tax rate. Huizinga and Nicodème (2004) show that tax rates on interest income in OECD countries help to drive the international location of deposits.

In general, data on the tax rates applicable to different types of capital income are not as readily available or comparable on an annual basis as top statutory rates on earned income. Data from OECD (2008) however suggest that top rates of personal tax on dividend income are highly correlated (across counties) with top personal rates on earned income.[8] Since previous studies have used versions of implicit average tax rates (IATRs), and because they capture aspects of the government budget constraint (see below), we also examine the growth impacts associated with IATRs. These are calculated from annual IMF *Government Finance Statistics* (GFS) data on tax revenues and GDP.

3.2 Recognising international dimensions

We have argued that foreign corporate tax rates are relevant to domestic investment decisions, and should therefore be included in an empirical growth model. The prevalence of the 'tax credit' system in most OECD countries also suggests that the asymmetric aspect of foreign tax rates should be allowed for. For each country in the sample we therefore construct a weighted average of statutory tax rates, EATRs and EMTRs, in other countries. These averages use as weights: (a) GDP; (b) distance; and (c) unweighted; i.e. equal weight. Since the 'economic distance' that influences corporate responses to international tax differences may be reflected in a variety of factors, we explore all three of these weighting schemes. In fact, we find each behaves similarly and mainly report results for the unweighted case. To examine asymmetry aspects, we further construct weighted averages as above, for each country, *i*, in each year, *t*, but separately for those countries where corporate rates are respectively above and below the rate in country *i* in year *t*. The 'above' average for country *i* is the mean of those countries with a higher tax rate than *i*, whereas the below average is the mean of those countries with a lower tax rate than *i*.

Our hypothesis is that countries with tax rates *below* that in *i* will serve as an attractor for investment that otherwise would locate in *i,* as capital becomes more mobile, hence reducing growth in country *i*. Countries with tax rates *above* *i*'s, however, are irrelevant to country *i* investors. They will therefore not attract investment from *i* and hence have zero effect on growth in country *i*. Given that the tax credit system does not operate in practice in quite the simplified manner described earlier, the alternative 'symmetric' hypothesis is that investment is attracted *to* country *i* from countries with higher tax rates, but away from *i* to countries with lower tax rates. That is, in response to the ranking of corporate tax rates, investment begins to flow 'downhill' as capital becomes more mobile.

In the context of examining international tax competition, Devereux *et al* (2008) argue that each individual country's corporate tax rate is endogenous – as tax competition causes country *i*

[8] For 2007, for example, personal MTRs on dividend and wage income are correlated across our 17 country sample at r = 0.75. Data from Tables I.4 & II.4 at www.oecd.org/ctp/taxdatabase.

to react to country *j*'s tax-setting choices and *vice versa*. Their empirical solution is to instrument directly for each country's tax rate using the determinants of *other* sample counties' tax rates. We follow a similar approach, discussed further in section 4.

3.3 Econometric issues and control variables

This sub-section deals with a number of econometric testing issues before turning to our results in section 4.

The Government Budget Constrain (GBC)

As most recent tests of the aggregate impact of taxes on growth now recognise, it is important to accommodate the GBC in empirical tests. That is, since the government budget is a 'closed system', any change in one element must be accompanied by equivalent changes in at least one other element. As a result, any government budget items not included in the estimating equation are implicitly the funding elements associated with the included budget categories. Recent empirical tests of the impact of fiscal variables on growth have, following Barro (1990), typically summarised these as 'distortionary'/'non-distortionary' taxes, 'productive'/ 'unproductive' expenditures and budget deficits; see Bleaney *et al* (2001), Adam and Bevan (2005).

'Implicit' tax rates (IATRs), when included, and government spending categories, are defined as ratios of GDP. Thus, the GBC can be specified 'exactly' in growth regressions with one or more categories omitted (the implicit financing) to avoid perfect collinearity.[9] However, when statutory or effective marginal or average tax rates are used in regressions the 'omitted financing element' is less clear, making interpretation of parameters less precise. For this reason, in regressions reported below we always include budget deficits and 'productive' public spending. We also report results both including and excluding distortionary tax IATRs. This allows us to consider whether this variable has any residual explanatory power when other relevant statutory or effective tax rates are included. It also helps to identify whether omitting this element of the GBC matters for interpretation of the remaining fiscal parameters.

Control variables

Controlling for non-fiscal determinants of growth is not straightforward. Most previous exercises have attempted to control for standard growth model determinants: labour, capital

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[9] Kneller *et al* (1999) recommend omitting unproductive spending and/or non-distortionary taxes from such regressions – since theory suggests these should have little or no growth effect, making interpretation of parameters on included fiscal variables easier.

(more usually, investment rates) and human capital, with or without various other macro variables (inflation, trade openness etc). However, since taxes are hypothesised to impact on output partly via physical and/or human capital investment, arguably these controls will capture some of the fiscal effects of interest, leaving only productivity-transmitted effects to be picked up by tax rate variables. This problem is compounded when poor proxies are relied on to measure fiscal impacts.

We therefore begin by examining possible interactions between our fiscal and control variables, comparing regressions which include and exclude each in turn. We use three control variables: labour force growth, human capital growth (measured as years of schooling embodied in the labour force)[10], and the ratio of private non-residential investment to GDP. To minimise the likelihood of over-estimating the growth impact of taxes, we also (see section 4) allow non-fiscal determinants to explain growth first, and then examine the ability of our fiscal variables to explain the 'growth residual' (a form of multi-factor productivity growth measure). Finally, the limited availability of some fiscal data limits our sample coverage to 17 OECD countries; data for most countries spanning the late-1970s to 2004.[11] To facilitate comparisons across specifications we generally use a common set of countries in all regressions. When using effective tax rate data, the sample is limited further, to 12 countries from 1980.

