BOND UNIVERSITY
GLOBALISATION & DEVELOPMENT CENTRE

Norman Gemmell, Richard Kneller and Ismael Sanz

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No. 49 May 2011

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Norman Gemmell[*+], Richard Kneller[*] and Ismael Sanz[**]

This version: February 2011

ABSTRACT

Recent aggregate tests of the impact of taxes on long-run growth rates in OECD countries remain vulnerable to two important 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. This paper confronts both these criticisms with new data and new methods. 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 small sample of similar OECD countries. Unlike most previous studies, these are *not* constructed from data on tax revenues. We find evidence that:

(i) using the best available exogenous tax rates, there is evidence of statistically robust, but economically small, GDP growth effects from changes in marginal rates of both personal and corporate income tax;
(ii) domestic *and* foreign corporate tax rates (statutory and/or effective) have affected OECD growth rates in the asymmetric manner predicted by theory;
(iii) 'bucking the OECD trend' towards lower corporate tax rates is likely to be growth-retarding, but joining it is likely to be approximately growth-neutral.
(iv) tax effects on growth appear to operate largely via impacts on factor productivity rather than factor accumulation.

Keywords: personal tax, corporate tax, GDP growth

JEL classification: H24; H30;

Corresponding author: Norman Gemmell (norman.gemmell@treasury.govt.nz); Chief Economist, The Treasury, PO box 3724, Wellington, New Zealand. Tel +64 4 9176193.

† We are grateful to participants at the Western Economic Association Annual Conference, Vancouver, Canada, July 2009, the Victoria University of Wellington, tax conference, Wellington, February 2009, and seminar participants at the Universities of Oxford, Oregon and Canterbury. We also thank Peren Arin (Massey) and Bob Reed (Canterbury), for their helpful comments on earlier drafts of this paper.

[*] University of Nottingham, UK; [+] The Treasury, New Zealand; [**] Universidad Rey Juan Carlos, Madrid, Spain.

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 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 of 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

[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).

statutory and 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, we show that 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 effects. 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;

[2] See, for example, Devarajan *et al* (1996), Kneller *et al* (1999), Bleaney *et al* (2001), Adam and Bevan (2005), Arnold *et al* (2011), Gemmell *et al* (2011).

[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.

Bartelsman and 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 (ITPR) at the University of Michigan, and the statutory, effective average and marginal tax rates (ETRs) calculated by Devereux *et al* (2002) and updated by the Institute for Fiscal Studies (IFS). 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), aim to reflect the tax rates relevant to corporate investment

[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.

decisions under a variety of assumptions. In addition, 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. Countries' *measured* GDP will also 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 introduce 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. 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 'average' public spending impacts.

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

[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.

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. 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. Mintz and Smart (2004) and 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 effective average tax rate (EATR) can be as, or more, important, than the effective marginal rate (EMTR); the latter being more 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.

For international profit-shifting decisions, 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. Consider 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. While the effective tax rate on parent firms' profits earned at home is always the domestic statutory rate ($\tau_p = t_p$), the rate payable 'at home' on foreign subsidiaries' profits differs across the three cases.

In general, there is an incentive to shift profits to the subsidiary if $\tau_s < \tau_p$. In the *exemption* case, this condition applies to statutory rates ($t_s < t_p$), 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. Firstly, there is an incentive to shift parent HQs to low tax countries. Secondly, 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'. 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]

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 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.

[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).

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 new steady-state becomes sensitive to the tax rates on both domestic income *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 OTPR and 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 reflects 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. In their analysis of corporate tax

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[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.

competition, Devereux *et al* (2008) use countries' GDP and recent FDI flows as weights. We use as weights: (a) the inverse of distance; (b) GDP; and (c) unweighted; i.e. equal weight.[9]

It might be expected that, conditional on a given difference in corporate tax rates across countries, a greater physical distance between countries would deter investment flows. Alternatively, *ceteris paribus*, a larger domestic economy (as proxied by GDP) may be more attractive to foreign investment inflows. However, 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 that (a) and (c) behave similarly and mainly report results for the distance-weighted case. GDP-weighting generates unreliable estimates, probably because GDP-weighting leads to an emphasis on just a few countries. Of the 15 countries included in most of our regressions, the US accounts for around 50% of total GDP, with 75% accounted for by just four countries: the US, Germany, UK, France. 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* in year *t* is the mean of those countries with a higher tax rate than *i* in year *t*, 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* to react to country *j*'s tax-setting choices and *vice versa*. Their empirical solution is to instrument

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[9] We do not use FDI data due to limited availability for early years of our sample. Physical distance is measured by the inverse of distance between the capital cities of all sample countries. This means, for example, that for a country such as New Zealand, Australia takes a 95% weight compared to a 5% weight for other countries – reflecting the likelihood for New Zealand's case that flows to/from Australia dominate the potential gains/losses from international inflows or outflows. Data on New Zealand's investment in/out-flows suggest this is the case.

