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Tax revenue potential and effort

An empirical investigation

Ben Langford
Tim Ohlenburg

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Ben Langford (HM Treasury)

and

Tim Ohlenburg (International Growth Centre, Uganda)

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Abstract

Many countries want to raise additional revenue, be it primarily for public investment, for social services, or for debt and deficit reduction. Regardless of revenue mobilisation plans, economic and institutional conditions limit the amount of taxes that a country can realistically raise. This paper aims to quantify such tax capacity for a 27-year panel of 85 non-resource-rich economies. Using stochastic frontier analysis, it proceeds to estimate actual tax effort exerted, measuring the gap between realised performance and the stochastic tax frontier for each country. The analysis relies on the ICTD Government Revenue Dataset, a new and high-quality source for internationally-comparable tax-to-GDP ratios. We identify industrial structure, education and trade as 'inputs' of tax capacity. A higher age dependency ratio is found to push the tax frontier out, whereas high inflation pulls it in. Reflecting the political and administrative components of taxation, three institutional variables are found to affect tax effort. The estimated effort for 2009 ranges from 38% in Guatemala to 90% in Sweden, with a mean of 62% across all observations. Subject to methodological caveats, the results suggest wide scope for tax policy and administration reform, especially for many low-income countries.

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Contents

List of Acronyms and Abbreviations

EAC	East African Community
ECOWAS	Economic Community of West African States
GDP	Gross Domestic Product
GRD	Government Revenue Dataset
ICRG	International Country Risk Guide
ICTD	International Centre for Tax and Development
IGC	International Growth Centre
IMF	International Monetary Fund
MIT	Massachusetts Institute of Technology
OLS	Ordinary Least Squares
PRIO	Peace Research Institute Oslo
RE	Random effects
SFA	Stochastic Frontier Analysis
TFE	True Fixed Effects
TRE	True Random Effects
UN	United Nations
UNU-WIDER	United Nations University – World Institute for Development Economics Research
WDI	World Development Indicators
WEO	World Economic Outlook

Executive Summary

Many countries want to raise additional revenue, be it primarily for public investment, for social services, or for debt and deficit reduction. Regardless of revenue mobilisation plans, economic and institutional conditions limit the amount of taxes that a country can raise within the bounds of reason. This paper aims to quantify such tax capacity for a 27-year panel of 85 non-resource-rich economies. Using stochastic frontier analysis, it proceeds to estimate actual tax effort exerted, measuring the gap between realised performance and the stochastic tax frontier for each country.

The estimated tax effort for 2009 ranges from 38% in Guatemala to 90% in Sweden, with a mean of 62% across all observations (Table 3 summarises the main results of this paper). Subject to methodological caveats, the results suggest wide scope for tax policy and administration reform, especially for many low-income countries. The policy implications of this line of research tend to be two-fold. The first focuses on factors that determine tax capacity, either directly or as environmental variables. A larger tax base makes for more tax potential, and indeed we find that industrialisation, in the form of a high manufacturing share of output, is associated with a rise in tax potential. The level of education also determines tax potential in our preferred specification – the more educated the workforce, the more value-added in the economy that can be taxed due to a larger formal sector and higher incomes. The third factor in generating tax potential is the level of imports, which not only correlates with traded goods that attract import duty but also suggests an open economy that is competitive enough to engage in international trade.

The second strand of policy implications revolves around achieving higher tax effort. Higher tax potential is clearly desirable for any country, but the same cannot necessarily be said about tax effort. The results indicate that some countries with strong institutions, such as Singapore and Ireland, choose to exert low tax effort. However, many developing countries need fiscal resources to support growth and improve socio-economic outcomes. For these countries, the results suggest that institutional improvements will help in realising a greater share of the tax potential. Specifically, it appears that efforts to fight corruption, to enhance security and the legal system, and to make the state more responsive to citizens' wishes are associated with higher tax effort.