Econometric Methods and Endogeneity

Our analysis uses annual panel data and the pooled mean group (PMG) methodology proposed by Pesaran *et al* (1999). This allows heterogeneous constants and marginal short-run effects across countries to be accommodated, while maintaining homogeneity of the long-run responses. The major advantage of this approach is that it makes full use of the available time-series information and provides estimates of long-run parameters without the need for long lag structures. For regressions including IATRs, Gemmell e*t al.* (2006) report that the PMG estimator performs better than alternative dynamic fixed-effects or mean group (MG) estimators in the current context. [12]

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[10] The human capital data is based on Arnold *et al* (2007). We are grateful to Jens Arnold, Andrea Bassanini and Stefano Scarpetta at the OECD for supplying the data.

[11] The full 17 country sample is: Australia*, Austria*, Canada*, Denmark, Finland*, France*, Germany*, Iceland, Luxembourg, Netherlands*, New Zealand, Norway*, Spain*, Sweden*, Turkey, UK*, USA*. An asterisk indicates the country is included in the reduced EMTR/EATR sample.

[12] The MG estimator additionally allows long-run parameter heterogeneity but sacrifices degrees of freedom, hence restricting the number of right-hand-side variables. That analysis also demonstrates that allowing for short-run heterogeneity reveals that most of the so-called 'long-run' growth effects occur within a small number of years (<7) in most countries. A Hausman test supports the assumption of long-run homogeneity in the PMG model.

Concern over endogeneity is perhaps the major source of unease over the reliability of previous tests of tax rates on growth, despite some attempts to control for this. Income taxes in particular typically experience fiscal drag – such that revenues increase disproportionately to the tax base as income growth shifts taxpayers into higher tax brackets. For this reason, we rely more on statutory and effective rates rather than IATRs, which makes our estimates less vulnerable to these endogeneity concerns. Nevertheless, governments' discretionary tax changes are sometimes made in response to macroeconomic conditions, and other variables in our regressions (e.g. investment, public expenditure, deficits) may also be endogenous. We therefore use instrumental variable methods based on lag structures (which we test for exogeneity), and use various weighted averages of other countries' corporate tax rates, described more fully in section 4 below.

The resulting regression equation which we estimate by PMG or IV methods is of the following 'error correcting' form:

$$\Delta g_{i,t} = \phi_i (g_{i,t-1} - \beta F_{i,t-1}) + \sum_{m=1}^{M} \lambda_{i,m} \Delta g_{i,t-m} + \sum_{k=0}^{K} \gamma_{i,k} \Delta F_{i,t-k} + \varepsilon_{i,t} \qquad (1)$$

where i denotes the country, t is time, g is the rate of growth of GDP, F is a matrix of fiscal and control variables and $\varepsilon_{i,t}$ is a classical error term. The parameter vectors ϕ_i and $\boldsymbol{\beta}$ respectively capture the error correction and (homogeneous) long-run growth effects, while $\lambda_{i,m}$ and $\gamma_{i,k}$ capture the heterogeneous short-run responses to g and F respectively (with lag lengths $M, K = 1$). We focus on results for the long-run parameter vector, $\boldsymbol{\beta}$.

4. Empirical Results

4.1 Controls versus fiscal variables

We begin this section by considering - in regression [1] of Table 1 - how well a model that excludes all fiscal variables explains OECD GDP growth. [13] This can be interpreted as a form of growth-accounting regression but with an investment/GDP ratio rather than a capital growth rate on the RHS. As a result, parameters are not necessarily expected to sum to unity. This simple relationship performs fairly well with human capital growth driving the largest impact on GDP growth (0.85) compared to values less than 0.2 for labour growth and investment.[14]

[13] For all regression results we report the homogeneous long-run parameters and omit country-specific, short-run parameters to save space. Unweighted statutory rates are used here.

[14] Replacing human capital growth in regression [1] with the stock (in each year) produces implausible parameter values suggesting that it is the *flow*, rather than the *stock*, of human capital that matters for growth.

To examine fiscal impacts we begin by including *only* the ‘fiscal control’ and statutory tax rate variables – regression [2] - and then nesting all variables in regression [3]. The tax rates are: the top statutory rate of personal income tax (P_i-top), the statutory corporate rate in each country, *i*, (C_i-stat) and the average statutory corporate rate in other countries, *j*, where corporate rates are respectively lower (C_j-stat-L) and higher (C_j-stat-H). The ‘fiscal controls’ are productive public expenditures (as % of GDP) and the budget surplus. We delay discussion of the fiscal variables to sub-section 4.2 and focus first on the interaction between the fiscal and control variables.

When fiscal variables are included in regression [2] *omitting the ‘production function’ control variables*, the tax rate variables take the expected signs – negative impacts from higher personal and domestic corporate tax rates (P_i-top, C_i-stat) and a positive impact from increases in the corporate rate in ‘lower tax’ countries (C_j-stat-L). Unlike C_j-stat-L, increases in corporate tax rates in ‘higher tax’ countries, (C_j-stat-H), appear to have no significant growth impacts on *i*. In regression [3], which nests both sets of variables, the fiscal variables remain statistically strong with generally slightly larger and more precisely identified point estimates, while the investment and human capital parameters become small, and statistically insignificant (and wrongly signed). The other regressions in Table 1 broadly repeat this pattern for control variables.

These results suggest that when fiscal and control variables are nested within a single model, it is the fiscal variables (at least those examined so far) that dominate, with the production function related variables yielding poor results. Thus, perhaps surprisingly, investment and human capital have no identifiable, independent (i.e. not fiscal-induced) long-run growth effects. To investigate this further, in sub-section 4.5, we consider the other extreme by allowing maximum impact from the control variables *before* allowing tax variables to impact on growth.

4.2 Results using statutory tax rates

Considering regression [3] of Table 1, the statutory tax rates reveal significant negative effects on growth associated with higher marginal personal tax rates (P_i-top) and domestic corporate tax rates (C_i-stat). The point estimate for the corporate rate is significantly larger, in absolute terms, than the personal rate parameter, with the hypothesis that both coefficients are the same rejected at a 5% significance level. The parameter on C_j-stat-L confirms our predictions that growth in country *i* is adversely affected by reductions in corporate rates in countries where C_j-stat is initially below C_i-stat. By contrast, countries with higher initial corporate rates, C_j-stat-H, appear to exert no significant influence on growth rates in country *i* (parameter = -0.001; *t*-ratio = 0.05). This is in line with the prediction, discussed above, of asymmetric effects on investment flows associated with the prevailing use of the corporate 'tax credit' system to avoid international double taxation in most OECD countries.