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 Gemmell *et al* (2011), 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.[10] 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 (more usually, investment rates) and human capital, with or without various other macro variables (inflation, trade openness, convergence effects, etc). However, since taxes are

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[10] 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.

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 comparing regressions respectively with/without fiscal and control variables. We use four control variables: labour force growth, human capital growth (measured as years of schooling embodied in the labour force)[11], the ratio of private non-residential investment to GDP, and (the log of) lagged per capita GDP to capture convergence effects. To minimise the likelihood of over-estimating the growth impact of taxes, we also (see sub-section 4.4) 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 15 or 17 OECD countries (depending on specification); data for most countries spanning the late-1970s to 2004.[12] 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 two methodologies applied to annual panel data. Firstly, we use 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 similar regressions - but based on IATRs - Gemmell e*t al.* (2006, 2011) report that the PMG estimator performs better than alternative dynamic fixed-effects or mean group (MG) estimators in the current context. We test robustness to these methods in sub-section 4.4].[13]

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[11] 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.

[12] The full 17 country sample is: Australia*, Austria*, Canada*, Denmark, Finland*, France*, Germany*, Iceland, Luxembourg, Netherlands*, New Zealand, Norway*, Spain*, Sweden*, Turkey, UK*, USA*. Most regressions use 15 countries (there is insufficient human capital data for Iceland and Luxembourg); an asterisk indicates the country is included in the reduced sample when *effective* corporate tax rates are used.

[13] 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 use 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. Secondly, we therefore use instrumental variable methods based on lag structures (lags 3 and 4, 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 variables only

We begin in Table 1 by considering how well a model that excludes all fiscal variables explains OECD countries' GDP growth.[14] Regression [1] can be interpreted as a form of growth-accounting regression (including per capita income convergence), but with an investment/GDP ratio rather than a capital growth rate on the RHS. As a result, parameters on inputs are not necessarily expected to sum to unity. This simple relationship performs fairly well, supporting positive growth effects associated with larger investment, labour force and human capital growth (though human capital is not statistically significant). Strong convergence effects are evident –

[14] For all regression results we report the homogeneous long-run parameters and omit country-specific, short-run parameters to save space. For 'foreign' corporate tax rates, distance-weighted statutory rates are reported.

countries, and years, in which per capita income is high tend to be associated with lower subsequent GDP growth.

Regression [2] in Table 1 introduces fiscal variables. The tax rate variables are discussed below; first we focus on the 'fiscal controls' – productive spending levels and budget surpluses (as % of GDP), which aim to take account of the government budget constraint within fiscal-growth regressions as discussed above. It can be seen that both variables take positive signs as expected (more productive spending and larger surpluses are growth-enhancing). The introduction of all the fiscal variables can also be seen to improve the estimates of the 'productions function' input parameters. These parameter estimates are plausible and now sum to around 1. In later robustness checks (sub-section 4.4) we also include implicit tax rates that allow the GBC to be specified more fully but omit these here because of the concerns described above, and potential correlation with the included tax rates.

These results suggest that when fiscal and control variables are nested within a single model, the robustness of both fiscal and non-fiscal parameter estimates improves. Of course, as noted above, the inclusion of some input variables might be expected to pick up some fiscal effects transmitted through private investment or human capital accumulation. To investigate this further, in sub-section 4.5, we consider the extreme case of 'minimum fiscal impact' by allowing non-fiscal variables to impact on growth first; i.e. *before* allowing tax variables to impact on growth.

4.2 Including statutory tax rates

The statutory tax rate variables included in regressions in Table 1 are: the top statutory rate of personal income tax (P_i-top), the domestic statutory corporate tax rate, 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). Regression [2] includes those four statutory rates, with regression [3] omitting the statistically insignificant C_j-stat-H variable – in each case using PMG methods. Regressions [3'] and [3"] repeat [3] but using IV methods for two alternative instrument sets.

The estimates in regression [2] reveal significant negative effects on growth associated with higher personal marginal tax rates (P_i-top) and domestic corporate tax rates (C_i-stat). We discuss the relative magnitude of parameters later after considering a range of regression specifications. In general, since tax rate and other fiscal controls are expressed as percentages, parameters can be interpreted as the percentage point (ppt) impact on growth of a one ppt increase in the relevant tax rate, expenditure/GDP ratio, etc. Hence in regression [2] a 1 ppt fall in the top personal rate (e.g. from 40% to 39%) raises growth by around 0.05 ppt (e.g. from 2.5% to 2.55%). A similar reduction in the corporate rate raises growth to 2.53%. This is noticeably less that that 0.1 ppt increase in growth from a 1 ppt rise in productive expenditure, for example. Put another way, *in this regression*, raising the corporate tax rate by 3 ppt to fund a 1 ppt increase in the productive expenditure to GDP ratio is predicted to be approximately growth neutral (though such a policy may not be deficit-neutral, raising the possibility of further growth effects).