The analytic approach of this paper is to look at the big picture, determining tax potential and effort via comparison with the experience of other countries. It reveals what a reasonable limit of tax is for a given economic structure, and thus allows an estimate of how much more tax a country may hope to raise. The factors identified as being related to tax capacity and tax effort point towards broad areas for reform in countries wishing to raise additional revenue. Specific tax policy and administration reforms must be grounded in detailed, country-specific analysis. The objective of this paper is to quantify how much potential there is for such revenue mobilisation.

1. Introduction

The need to raise additional tax revenue is fundamental for developing countries seeking to increase public expenditure, reduce reliance on foreign assistance, and limit recourse to borrowing. Reflecting this, increasing the tax-to-GDP ratio is an explicit, central aim of policy in many developing countries – often underpinned by specific quantitative targets.[1] A natural starting point for countries aiming to increase revenues from taxation is to consider the question: how much additional revenue is it possible to raise?

The question of how much revenue a country *could* raise is distinctly different to asking how much tax revenue it *should* raise. The former amount, which can be estimated through empirical investigation, is the theme of this paper. The magnitude of the latter is a much deeper question, the answer to which will depend on a variety of political and technical factors – such as the preferences of the population, the efficiency costs and equity implications of taxation, and the efficiency with which public funds can be spent, that are beyond the scope of this paper. By estimating how much tax revenue it is feasible for a country to raise, we aim to identify the boundaries within which such technical and political considerations must take place.

Efforts to quantitatively estimate tax potential and tax effort – that is, the maximum amount of tax a country could hope to raise at a given point in time, and how close actual collections are to this level – stretch back to Lotz and Morss (1967). More recent research has begun to move beyond a previous focus on linear regression to the use of stochastic frontier analysis, which more satisfactorily captures the notion of potential; Cyan et al (2013) discuss these methodological developments. A related literature, surveyed by Drummond et al (2012), identifies the determinants of public revenue collection. Besley and Persson (2013) provide a useful theoretical framework for approaching tax system analysis, including the notion of tax capacity.

From a tax policy perspective, the main objective of this paper is to give a quantitative indication of the scope for additional domestic revenue mobilisation in low- and lower-middle income countries. We build on advances in the stochastic frontier literature by applying panel data techniques to the estimation of overall tax potential and effort, using a new cross-country tax revenue dataset that offers an enhanced level of international comparability. We also investigate a range of possible determinants not previously explored in the empirical tax capacity literature.

The paper proceeds as follows. After this introduction, Section 2 discusses the concepts of tax potential and effort, including how we define them in this paper. Section 3 sets out our model, estimation methodology, the variables used, and addresses some caveats. Section 4 presents and discusses the results, before Section 5 concludes.

[1] For example, the Economic Community of West African States (ECOWAS) has specified a minimum target for countries' tax-to-GDP ratios of 20% (Ndiaye and Korsu, 2011); the five states of the East African Community (EAC) have agreed to aim for a tax-to-GDP ratio of 25% (EAC, 2013).

2. Tax potential, tax effort, and stochastic frontier analysis

In this paper, we define tax potential as the maximum amount of tax revenue a country could reasonably raise at a given point in time, conditional on its prevailing characteristics. Tax potential is inherently unobservable – but can be estimated empirically. The extent to which estimation can capture the true underlying determinants, precisely how determinants enter into estimation, and the precise interpretation of the resulting estimates for tax potential, are important issues discussed further below.

Tax effort is the extent to which actual tax revenue reaches estimated capacity, and is here expressed as a proportion. Such effort reflects a) policy choices and b) inefficiency in policy enforcement. Policy choices are expressed in tax rates and bases, and any exemptions. These policy choices reflect a variety of factors, including public preferences for the size of the state, and could well incorporate a deliberate decision not to aim for maximum possible tax collection at the top of a hypothetical Laffer curve. Inefficiency in enforcement encompasses issues of tax administration, taxpayer compliance, and interactions between the two. As suggested by Alfirman (2003), effort is thus best considered as 'unused tax potential', and represents a composite measure of policy and enforcement factors.