Regressions [3] to [6] compare the outcomes for different combinations of corporate tax rates. In regression [4] we omit the (insignificant) C_j-stat-H variable and note that remaining tax rate (and other) parameters are essentially unaltered. Regression [5] replaces C_j-stat-L with the average C_j-stat across *all* other countries. It can be seen that, while this variable continues to support significant positive effects on growth in country *i* (lower foreign tax rates reduce growth in *i*), the parameter on country *i*'s own corporate rate, C_i-stat, becomes statistically insignificant. That is, failing to differentiate between high-tax and low-tax competitor countries makes it harder to identify the respective growth effects of domestic and foreign corporate tax rates.

Further, regression [6] reveals that if foreign corporate tax rates are ignored altogether, the domestic corporate rate becomes positive and statistically significant, albeit small in magnitude. This provides strong confirmation for our hypothesis that ignoring open economy aspects of countries' corporate tax settings leads to falsely identifying higher domestic corporate tax rates as growth-enhancing. This may help to explain previous findings of some positive (domestic) corporate tax rate parameters by Angelopoulos *et al* (2007), Reed (2008) and others.[15]

Table 1 provides a number of robustness checks on the statutory tax rate results discussed above. First, in regressions [4′] and [4″], we consider the impact of alternative weighting schemes in constructing the average corporate rate in other countries. The issue here is what determines the sensitivity of investment, declared profit and firm location, *ceteris paribus*, to tax settings in other countries? This will be a function of a number of country-specific factors that we cannot hope to capture here. However, more general measures of 'economic distance' and/or physical distance are also likely to be relevant to corporate location decisions over their headquarters, subsidiaries etc.

In their analysis of corporate tax competition, Devereux *et al* (2008) use countries' GDP and recent FDI flows as weights. We use GDP and physical distance measures as weights.[16] Regressions [4′] and [4″] show that results are insensitive to the weighting scheme adopted. In general, using GDP or distance as weights reduces the absolute magnitude of the parameter estimates (and the implied elasticities at variable means). Note however, that in each of [4], [4′]

[15] Reed (2008, 2009) provides robust evidence of various negative tax rate effects on growth, but positive State corporate tax revenue effects, at the individual US State level. In that context, the relevant 'foreign' corporate rate would be the rate applying in other, competing States.

[16] We do not use FDI data due to limited availability for early years of our sample. Physical distance is measured by the distance between the capital cities of all sample countries.

and [4″], the point estimate for the growth impact of 'foreign' corporate tax rates, C_j-stat-L, is greater (in absolute value) than that for the domestic corporate rate, C_i-stat.

We noted earlier that including implicit average tax rates in regressions helps to specify the GBC more fully, but may not pick up the kinds of average or marginal tax rate effects on growth of interest. Table 1, regressions [7], therefore includes the IATR for 'distortionary' taxes. This enters [7] significantly with the expected negative sign and appears to be almost orthogonal to our statutory tax rate effects. The main effect of introducing the IATR is to increase the estimated positive impact of productive public spending and reduce the impact of budget surpluses (comparing [4] and [7]). This is to be expected since, in [4], distortionary taxes are a large (omitted) implicit financing element of expenditures and surpluses, hence altering their estimated growth effects when the IATR is explicitly introduced. It is interesting however that the IATR identifies additional adverse growth effects to those already captured in the statutory tax rate variables, perhaps because the latter are not capturing all of the relevant marginal or average responses.

Since our hypothesis is that country *i* will respond asymmetrically to higher and lower tax rates abroad, in regression [8] we include C_j-stat-L and C_j-stat-H separately and omit C_i-stat. Regression [8] reveals that C_j-stat-H now displays the negative sign (though not statistically significant) that was previously observed for country *i*'s tax rate. The parameter on C_j-stat-L (0.072; t = 1.94) continues to suggest adverse growth effects in country *i* from reductions in statutory rates in initially lower tax rate countries (i.e. positive sign). Note however that the smaller parameter sizes in [8], (0.072 & -0.025 compared with 0.223 & -0.130 in [4]) may be indicative of a bias away from zero in previously estimated parameters. We explore this issue further in sub-section 4.4.

Finally, in all regressions in Table 1, a statistically significant estimate is obtained for the effect of higher top personal tax rates on GDP growth. Excluding those regressions we regard as mis-specified – [5] & [6] – the point estimates for the personal tax rate are always below, in absolute terms, the corporate tax parameter estimates; significantly below except for [4′].

4.3 Results using effective corporate tax rates

Table 2 reports equivalent results to those discussed in sub-section 4.2, but replacing the statutory corporate rate with effective average or marginal corporate tax rates (C_i-eff, C_j-eff-L, C_j-eff-H) from the IFS/Devereux *et al* (2002) dataset. As noted above, this limits our sample size to 12 countries, post-1980. These effective rates are hypothetical rates applicable to specified investment types undertaken under alternative assumptions regarding, for example, the relevant rate of interest, inflation rate, method of financing (debt, equity) etc. Table 2 reports regressions for two cases: (i) assumed uniform inflation rates across countries (labelled 'base case': *bc*); and (ii) using countries' own rates of inflation ('variable inflation' case: *vi*).[17] In view of Devereux *et al*'s arguments that, for many corporate investment decisions, it is the average, rather than marginal, tax rate that is relevant, we consider both effective rates.[18] Regressions (1) – (3) in Table 2 are equivalent specifications to regressions [3], [4], and [7] in Table 1.