The parameter on 'lower tax' foreign countries, C_j-stat-L, confirms our predictions that growth in country *i* is adversely affected (positive sign) by reductions in corporate rates in countries where C_j-stat is initially below C_i-stat, though in [2] the estimate is barely statistically significant at 10% (on a one-tailed test). 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 = 0.18). 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] omits the (insignificant) C_j-stat-H variable and, as expected, the remaining tax rate (and other) parameters are essentially unaltered.

Regressions [1] to [3] treat tax rate and other variables as exogenous. The arguments around the potential endogeneity in growth regressions of private investment and tax rates calculated from revenue data (IATRs) in growth regressions are well-known. Though statutory tax rates are less susceptible to these arguments, they 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.[15] For similar reasons, public spending and budget surplus variables may be endogenously determined.

In regressions [3'] and [3"] we attempt to control for endogeneity using standard IV methods, for two alternative instrument sets.[16] 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. Instrumented variables in [3'] 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 [3"] additionally instruments for those tax rates, using 3rd and 4th lagged values. Table 1 shows that these IV regressions appear to lower the measured impact of personal income tax rates, with impacts of corporate tax rates increased, especially when these rates are

[15] 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.
[16] In all cases first stage regressions are estimated by fixed-effects methods with second stage regressions using PMG methods.

instrumented in [3"]. Corporate tax rate effects on growth – from both domestic and foreign 'low tax' countries - are now especially robustly estimated with the predicted signs. Appendix 1 reports and discusses a number of diagnostic tests for instrument validity in these IV regressions. In sum, the regressions easily pass a number of exogeneity tests.

Notwithstanding these IV results it may still be objected that international corporate tax rates are jointly determined such that C_i-stat with C_j-stat are not set independently. Evidence from Devereux *et al* (2008) of strategic competition between countries over corporate tax settings tends to support this view. To allow for this, C_i-stat could be omitted with other countries' corporate tax rates included instead as direct instruments; this is the approach followed by Lee and Gordon (2005). However, as noted above the expected response to 'low' and 'high' tax competitor countries is different. In regressions [4] and [4'] we therefore omit C_i-stat but include C_j-stat-L and C_j-stat-H separately. If tax rates in both sets of countries determine tax rates in country *i*, then both could potentially influence growth in *i* (but again with opposite signs). On the other hand if only tax rates in 'low tax' countries influence *i*'s corporate tax rate, then C_j-stat-H should be redundant, and *vice versa*. For example, if country *i* joins a 'race to the bottom' whilst ignoring those countries who choose not to join the race or at least retain corporate tax rates above *i*'s. Note that this specification effectively assumes that domestic corporate tax rates are *fully determined* by foreign rates, such that all growth effects are mediated through the two foreign tax rate variables.

In regression [4], both foreign corporate tax variables take the expected signs but are not statistically significant; personal tax rates continue to support negative growth effects. Regression [4'] on the other hand, which uses up to the 4^{th} lag values as instruments, suggests that both personal and 'low tax' foreign corporate rates impact significantly on growth in country *i*; in the case of C_j-stat-L the point estimate is lower than those in [3'] and [3"]. That the effect of foreign tax rates is both more robustly estimated, and smaller in absolute value, when relying on lagged effects, is plausible: both domestic corporate tax rates and any consequent growth effects might be expected to take time to respond to foreign tax changes. In addition, to the extent that there is any independent effect of domestic corporate tax rates, C_i-stat, on growth, this is omitted from [4] and [4'] by assumption.

The regressions in Table 1 therefore provide broad support for the conclusion that 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. Though the precise magnitudes are hard to pin down, they take the predicted signs and are generally highly significant; it would be difficult to sustain the argument that they are zero. Comparing the point estimates in the IV regressions with PMG equivalents indicates that the responses to top personal income tax rates in IV versions are generally smaller in absolute value than their PMG equivalents. However this is not necessarily the case for corporate tax rate responses. In our view, possible endogeneity concerns are most fully dealt with in regression [4'], which estimates a (foreign) corporate tax-growth parameter around 0.02, similar to those estimated using PMG methods in [2] or [3], and similar to the estimated personal income tax parameter. We postpone further discussion of parameter sizes till after examining *effective* tax rates.