The bulk of the empirical literature to date has estimated tax potential – often used interchangeably with the term tax capacity – using a 'traditional' regression approach,[2] in which standard ordinary least squares (OLS) based cross-section or panel data techniques are applied to regressions of tax-to-GDP ratios on a range of potential determinants. In this traditional approach, tax capacity (and hence effort) is identified differently to the definition we adopt above: rather than referring to a measure of some true maximum, 'potential' is instead interpreted as the predicted tax ratio from the estimated model – and tax effort can be less than or greater than 1 accordingly, depending on whether actual collection is less than or greater than the regression prediction. The measure of tax 'potential' as defined in this approach is thus more akin to an average level achieved for a given set of determinants, rather than an indication of true maximum potential. Importantly, it provides no measure of the extent to which a country may be able to raise additional revenues.

In contrast, in this paper we adopt stochastic frontier analysis (SFA) techniques,[3] which support a more intuitive – and potentially more policy-relevant – measure of tax potential and effort. SFA can be used to generate a stochastic tax frontier, which defines an estimated maximum potential tax-to-GDP ratio for a given set of determinant 'inputs' and environmental factors. SFA was applied to tax capacity by Jha et al (1999) and Alfirman (2003), in the investigation of capacity and effort at the sub-national level in India and Indonesia respectively. Several applications followed, including further analysis of Indian states (Garg et al, 2014), tax potential at a sub-national level in Mexico (Casteñeda and

[2] This approach dates back to the seminal study by Lotz and Morss (1967). Le et al (2012) is a recent example. The terminology of the 'traditional' regression approach is attributable to Cyan et al (2013).
[3] Aigner et al (1977) and Meeusen and van den Broeck (1977) are the seminal papers for stochastic frontier analysis.

Pardinas, 2012), capacity across countries (Ndiaye and Korsu, 2011, Fenochietto and Pessino, 2013, IMF, 2013b, and Cyan et al, 2013), and the efficiency of tax agencies across countries (Alm and Duncan, 2014).

Underlying the SFA approach, using panel data, is an assumption of a model of the following form:

$$\frac{T}{Y}_{it} = f(\boldsymbol{X}_{it};\boldsymbol{\beta}).\xi_{it}.e^{v_{it}} \qquad (1)$$

The left hand side is the observed tax revenue (T) to GDP (Y) ratio for country i at time t. The first term on the right hand side, $f(\boldsymbol{X}_{it};\boldsymbol{\beta})$, is an expression for the 'production function' by which a vector of inputs $\boldsymbol{X}$ are transformed into tax revenues, in line with parameter vector $\boldsymbol{\beta}$. This production function is interpreted as defining the maximum tax-to-GDP ratio that could be achieved if policy were set to raise maximum potential revenues, the policy were perfectly enforced, and there were no random shocks to collections. ξ is tax effort, and is restricted to being between 0 and 1. An extension to the model in (1), discussed in the next section, is for ξ to be specified as being dependent on certain explanatory variables. The final term $e^{v_{it}}$ represents random shocks; these will reflect factors such as one-off windfalls, as well as measurement errors and model misspecification. The expression $f(\boldsymbol{X}_{it};\boldsymbol{\beta}).e^{v_{it}}$ defines the stochastic tax frontier; this specifies the tax potential for country i at time t, and what the actual tax-to-GDP ratio would be if effort ξ were equal to 1.

We discuss various econometric issues raised in estimating this model, and our methodology, in the following section. However, some preliminary conceptual issues are worthy of note here.

The first conceptual issue concerns the application and interpretation of SFA in the context of taxation. In the more traditional application of SFA to investigations of firm efficiency, there is generally a very clear set of inputs and outputs; in contrast, for taxation, what constitutes an 'input' is much less concrete. There is general agreement in the literature that a stochastic tax frontier should be defined and estimated *conditional* on the prevailing state of a set of 'structural' economic, demographic and institutional factors, with 'effort' capturing factors more immediately under government control. However, what counts as a 'structural' factor is not necessarily clear, and the modeller's choices on whether to treat certain variables as determinants of the stochastic frontier or of inefficiency can substantively influence how capacity and effort should be interpreted. Indeed, even many factors commonly accepted in the literature as structural, such as the sectoral composition of GDP, will partly be determined by government policy – and thus could be incorporated in a very broad definition of government 'effort'. We address these issues in more detail in the following section. The overarching point is that the modeller must be clear on the assumptions being adopted in the construction of tax capacity and effort estimates, and for the estimates to be interpreted accordingly.