It can be seen that the Table 2 regressions tell a very similar story: the EATR(*bc*) yields significant negative effects for the country's own corporate rate (C_i-eff) and positive for the foreign rate, C_j-eff-L, but zero for C_j-eff-H. In regression (3) – where the distortionary tax IATR is again added to the regression – this generates a small, insignificant negative parameter and the parameter on the productive expenditure variable is essentially unaffected by inclusion of the IATR. One interpretation of this result is that when *effective* average tax rates are used in the regression, the IATR adds little additional relevant fiscal information in explaining growth.

Regressions (4)–(6) repeat regression (2) but using EATR(*vi*), EMTR(*bc*) and EMTR (*vi*) respectively. It can be seen that results are generally highly robust to these alternative definitions. Given the high correlations between these alternative effective tax rates, this result is not surprising and suggests that it is not likely to be possible to discriminate between effective *average*, and effective *marginal*, tax rates in terms of their growth impacts. Both rates appear to succeed in picking up statistically significant growth effects and the '*bc*/*vi*' distinction is fairly immaterial. These results are especially interesting because the effective tax rates used here can be regarded as genuinely exogenous, having been calculated for a hypothetical investment type within each country/year, and are not constructed from countries' tax revenue data.

As in Table 1, Table 2 regressions again reveal strong, statistically significant adverse growth effects associated with increases in top personal tax rates. Given the variety of personal rates likely to impact on different marginal decisions with potential effects on aggregate growth, we do not interpret these results as indicating impacts specific to the *top* personal rate. As we argued earlier, of the various personal marginal tax rates, the top marginal rate is likely to be the most growth-relevant in many cases, but in our regressions may simply be proxying for those various

[17] Other 'base case' assumptions are: investment is in plant and machinery, financed by equity or retained earnings, taxation at shareholder level is not included, rate of economic rent = 10% (i.e. financial return = 20%), real discount rate = 10%, inflation rate = 3.5%, depreciation rate = 12.25%; see Devereux and Griffith (2003) for details.

[18] In fact in this IFS dataset the EATRs and EMTRs are highly correlated: r = 0.90 to 0.98 across the 12 OECD countries included in our sample.

rates. Overall the tax rate results in Table 2 are highly consistent with those in Table 1 despite being obtained for a reduced sample over a shorter period.

4.4 Instrumental variable (IV) regressions

The previous sub-section considered possible endogeneity in the C_i-stat variable but otherwise treated tax rate and other variables as exogenous. To maximise available degrees of freedom for IV regressions we return to our larger dataset involving statutory tax rates. The arguments around the potential endogeneity of IATRs are well-known, but statutory tax rates may suffer from similar problems to the extent that governments adjust tax parameters, including rates, in response to macroeconomic and other conditions related to GDP growth rates.[19] In addition, our public spending, budget surplus and private investment variables may be endogenously determined. In this sub-section we control for endogeneity using standard IV methods, for three alternative instrument sets. The instrument sets are based on using sufficient lags of suspected endogenous variables to pass relevant diagnostic tests, and we again incorporate 'other countries' tax rates as instruments.

The right-hand section of Table 2 reports estimates from these IV regressions; with regression [4] from Table 1 repeated to assist comparisons. In (IV1), instrumented variables are the fiscal controls (productive expenditure, budget surplus) and private investment, but we do not instrument for tax rates: P_i-top, and C_i-stat. Regression (IV2) additionally instruments for those tax rates, using lagged values, If the Devereux *et al* (2008) evidence of strategic competition between countries over corporate tax settings is correct, then our above average tax rates in other countries (C_j-stat-H) potentially provide instruments for the country-specific tax rates (C_i-stat). In (IV2), we instrument C_i-stat with C_j-stat-H.[20] In Table 3 we report a number of diagnostic tests for instrument validity in these IV regressions, which we discuss further below. In sum, all three regressions pass relevant exogeneity tests.

On the effect of personal and corporate tax rates on growth, the three IV regressions all support our earlier conclusions; namely there are significant negative growth effects from higher personal, and domestic corporate, tax rates, but positive growth effects arising from increased corporate tax rates in countries initially below the country of interest. Note that the parameter on on C_j-stat-H in (IV3), now capturing the effect of the omitted C_i-stat, (IV3), is now significantly

[19] For the US, Romer and Romer (2007) propose a novel method of distinguishing different types of endogenous response, using Budget statements on the reasons for, and costing of, fiscal reforms. They provide evidence of robust growth responses to 'exogenous' tax changes. Their approach is not viable here, given the number of sample countries.

[20] In all cases first stage regressions are estimated by fixed-effects methods with second stage regressions using PMG methods.

negative, whereas previously it was negative but not statistically significant. Comparing the point estimates in the IV regressions with those in regression [4] from Table 1 shows that IV versions are generally smaller in absolute value than their PMG equivalents. This generally confirms that earlier regressions may over-estimate the impact of taxes on growth but qualitatively these effects remain highly robust.

An interesting question to arise from this concerns the individual country growth responses to *global* corporate rate reductions. That is, if all countries simultaneously reduced their statutory corporate tax rates similarly, is growth affected? Though *relative* corporate tax rates would remain unchanged in this scenario, tax-growth effects may still be expected to the extent that a lower corporate tax rate domestically stimulates greater domestic economic activity (e.g. via increased local investment or entrepreneurial activity), even though incentives for international capital or profit mobility are unchanged. On the other hand, the resulting increase in the corporate-personal tax wedge could worsen growth-retarding distortions. With our limited sample we cannot answer questions relating to *global* corporate tax rate reductions but we can consider the effect of uniform reductions across the 17 country sample.

If we accept the evidence from Tables 1 and 2 that corporate tax rates in 'higher-tax' countries (C_j-stat-H) have a zero or negligible effect on country i, then the results in (IV1) and (IV2) suggest that uniform sample corporate tax reductions would have a small net negative effect on growth in country i.[21] That is, the absolute value of the parameter on C_j-stat-L typically exceeds by a small, but statistically significant, margin the C_i-stat parameter (except for (IV2) where the difference is insignificant). Though this does not capture *global* tax reductions for the reasons given above, it suggests at the very least that advocating that countries cut their corporate tax rates to boost their GDP growth could be misplaced. Growth effects may be negligible when many countries follow the same policy.