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) from the IFS/Devereux *et al* (2002) dataset. As noted above, this limits our sample size to 12 countries, post-1980. To maximise degrees of freedom in this restricted sample, we examine the parsimonious specification [3] which excludes C_j-eff-H, and regression [4] where each country's own effective corporate tax rate, C_i-eff, is omitted but C_j-eff-H is included. 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. Devereux *et al* calculate ETRs using a number of alternative assumptions; Table 2 reports regressions for the case of assumed uniform inflation rates across countries.[17] In view of the arguments that, for many investment location decisions, it is the average, rather than marginal, tax rate that is relevant, we consider both effective rates in regressions (1) – (4).

It can be seen that the Table 2 regressions tell a qualitatively similar story: in column (1) the E*M*TR yields significant negative effects for the country's own corporate rate (C_i-eff) and positive for the foreign rate, C_j-eff-L. Regression (2) repeats regression (1) but using E*A*TRs. Results are robust to the alternative ETR definition with both regressions suggesting stronger 'foreign' corporate tax effects than from domestic corporate rates. Regressions (3) & (4) substitute C_j-eff-H for C_i-eff, effectively assuming that domestic corporate tax rates have no independent affect on growth. These regressions again reveal strong positive growth effects

[17] Other 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. We also obtained results using ETRs calculated using each country's own inflation rate; results are similar.

associated with higher values of C_j-eff-L, with C_j-eff-H now revealing some of the negative growth effects previously picked up by C_i-eff. As previously, growth impacts from 'low tax' countries would be appear to be larger in absolute size and more robustly estimated. Given the high correlations between EATRs and EMTRs, it is not possible to discriminate between them in terms of their growth impacts though estimated impacts are generally larger and more robust for EMTRs.[18] Both rates however appear capable of picking up statistically significant growth effect. These results are especially interesting because the effective tax rates used here can be regarded as genuinely exogenous, having been calculated for hypothetical investment types within each country/year, and are independent of 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 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.

Interpreting the magnitude of the various estimated tax rate effects on growth requires some care. Firstly, as we have stressed above, when tax rates change, it is important to know which other government budget constraint elements change. The regressions in Tables 1 and 2 hold constant productive public spending and deficits, but not any tax *revenue* variable, nor 'unproductive' spending (mainly social welfare).[19] Reductions in an individual tax rate such as the top personal rate, could be consistent with either rising or falling personal tax revenue (depending on Laffer effects) but in general would likely involve falling revenues. This could be compensated by increases in other tax revenues (for example, via rises in consumption tax rates/revenues not included in regressions) and/or declines in unproductive spending (also omitted from the regressions).

Secondly, the estimated parameters in Tables 1 and 2 in general imply economically small but statistically significant, impacts on long-run GDP growth rates from the above fiscal changes – where the 'long-run' captured by these regressions lies within the time-series dimension of our data, typically around 30 years. Parameter estimates in Table 1 for the top personal tax rate are in

[18] In this sample the EATRs and EMTRs are highly correlated overall: r = 0.90 to 0.98 across the 12 OECD countries.
[19] Unproductive spending is defined here is that which is assumed not to affect GDP growth rates but could of course be welfare-enhancing. If it *does* affect GDP growth, interpretation of other included fiscal parameters would change.

the region of 0.01 to 0.02, but could be as high as 0.05. This implies a one ppt cut in this tax rate (e.g. from 40% to 39%) is predicted to raise the annual GDP growth rate over the long-run by 0.01 (0.02, 0.05) ppt: e.g. from 2.5% to 2.51% (2.52%, 2.55%). This is a small effect: a parameter of 0.02, and a 1 ppt tax cut generates a GDP level that is about 0.2 of a percent (or two thousandths) higher after 10 years or 0.4 of a percent higher after 20 years, compared to maintaining the tax rate at its higher level throughout. When compared to conventional estimates of growth effects from increases in capital, labour or human capital inputs, these tax rate effects on growth are also small. This is generally confirmed by the estimated parameters on the input control variables in Table 1 where 1 ppt increases in labour force or human capital growth rates or the investment/GDP ratio generally have much larger estimated effects on GDP growth rates.

4.4 Robustness and mis-specification checks

Table 3 provides a number of robustness checks on the statutory tax rate results discussed above. Firstly, we noted earlier that various implicit average tax rates have been used in previous studies, but may not pick up the kinds of average or marginal tax rate effects on growth of interest. Regression [5] therefore includes the IATR for 'distortionary' taxes, while regression [6] adds this IATR but omits the other tax rate variables. Including the IATR in [5], its parameter has the expected negative sign but is not statistically significant. This has no effect on the personal tax rate parameter, while the domestic corporate tax parameter is reduced in size and statistical significance. The foreign corporate tax rate, C_j-stat-L, also becomes small. Thus the effect of introducing the IATR is essentially to reduce the contribution of the statutory rates. When those rates are omitted in [6] the IATR parameter becomes much larger (in absolute value) and statistically significant. This suggests that using IATRs instead of more direct statutory/effective tax rate measures in growth regressions, raises the apparent (negative) contribution of distortionary taxes to growth. It is unclear whether the IATR captures a genuine 'tax response', bearing in mind our earlier discussion regarding the interpretation of this variable. It seems unlikely to reflect endogeneity concerns since these predict a smaller, not larger, parameter estimate (as the effective tax rate rises, the tax base falls in response, lowering a revenue/base measure).

In Table 3, regression [7] we consider the estimated corporate tax rate effects if foreign corporate effects are treated identically for 'high tax' and low tax' foreign countries; that is we combine C_j-stat-L and C_j-stat-H to form C_j-stat in regression [7]. The results suggest that no foreign effects would be identified because of the erroneous conflating of the positive growth effects from increases in C_j-stat-L with the zero growth effects associated with increases in C_j-

stat-H. Unsurprisingly omitting foreign corporate tax rates leaves other parameters largely unaffected (regression [8]). However, in regression [9], when the per capita income convergence term, $ln(\text{GDP p.c.})_{t-1}$, is also omitted, this both radically alters the estimated parameters on input control variables (two of the three become wrongly signed) *and* the parameter on domestic corporate tax rates becomes positive and significant. While this does not explain the positive parameter obtained by Angelopoulos *et al* (2007) in some of their regression specifications, both [8] and [9] do demonstrate that zero parameter estimates or 'wrong' signs on these estimates can readily be obtained if the regression is mis-specified.

A number of recent studies, such as Lee and Gordon (2005) and Angelopoulos *et al* (2007) have added further macroeconomic control variables to their fiscal-growth regression – mainly inflation rates and trade openness variables (yet, interestingly, have ignored the 'openness' aspect to corporate tax impacts). In regression [10] we add both these variables: openness has the expect positive effect on growth while inflation is statistically insignificant and wrongly signed.[20] Importantly our fiscal variables are robust to the inclusion of these additional controls. Finally, since Lee-Gordon and Angelopoulos *et al* both use fixed effects (FE) models, which impose *homogeneous* short-run parameters, it is interesting to consider outcomes using this more restricted specification. Regression [11] shows that parameter signs on the personal and corporate tax rate variables remain as predicted and significant. Hence the evident difficulty of studies such as Angelopoulos *et al* (2007) in identifying significant negative growth effects from corporate tax rates is more likely related to the absence of 'foreign' corporate tax rates, and perhaps interactions with convergence terms, rather than their the use of FE methods.

Net corporate tax rate effects:

An interesting question to arise from our results 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 such a 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

[20] Openness is measured as the sum of exports and imports of goods and services as a percentage of GDP; inflation is the rate of change (%) of consumer prices; both variables sourced from World Development Indicators.

sample we cannot answer questions relating to *global* corporate tax rate reductions but we can consider the effect of uniform reductions across the 15 country sample.

If we accept the evidence from Table 1 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 Table 1 – regressions [3], [3'] and [3"] – suggest that uniform sample corporate tax reductions would have *at most* a small net positive effect on growth in country *i*.[21] That is, the absolute value of the parameter on C_i-stat typically exceeds the C_j-stat-L parameter, or is of similar size From regressions [3], [3'] and [3"], a simultaneous 1 ppt reduction in both domestic and foreign sample countries' corporate tax rates is predicted to raise long-run growth in country *i* by 0.013, -0.003 or 0.070 percentage points respectively (depending on specification; and only the last of these is statistically significantly different from zero). Though this does not necessarily capture responses to *global* tax reductions for the reasons given above, it suggests that advocating that countries cut their corporate tax rates to boost their GDP growth could be misplaced if based on apparent responses to *domestic* corporate tax rates only. Growth effects may be negligible when many countries follow the same policy. On the other hand, individuals countries failing to follow a global downward trend in corporate tax rates would be expected to suffer adverse growth consequences.

4.5 'Residual growth' regressions

The nested regressions in Tables 1 and 2, including both fiscal variables and the standard growth accounting controls, generally produced robust support for both sets of variable. Two issues with these regressions are: (i) some tax effects may be mediated through such control variables as investment and human capital growth so that the previously estimated tax rate parameters underestimate total tax rate effects; (ii) tax rate effects on growth may operate primarily through factors such as innovation and entrepreneurship that affect factor *productivity*. To pursue (i), simply omitting the control variables will not be helpful, since this would induce omitted variable bias whenever these control variables are a function of non-tax as well as tax variables.[22] An alternative is to disallow *any* impacts of tax via our control variables and compare the resulting estimates with those obtained above. To the extent that these parameters are similar, it would suggest that tax impacts on GDP growth operate primarily through productivity rather than factor inputs.

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[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.