For our control variables, IV regressions in Table 2 indicate some differences compared to equivalent Table 1 regressions. Firstly, productive public spending parameters generally continue to support positive growth effects though point estimates now vary more across specifications. Secondly, the budget surplus – with a predicted positive sign – turns negative, sometimes significantly. At a minimum this suggests that previously estimated positive long-run effects from larger budget surpluses are non-robust. Indeed, since 'long-run' increases in budget imbalances are, by their nature, unsustainable, it would be surprising if short-run changes in

[21] Since our sample excludes many countries to/from which sample countries' investment etc might flow, our empirical results are consistent with positive, zero or negative net growth effects if *all* countries reduce their corporate tax rates, even though uniform reductions in all *sample* countries appear to be slightly growth-negative.

imbalances had long-run growth effects. Among the other control variables, investment again fails to display significant growth effects but the IV estimates now suggest positive growth effects from human capital increases. Given the lags involved in human capital accumulation this long-run effect is more plausible. For investment, however, these results continue to support the view that inclusion of fiscal variables renders autonomous investment effects redundant. While the main channels through which taxes are often hypothesised to affect growth is via private investment, the absence of an autonomous investment effect is surprising. In sub-section 4.5 we therefore investigate tax-growth effects *after first allowing for* private investment effects on growth.

Before doing so, Table 3 provides some diagnostic testing of our IV regressions. For each case, the Sargan test results do not reject the hypothesis that the instruments are valid. However, the instruments should also be correlated with the included endogenous variables. The usual F-statistic and the partial R^2 between all excluded instruments and the endogenous regressors of the first-stage cannot reveal the weakness of a particular instrument if the rest of the instruments are highly correlated with the endogenous variables (Staiger and Stock, 1997). The Shea partial R^2 (Shea, 1997) overcomes this by taking into account cross-correlations among the instruments.

Table 3 shows that the Shea partial R^2s are all satisfactorily high in each IV regression, with the possible exception of (IV2). In that regression, the Shea partial R^2s for the domestic corporate rate is relatively low. Baum *et al* (2003) suggest as a rule of thumb that if the standard R^2 is large whereas the Shea partial R^2 is small, we may conclude that the instruments lack sufficient relevance to explain all the endogenous regressors.

A more formal test, which we also report, is the Stock and Yogo (2005) weak instrument test based on the Cragg-Donald statistic. This tests whether the bias in IV parameter estimates due to weak instruments exceeds (above a certain threshold) the bias in equivalent OLS estimates.[22] For regressions (IV1) and (IV3), we can reject the null hypothesis that our instruments are weak. In contrast, for regression (IV2), we do not reject the weak instrument hypothesis: the Cragg-Donald statistic is below the critical value. In this case, instrumenting P_i-top and C_i-stat may not lead to a reduction in any bias present in the PMG parameters in Table 1.

[22] Stock and Yogo (2005) class an instrument as weak, or 'performing poorly', using two alternative definitions. The first is that "a group of instruments is weak if the bias of the IV estimator, relative to the bias of the OLS, could exceed a certain threshold *b*" (we use $b = 5\%$). The second is that the instruments are weak "if the conventional α-level Wald test based on IV statistics has an actual size that could exceed a certain threshold *r*" (we use $r = 10\%$).

4.5 'Residual growth' regressions

The nested regressions in Table 1, including both fiscal variables and the standard growth accounting controls, produced robust support for the former at the expense of the latter. This would appear to give a strong role to fiscal policy such that investment - and perhaps human capital accumulation - have little independent effect on growth or, at best, have effects that cannot be robustly identified. Human capital accumulation in most OECD countries is heavily conditioned by government provision of education such that it might be the case that inclusion of fiscal variables (especially productive public spending) in growth regressions renders a human capital variable redundant. However it is more surprising that this appears to hold for physical capital investment.

To test whether the tax effects identified earlier are robust to assumptions about the impact of investment and human capital on growth, we therefore use residuals from regression [1] in Table 1, where only 'production function' control variables were included. These residuals represent a form of total factor productivity (TFP) growth measure, being the growth rate of GDP net of any associated changes in investment, labour and human capital growth. We refer to this as 'residual growth', g_R, and examine how far our fiscal variables can explain this residual. Effectively this will capture only those fiscal-growth effects that operate through total factor productivity.

Table 4 reports PMG and IV regressions for g_R for the cases where the specifications either include or exclude the distortionary tax IATR. We would not suggest that these regressions represent appropriately specified explanations of total factor productivity growth. Even a cursory reading of the literature on the determinants of productivity growth can throw up several non-fiscal right-hand-side variables likely to affect TFP (R&D expenditure, innovation, business regulation, financial market constraints, etc.). Rather, our objective here is to establish whether the tax rate variables continue to have any explanatory power when our previous control variables are first allowed maximum effect; effects that Table 1, regression [1], suggested were statistically strong.

Considering Table 4 results for the tax rate variables first, these generally mirror those obtained for GDP growth and suggest that, even after attributing maximum effect to 'input' variables, both personal and corporate tax rates continue to display strong effects on growth via productivity impacts. In particular, a country's 'own' statutory rate, C_i-stat, impacts adversely on g_R while the average 'lower-tax' foreign rate, C_j-stat-L, has a positive impact. The top personal tax rate parameter is again robustly negative. As in the GDP growth regressions, the IATR effects on residual growth are largely orthogonal to the effects associated with the marginal/statutory tax rates.

5. Conclusions

This paper has sought to deal with two weaknesses in recent aggregate tests of the impact of taxes on long-run growth rates in OECD countries. First, existing evidence is largely based on 'an aggregate average rate, or constructed marginal rate, that probably does not affect the rate that any particular economic decision maker is facing' (Myles, 2007, p.89). Second, despite increased awareness and testing of corporate tax effects on aggregate growth, the models examined are essentially 'closed economy' in nature. However, separate evidence increasingly links international competition for firms, corporate profits and investment to international differences in corporate tax rates. Based on an open economy model, we have proposed an approach to test how far both domestic and foreign corporate tax settings affect individual countries' aggregate long-run growth rates. We suggest that these 'foreign' effects can be expected to be asymmetric between countries with corporate tax rates (statutory and/or effective) below, or above, the domestic equivalent rate.