[22] Ideally, a structural model that sought to model both tax and non-tax determinants of our controls variables could be used. While such components of such a model are increasingly being pursued at the micro level – e.g. estimating tax impacts within investment equations – it is because of difficulties fully specifying and estimating such structural models at the aggregate level that the reduced forms used here have been commonplace in recent literature.

To test this we therefore use residuals from a regression similar to regression [1] in Table 1 but excluding the per capita income convergence term. 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 in addition to lagged GDP per capita (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.

Considering results for the tax rate parameters first, these generally mirror those obtained for GDP growth – in both signs and magnitudes – and suggest that, even after attributing maximum effect to 'input' variables, both personal and corporate tax rates continue to display statistically 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, tends to have a similarly sized positive impact. The top personal tax rate parameter is again robustly negative and generally slightly smaller (but not statistically) than corporate tax parameters. These results suggest that the previously estimated GDP impacts of personal and corporate tax rates operate primarily through productivity effects rather than via investment etc, and though statistically robust are 'economically small' – a 1 ppt change in these tax rates generating around a 0.02 to 0.03 ppt change in long-run TFP growth rates (e.g. from 2.0% to 2.02% or 2.03%). Interestingly however, unlike the GDP regressions, adding the distortionary tax IATR to regressions, in statistical terms yields no additional estimated growth impact and in any case appears to be orthogonal to estimated growth effects from the marginal/statutory rate variables. Though there are many difficulties interpreting the IATR parameter, this result would be consistent with the view that, since the IATR is measured from revenues as a percent of GDP, it reveals an endogenous negative association with GDP growth that would not necessarily be expected with TFP growth.

Regarding the other fiscal control variables, Table 4 shows that these generally have no statistical impact on long-run TFP growth (unlike their estimated impact on GDP). Budget surpluses in particular have no significant impact using IV methods (regressions [ii] & [iv]) which likely reflects the effect of omitting the contemporaneous co-movement in GDP and deficits. That is, plausibly there are no 'long-run' effects of surpluses/deficits on TFP when potentially endogenous co-movement is eliminated. Further, productive public expenditures appear to have no long-run effects on TFP growth (using either method). This is also a plausible outcome, suggesting that to the extent that increases in, for example, public infrastructure and education expenditures affect output growth, this is primarily observed via increases in investment and human capital inputs rather than TFP.

5. Conclusions

This paper has sought to deal with two important 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). A significant exception is Lee and Gordon (2005) but they use a very wide sample of 70 mainly developing economies and find apparently robust growth effects from corporate tax rates but not from personal income taxes.

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 15 OECD countries, we have tested for aggregate tax-growth effects associated with changes in statutory personal and corporate tax rates 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 could be negligible, though reducing both corporate *and* personal rates can have larger impacts.

Thirdly, when we use statutory or effective marginal tax rates we obtain estimates of growth impacts that appear statistically robust but are nevertheless relatively small in terms of 'economic magnitude'. It is unclear if this is because these tax rates are picking up *only part* of the growth effects of tax changes or the aggregate effect is, in fact, small. Our estimates suggest growth effects of a 1 percentage point change in personal or corporate tax rates that would be observed at the second, not the first, decimal point: e.g. annual GDP growth rising from 2% to 2.03% not 2.3%. These results seem plausible to us as estimates of aggregate tax effects. For example, it would need a tax cut such as from 40% to 30% in the top personal or corporate rate to raise growth from 2.0% to 2.3% over the long-run, assuming other countries do not follow suit. Finally, our evidence suggests that most of the impact of statutory or effective tax rates on aggregate growth appears to operate via impacts on multi-factor productivity.

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Table 1 Long-Run Parameters: Regressions Using Statutory Tax Rates