Based on annual panel data for a sample of 17 OECD countries, we have tested for aggregate tax-growth effects associated with changes in statutory tax rates (both personal and corporate), and exogenous, effective average and marginal corporate tax rates. We find robust evidence that (i) marginal rates of personal income tax (as measured by the top personal rate); and (ii) both domestic and foreign corporate tax rates (statutory and/or effective), have affected OECD growth rates as predicted by theory. In particular, corporate tax effects appear to be asymmetric, with tax reductions in 'lower-tax' foreign countries having a different effect to reductions in 'higher-tax' foreign countries. The latter effect is expected to be zero and appears to be so empirically.

The evidence on corporate tax rates suggests two things. Firstly, retaining high corporate tax rates in the face of a general trend towards lower rates could involve a significant growth penalty. Secondly however, when many countries lower their corporate tax rates, the growth benefits for each are negligible – it appears to approximate a zero-sum game. Finally, our evidence suggests that there are distinct, but equally robust, tax effects on aggregate growth operating through factor accumulation and those operating via impacts on factor productivity.

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Table 1 Long-Run Parameters for PMG Regressions Using Statutory Tax Rates

Regression No.:	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[4′]**	**[4″]**	**[7]**	**[8]**
Comment:	*'Controls' only*	*'Fiscal' only*	*Testing foreign corporate tax rate effects (Unweighted C_j-stat)*				*Using weighted C_j-stat: 'Distance'*	*'GDP'*	*Including IATRs*	*Endogenous C_i-stat ?*
Tax Rates:										
P_i-top		**-0.017**	**-0.033**	**-0.031**	**-0.033**	**-0.022**	**-0.027**	**-0.024**	**-0.039**	**-0.022**
		(1.49)	(4.31)**	(4.51)**	(4.63)**	(3.34)**	(3.96)**	(3.47)**	(6.03)**	(2.99)**
C_i-stat		**-0.112**	**-0.129**	**-0.130**	**-0.004**	**0.020**	**-0.035**	**-0.073**	**-0.130**	□
		(1.77)	(2.85)**	(3.28)**	(0.32)	(2.02)*	(2.39)**	(2.69)**	(3.44)**	
C_j-stat					**0.068**					
					(3.23)**					
C_j-stat-L		**0.208**	**0.225**	**0.223**			**0.074**	**0.117**	**0.231**	**0.072**
		(2.28)*	(3.51)**	(3.84)**			(4.86)**	(3.47)**	(4.20)**	(1.94)
C_j-stat-H		**-0.015**	**-0.001**							**-0.025**
		(-0.39)	(0.05)							(0.91)
'Fiscal Controls':										
Productive Expend.		0.081	0.076	0.081	0.081	0.084	0.071	0.094	0.158	0.052
		(1.25)	(2.12)*	(2.51)*	(2.23)*	(2.18)*	(2.34)**	(2.81)**	(6.35)**	(1.18)
Budget Surplus		0.051	0.150	0.146	0.132	0.125	0.136	0.147	0.099	0.103
		(1.31)	(5.28)**	(5.24)**	(4.67)**	(4.27)**	(4.95)**	(5.37)**	(3.50)**	(3.37)**
Distort. Tax IATR									**-0.208**	
									(6.64)**	
Other Controls:										
Investment ratio	0.150		-0.048	-0.051	0.040	-0.034	-0.103	-0.051	0.033	-0.009
	(4.02)**		(0.98)	(1.26)	(0.92)	(0.84)	(2.60)**	(1.32)	(0.85)	(0.20)
Labour force growth	0.195		0.287	0.304	0.273	0.261	0.301	0.305	0.337	0.235
	(4.84)**		(7.38)**	(8.18)**	(7.44)**	(6.61)**	(8.47)**	(8.11)**	(11.94)**	(5.87)**
Human cap. growth	0.854		-0.156	-0.194	0.382	-0.029	-0.195	-0.236	0.138	-0.032
	(2.17)*		(0.49)	(0.73)	(1.32)	(0.10)	(0.76)	(0.92)	(0.51)	(0.11)
Observations	472		420	420	420	420	420	420	420	

Parameters shown are long-run estimates. Absolute value of *z* statistics in parentheses; * = significant at 5%; ** = significant at 1%. P_i-top = top statutory rate of personal income tax; C_i-stat = statutory corporate rate; C_j-stat = average statutory corporate tax rates in other countries; C_j-stat-L/H = average statutory tax rates in other countries when below/above those in country *i*.