Regression No: *Method:*	**[1]** PMG	**[2]** PMG	**[3]** PMG	**[3']** IV	**[3"]** IV	**[4]** PMG	**[4']** IV
Comment:	*'Controls' only*	*Testing domestic/foreign corporate tax rates (Distance weighted C_j-stat)*				*Omitting C_i-stat*	
Tax Rates:							
P_i-top		**-0.053**	**-0.054**	**-0.017**	**-0.010**	**-0.041**	**-0.019**
		(6.70)**	(6.82)**	(5.53)**	(0.96)	(6.07)**	(5.95)**
C_i-stat		**-0.033**	**-0.030**	**-0.032**	**-0.173**		
		(3.32)**	(3.04)**	(4.85)**	(5.19)**		
C_j-stat							
C_j-stat-L		**0.016**	**0.017**	**0.035**	**0.103**	**0.006**	**0.020**
		(1.67)	(1.74)	(5.93)**	(5.00)**	(0.75)	(4.28)**
C_j-stat-H		**0.001**				**-0.007**	**-0.001**
		(0.18)				(1.42)	(0.21)
Fiscal Controls:							
Productive expenditure		0.094 (4.04)**	0.101 (4.34)**	0.100 (3.77)**	0.223 (2.55)**	0.091 (3.31)**	0.082 (2.95)**
Budget surplus		0.132 (5.55)**	0.133 (5.44)**	-0.052 (2.61)**	-0.278 (4.11)**	0.067 (2.55)**	-0.074 (3.65)**
Other Controls:							
Investment ratio	0.164 (4.16)**	0.089 (2.09)*	0.085 (1.96)	-0.016 (0.74)	0.114 (2.08)*	0.163 (2.99)**	0.007 (0.32)
Labour force growth	0.195 (4.70)**	0.311 (7.36)**	0.330 (8.46)**	0.320 (16.8)**	0.495 (11.0)**	0.333 (7.13)**	0.300 (15.4)**
Human capital growth	0.304 (0.62)	0.573 (2.19)*	0.557 (2.12)*	0.760 (6.45)**	2.29 (5.44)**	-0.054 (0.19)	0.414 (2.76)*
ln(GDP p.c.)$_{t-1}$	-0.781 (1.86)	-4.15 (6.38)**	-4.21 (7.31)**	-0.502 (1.80)	-0.933 (1.21)	-3.92 (5.61)**	-0.259 (0.93)
Observations/ countries	472/15	420/15	420/15	405/15	386/15	431/15	415/15
Log likelihood	-709.7	-522.8	-533.6	-406.0	-499.8	-582.0	-431.0

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 Using Effective Tax Rates

Regression No:	**(1)**	**(2)**	**(3)**	**(4)**
Effective tax rate:	*EMTR*	*EATR*	*EMTR*	*EATR*
Tax Rates:				
P_i-top	**-0.021**	**-0.075**	**-0.047**	**-0.061**
	(2.23)*	(4.25)**	(3.94)**	(4.38)**
C_i-eff	**-0.055**	**-0.037**		
	(2.76)**	(1.72)		
C_j-eff				
C_j-eff-L	**0.109**	**0.231**	**0.254**	**0.173**
	(3.76)**	(4.56)**	(3.85)**	(3.94)**
C_j-eff-H			**-0.118**	**-0.013**
			(2.73)*	(0.66)
Fiscal Controls:				
Productive expend.	0.102	0.099	0.060	0.054
	(3.41)**	(2.75)**	(1.54)	(1.78)
Budget surplus	0.170	0.171	0.137	0.113
	(5.04)**	(4.37)**	(3.10)**	(3.23)**
Other Controls? (investment ratio, labour force growth, human capital growth, lagged GDP p.c.)				
	YES	YES	YES	YES
Observations/ countries	278/12	279/12	278/12	279/12
Log likelihood	-273.9	-292.2	-272.9	-289.3

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

Table 3 Robustness and Specification Checks

Regression No: *Method:*	**[5]** PMG	**[6]** PMG	**[7]** PMG	**[8]** PMG	**[9]** PMG	**[10]** PMG	**[11]** FE
Comment:	*Including IATRs*	*Incl. IATRs excl. other tax rates ?*	*Combined* C_i-stat	*Excluding* C_i-stat	*Excluding* C_i-stat & *ln*(GDP p.c.)	*Adding inflation & openness*	*Fixed effects model*
Tax Rates:							
P_i-top	**-0.059** (6.85)**		**-0.053** (7.08)**	**-0.055** (6.76)**	**-0.022** (3.34)**	**-0.057** (6.40)**	**-0.029** (3.23)**
C_i-stat	**-0.019** (1.77)		**-0.019** (2.41)*	**-0.020** (2.72)**	**0.020** (2.02)*	**-0.040** (3.62)**	**-0.048** (2.46)*
C_j-stat			**0.000** (0.00)				
C_j-stat-L	**0.008** (0.74)					**0.041** (2.82)*	**0.031** (2.10)
Fiscal Controls:							
Productive expenditure	0.101 (4.43)**	0.055 (1.78)	0.110 (4.84)**	0.109 (4.81)**	0.084 (2.18)*	0.163 (5.42)**	-0.014 (0.21)
Budget surplus	0.125 (4.65)**	0.012 (0.39)	0.147 (6.00)**	0.151 (6.44)**	0.125 (4.27)**	0.108 (3.09)**	0.039 (0.98)
Distortionary tax (IATRs)	**-0.033** (1.12)	-0.132 (3.86)**					
Other Controls:							
Investment ratio	0.083 (1.73)	0.332 (4.24)**	0.100 (2.21)*	0.084 (1.84)	-0.034 (0.84)	0.085 (1.77)	0.022 (0.45)
Labour force growth	0.316 (7.75)**	0.181 (4.37)**	0.316 (7.94)**	0.301 (7.91)**	0.261 (6.61)**	0.349 (8.25)**	0.209 (4.09)**
Human capital growth	0.656 (2.36)**	-0.098 (0.33)	0.671 (2.77)**	0.785 (3.10)**	-0.029 (0.10)	0.322 (1.33)*	0.552 (1.61)
ln(GDP p.c.)$_{t-1}$	-4.14 (6.22)	-2.48 (3.57)**	-4.39 (6.09)**	-4.19 (6.00)**		-4.71 (5.57)	-3.193 (10.16)**
Openness						0.028 (3.66)**	
Inflation rate						0.025 (1.16)	
Observations/ countries	420/15	461/15	420/15	420/15	420/15	402/14	420/15
Log likelihood	-508.3	679.2	-536.1	-544.9	-597.3	-469.2	-