Table 2 Long-Run Parameters for PMG & IV Regressions Using Effective Tax Rates

Regression No.:	(1)	(2)	(3)	(4)	(5)	(6)		[4]	(IV1)	(IV2)	(IV3)
Effective tax rate:	*EATR bc*	*EATR bc*	*EATR bc*	*EATR vi*	*EMTR bc*	*EMTR vi*		*From Table 1:*			
Tax Rates:	*bc = 'base case' ; vi = 'variable inflation' case*								*Using IV methods*		
P_i-top	**-0.021**	**-0.032**	**-0.034**	**-0.025**	**-0.028**	**-0.022**		**-0.031**	**-0.018**	**-0.018**	**-0.012**
	(3.22)**	(4.49)**	(4.85)**	(3.58)**	(3.94)**	(2.69)**		(4.51)**	(6.03)**	(2.92)**	(3.73)**
C_i-eff	**-0.056**	**-0.068**	**-0.052**	**-0.116**	**0.010**	**-0.143**	C_i-stat	**-0.130**	**-0.049**	**-0.161**	
	(1.64)**	(2.18)**	(1.60)	(3.68)**	(0.94)	(4.84)**		(3.28)**	(2.43)**	(2.40)*	
C_j-eff							C_j-stat				
C_j-eff-L	**0.160**	**0.183**	**0.195**	**0.241**	**0.052**	**0.285**	C_j-stat-L	**0.223**	**0.087**	**0.217**	**0.049**
	(2.88)**	(3.71)**	(3.78)**	(5.00)**	(2.27)*	(6.20)**		(3.84)**	(2.90)**	(2.12)*	(2.77)**
C_j-eff-H	**-0.006**						C_j-stat-H				**-0.034**
	(0.19)										(2.66)**
'Fiscal Controls':											
Productive Expend.	0.064	0.082	0.081	0.062	0.096	0.094		0.081	0.087	0.001	0.047
	(2.33)*	(3.74)**	(3.17)*	(2.49)*	(3.98)*	(4.00)**		(2.51)*	(3.67)**	(0.03)	(1.89)
Budget Surplus	0.072	0.113	0.073	0.064	0.157	0.146		0.146	-0.035	-0.088	-0.045
	(2.75)**	(3.91)**	(2.42)**	(2.13)**	(5.41)**	(4.50)**		(5.24)**	(1.78)	(3.02)**	(2.30)*
Distort. Tax IATR			**-0.024**								
			(0.63)								
Other Controls:											
Investment ratio	0.017	-0.059	-0.010	-0.007	-0.130	-0.065		-0.051	-0.012	-0.016	0.000
	(0.35)	(1.22)	(0.17)	(0.13)	(2.91)**	(1.32)		(1.26)	(0.49)	(0.34)	(0.02)
Labour force growth	0.397	0.421	0.440	0.512	0.433	0.491		0.304	0.298	0.308	0.300
	(`13.44)**	(14.67)***	(15.15)**	(12.69)**	(14.78)**	(10.56)**		(8.18)**	(15.79)**	(8.42)**	(16.33)**
Human cap. growth	-0.134	0.166	-0.065	0.126	0.010	0.549		-0.194	0.676	1.141	0.677
	(0.40)	(0.55)	(0.21)	(0.38)	(0.04)	(1.69)		(0.73)	(4.61)**	(5.32)**	(4.55)**
Observations	279	279	279	270	279	270		420	405	382	405

Parameters shown are long-run estimates. Absolute value of *z* statistics in parentheses;* = significant at 5%; ** = significant at 1%.

Table 3 Instrumental Variable Regression Diagnostics

Table 2 regression No.:	**(IV1)**	**(IV2)**	**(IV3)**
Observations	405	382	405
Sargan test	$\chi^2(10) = 5.26$ p-value 0.87	$\chi^2(10) = 8.03$ p-value 0.63	χ^2 (9)=5.55 p-value 0.78
Anderson under-identification test	$\chi^2(10) = 285.4$ p-value 0.00	$\chi^2(10) = 83.8$ p-value 0.00	χ^2 (10)=203.90 p-value 0.00
Weak identification test: Cragg-Donald statistic *	30.25 CV (14, 3): 10.25	5.93 CV (16, 3): 10.41	29.8 CV (14, 3): 10.25
Endogenous variables: Shea Partial R^2 (regression R^2)			
P_i-top		0.47 (0.68)	
C_i-stat		0.20 (0.28)	
Productive expenditure	0.90 (0.90)	0.88 (0.92)	0.90 (0.90)
Budget surplus	0.54 (0.53)	0.56 (0.56)	0.54 (0.90)
Investment	0.80 (0.80)	0.74 (0.79)	0.80 (0.80)
Lagged growth	0.69 (0.66)	0.45 (0.46)	0.68 (0.66)

P_i-top = top statutory rate of personal income tax; C_i-stat = statutory corporate rate.

* Stock and Yogo (2005) have computed the critical values (CV) for up to 3 endogenous variables. The critical value for three endogenous variables, sixteen instrumental variables and 10% bias is 10.41. However, the critical value is a decreasing function of the number of endogenous variables. For (IV2), with six endogenous variables, the CV will be lower than 10.41. Therefore we cannot be sure whether the weak instrument hypothesis is rejected for this instrument set. We are grateful to James Stock for his comments and suggestions on this point.

Table 4 Regressions for 'Residual Growth' (g_R)

Regression No.: *Method:*	**[i]** PMG	**[ii]** IV	**[iii]** PMG	**[iv]** IV
<u>Tax Rates:</u>				
P_i-top	**-0.012**	**-0.018**	**-0.013**	**-0.020**
	(2.51)**	(3.14)**	(3.03)**	(3.34)**
C_i-stat	**-0.049**	**-0.116**	**-0.031**	**-0.113**
	(1.59)	(2.42)**	(1.04)	(2.12)*
C_j-stat-L	**0.083**	**0.118**	**0.053**	**0.179**
	(1.85)*	(2.64)**	(1.23)	(2.34)*
<u>'Fiscal Controls':</u>				
Productive Expenditure	0.032	0.054	0.063	0.076
	(1.13)	(1.55)	(2.28)*	(1.69)
Budget Surplus	0.052	-0.034	0.045	-0.004
	(2.54)*	(1.08)	(2.28)*	(0.13)
Distortionary Tax IATR			-0.106	-0.094
			(4.06)**	(2.76)**
Observations	417	381	417	381
Sargan test		$\chi^2(4) = 4.59$ p-value 0.33		$\chi^2(5) = 3.34$ p-value 0.65
Anderson under-identification test		$\chi^2(4) = 186.2$ p-value 0.00		$\chi^2(5) = 189.2$ p-value 0.00
Weak identification test: Cragg-Donald statistic		9.31 CV (7, 3): 8.50		9.50 CV (7, 3): 8.50
<u>Endogenous variables:</u> Shea Partial R^2 (regression R^2)				
P_i-top		0.66 (0.74)		0.67 (0.74)
C_i-stat		0.40 (0.43)		0.41 (0.43)
Productive expenditure		0.49 (0.48)		0.48 (0.48)
Budget surplus		0.86 (0.95)		
Investment		0.82 (0.91)		0.89 (0.91)
Lagged TFP growth		0.48 (0.48)		0.48 (0.48)

Parameters shown are long-run estimates. Absolute value of z statistics in parentheses; $^+$ (*, **) = significant at 10% (5%, 1%). P_i-top = top statutory rate of personal income tax; C_i-stat = statutory corporate rate; C_j-stat-L = average statutory tax rates in other countries when below those in country *i*.

Appendix The Barro (1990) and Barro/Mankiw/Sala-i-Martin (BMS,1995) Models

The Barro (1990) model depicts a proportional income tax used to finance 'productive' government spending in an "AK" model in which the production function displays constant returns to combined private capital per person, k, plus public 'services' per person, g; hence (in Cobb-Douglas form):

$$y = Ak^{\alpha}g^{1-\alpha} \tag{A1}$$

where y is output per person, and the government budget constraint is: $g = \tau y$, where g is public expenditure and τ is the marginal (= average) tax rate. Based on a representative individual maximising lifetime CES utility, Barro (1990) establishes that the steady-state growth rate, γ, of consumption, c, (and output, y), is given by:

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left[(1-\tau)A\left(\frac{g}{k}\right)^{\alpha} - \rho\right] \tag{A2}$$

where $(1-\tau)A(g/k)^{\alpha}$ is the after-tax private marginal return on capital, σ and ρ are respectively the inter-temporal elasticity of substitution and rate of time preference. In this model the marginal tax rate has two effects – a growth-retarding effect via reductions in the after-tax return on capital, and a positive effect via enabling higher (growth-enhancing) public expenditure, g. As is well-known in these models, if governments set fiscal parameters optimally, there are no growth consequences (in the vicinity of the optimum) from marginal changes in distorting tax rates. Barro also assumes that the technology is sufficiently productive for positive steady-state growth; i.e. in (A2), the first term in the square brackets exceeds ρ.

Though Barro (1990) assumes a proportional income tax, one aspect of the growth impact of progressivity can be illustrated from (A2) by noting that it is the *average* tax rate that is relevant in the budget constraint: $g = ty$, where t is the average tax rate. Thus raising the marginal, relative to the average, tax rate (increased progressivity) has a negative impact since this raises adverse marginal impacts relative to positive public spending impacts.

To illustrate the impact of international capital mobility on the tax-growth relationship, the endogenous model of Barro (1990) is not well suited. As BMS (1995) demonstrate, the absence of transitional dynamics in such endogenous models generates an instantaneous adjustment in income levels following a move to an open economy. Instead, BMS (1995) amend the 'closed' neoclassical model to allow for internationally mobile capital. In this context they assume two forms of capital (per person): physical, *k,* and human, *h* such that*:*

$$y = Ak^{\alpha}h^{\eta} \qquad \alpha + \eta < 1 \tag{A3}$$

where total capital per person is $z = k + h$. Human capital involves a private, rather than pubic, accumulation decision. Hence the impact of productive government expenditure on growth, shown in (A2), does not arise in this case and only the *direct* effects of taxes are captured.

BMS (1995) show that, *for a closed economy*, growth is given by (A4) where, to allow comparisons with Barro (1990), (A4) assumes that $\delta = \theta = 0$, where δ is the rate of depreciation and θ is the rate of labour-augmenting technical progress. Thus:

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left[(1-\tau)\tilde{A}z^{\alpha+\eta-1} - \rho\right] \tag{A4}$$

where $\tilde{A}$ is a transform of *A* involving the production function parameters α and η, and the after-tax marginal product of capital is given by $\left[(1-\tau)\tilde{A}z^{\alpha+\eta-1}\right]$, which is equal to the domestic real interest rate, *r*. As in the standard Solow model, per capita income growth is zero in steady-state where $r = \rho$, but is positive out of steady-state if capital intensities, *z*, are low - since in this case the marginal product of capital is above its steady-state; i.e. $\left[(1-\tau)\tilde{A}z^{\alpha+\eta-1} > \rho\right]$. Such countries grow more rapidly during convergence to steady-state levels.

The economy can be 'opened up' by allowing either physical or human capital or both to become internationally mobile in the sense that individuals may borrow from, and lend, abroad at a constant world interest rate, r^{w}. BMS (1995) demonstrate that where both types of capital are fully mobile, $r = r^{w}$ and there are no transitional dynamics: countries move instantly to their steady-state output levels. However, where only *k*, but not *h*, is internationally mobile, transitional growth arises as the human capital adjusts towards its steady-state level. The key assumption here is that only a fraction of *z* can serve as collateral for international borrowing. In the 'fully open' economy, individuals may borrow up the value of their total capital stock, *z*, but in the 'partially open' economy, the value of their physical capital, *k,* limits their foreign indebtedness.

In this 'partially open' context BMS (1995) show that the growth rate is given by:

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left[(1-\tau)\tilde{B}h^{\varepsilon-1} - \rho\right] \qquad \varepsilon = \eta/(1-\alpha) \tag{A5}$$

where:

$$\tilde{B} = \eta A^{1/(1-\alpha)}[\alpha(1-\tau)/r^w]^{\alpha/(1-\alpha)} \tag{A6}$$

and $(1-\tau)\tilde{B}h^{\varepsilon-1}$ is the after-tax marginal product of human capital. Hence in a small (partially) open economy, growth is described by a similar condition to that in the closed economy but in (A5) transitional growth is positive if the after-tax marginal product of immobile *human* capital exceeds the rate of time preference, ρ. BMS (1995) also show that the term in square brackets in (A6) arises because individuals will borrow/lend capital until the after-tax marginal product of capital is equated to its real rate of return on world markets, hence:

$$(1-\tau)\frac{\alpha y}{k} = r^w \tag{A7}$$

This implies a constant k/y ratio during transitional growth determined by α, τ and r^w. Both a lower marginal tax rate, τ, and a lower 'world' rate of interest raise domestic transitional growth.