Table 4 Regressions for 'Residual Growth' (g_R)

Regression No.: / *Method:*	[i] PMG	[ii] IV	[iii] PMG	[iv] IV
Tax Rates:				
P_i-top	**-0.022**	**-0.015**	**-0.018**	**-0.019**
	(4.31)**	(2.53)*	(3.53)**	(3.14)**
C_i-stat	**-0.027**	**-0.045**	**-0.020**	**-0.038**
	(2.70)**	(2.56)**	(1.90)	(2.24)*
C_j-stat-L	**0.024**	**0.034**	**0.022**	**0.033**
	(3.15)**	(3.04)**	(2.63)**	(2.93)**
Controls:				
Productive Expenditure	0.006	0.043	0.001	0.041
	(0.24)	(1.04)	(0.04)	(0.89)
Budget Surplus	0.062	-0.005	0.042	0.016
	(3.08)**	(0.16)	(2.12)*	(0.45)
Distortionary Tax IATR			-0.039	-0.014
			(1.19)	(0.34)
ln(GDP p.c.)$_{t-1}$	-1.342	-1.230	-0.934	-1.501
	(3.73)**	(18.3)**	(2.07)*	(16.2)**
Observations	417	381	417	381
Sargan test		$\chi^2(7) = 5.31$ p-value 0.62		$\chi^2(6) = 6.14$ p-value 0.52
Anderson under-identification test		$\chi^2(8) = 112.7$ p-value 0.00		$\chi^2(7) = 101.9$ p-value 0.00
Weak identification test: Cragg-Donald statistic		8.60 CV (7, 3): 8.50		9.50 CV (6, 3): 7.77
Endogenous variables: Shea Partial R^2 (regression R^2)				
P_i-top		0.73 (0.80)		0.72 (0.80)
C_i-stat		0.54 (0.58)		0.52 (0.58)
Productive expenditure		0.84 (0.88)		0.71 (0.88)
Budget surplus		0.28 (0.29)		0.28 (0.28)
Distortionary Tax IATR				0.69 (0.92)
Lagged TFP growth		0.47 (0.47)		0.47 (0.47)

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 1: Instrumental Variable Regression Diagnostics

Table A1 provides some diagnostic testing of the IV regressions in Table 1. 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 A1 shows that the Shea partial R^2s are all satisfactorily high in each IV regression. 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. 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%*). For all three regression we can reject the weak instrument hypothesis: the Cragg-Donald statistic is above the critical value.

Table A1 Instrumental Variable Regression Diagnostics

Regression	[3']	[3"]	[4']
Sargan test	$\chi^2(5) = 6.83$ p-value 0.23	$\chi^2(9) = 10.34$ p-value 0.32	$\chi^2(9) = 8.30$ p-value 0.50
Anderson under-identification test	$\chi^2(6) = 111.1$ p-value 0.00	$\chi^2(10) = 138.4$ p-value 0.00	$\chi^2(10) = 138.4$ p-value 0.00
Weak identification test: Cragg-Donald statistic *	13.66 CV (5, 3): 6.61	11.30 CV (9, 3): 9.37	10.28 CV (9, 3): 9.37
Endogenous variables: Shea Partial R^2 (regression R^2)			
P_i-top		0.66 (0.72)	0.66 (0.72)
C_i-stat		0.93 (0.99)	
Productive expenditure	0.84 (0.86)	0.90 (0.96)	0.90 (0.96)
Budget surplus	0.32 (0.33)	0.30 (0.33)	0.31 (0.33)
Investment	0.72 (0.71)	0.87 (0.91)	0.86 (0.92)
Lagged growth	0.39 (0.39)	0.47 (0.47)	0.49 (0.47)

* Stock and Yogo (2005) have computed the critical values (CV) for up to 3 endogenous variables. The critical value for three endogenous variables, five (nine) instrumental variables and 10% bias is 6.61 (9.37). However, the critical value is a decreasing function of the number of endogenous variables. For [3´], with four endogenous variables, the CV will be lower than 6.61, and for [3´´] and [4´] it will be also be lower than 9.37. We are grateful to James Stock for his comments and suggestions on this point.