A second key conceptual issue is the extent to which estimated stochastic tax frontiers can and do capture 'true' tax capacity. As tax potential is inherently unobservable, it must be estimated using observations of actual tax-to-GDP ratios. In reality, it may be reasonable to expect that very few, or no, observations of tax-to-GDP ratios within any given sample will equal the absolute maximum that could have been raised in that country-year – with the result that the true tax frontier will lie (at an unknown distance) beyond any estimated frontier. In this sense, estimated stochastic tax frontiers should be viewed more as indications of the maximum tax ratio that a certain country could raise, given the most that other countries with similar characteristics have been able to raise.

Finally, while the introduction of SFA techniques has begun to provide more policy-relevant estimates of the size of tax effort, relatively little attention has been paid to the determinants of effort (IMF, 2013b). In the context of the model set out in (1), this can be addressed by specifying ξ to be a function of certain observed variables. This should have two benefits: in econometric terms, it should improve the identification of tax effort in the model; and in policy terms, it could identify factors that support higher levels of effort.

3. Econometric approach

3.1 Model and estimation methodology

The basic econometric model for stochastic frontier analysis, as proposed by Aigner et al (1977), is generated by taking natural logarithms of the model in equation (1). The 'production function' component of the model in (1) is assumed to take a Cobb-Douglas form and is thus linear in logs. Defining $q_{it} = \ln(\frac{T}{Y_{it}})$ where T represents taxes and Y output, an input vector of structural economic factors $\boldsymbol{x}_{it} = \ln(\boldsymbol{X}_{it})$, and an 'inefficiency' term $u_{it} = -\ln(\xi_{it})$, gives the following:

$$q_{it} = \alpha + \boldsymbol{\beta}'\boldsymbol{x}_{it} + v_{it} - u_{it} \qquad (2)$$

We extend this base model to take into account observed heterogeneity – that is, a set of observable environmental variables **z** that are not direct inputs into tax collection, but that could influence potential tax capacity ($\mathbf{z_p}$) or the level of effort ($\mathbf{z_e}$)[4] – to give a model of the following form:[5]

$$q_{it} = \alpha + \boldsymbol{\beta}'\boldsymbol{x}_{it} + \boldsymbol{\delta_p}'\boldsymbol{z}_{it,p} + v_{it} - u_{it} \qquad (3)$$

where: $u_{it} \sim N^{+}(\mu_{it}, \sigma_u^2), \qquad \mu_{it} = \boldsymbol{\delta_e}'\boldsymbol{z}_{it,e}$ (3a)

and $v_{it} \sim N(0, \sigma_v^2)$ (3b)

The expression $v_{it} - u_{it}$ is a composite error term: it incorporates both the random shock v_{it}, assumed to be normally distributed (and independent of u_{it}), and the strictly positive 'inefficiency' term u_{it} assumed to take a truncated-normal distribution.[6] In the context of this paper, inefficiency is interpreted as a lack of tax effort, and in this section we use the terms interchangeably to accord with the stochastic frontier literature. Jondrow et al (1982) provide the now commonly-used method by which estimates of v_{it} and u_{it} can be separated out from the estimated composite error, and from which estimates of tax effort ξ_{it} can then be generated. The stochastic frontier is given by $\alpha + \boldsymbol{\beta}'\boldsymbol{x}_{it} + \boldsymbol{\delta_p}'\boldsymbol{z}_{it,p} + v_{it}$: this specifies the highest (log) tax ratio country i could achieve in period t, in the absence of any inefficiency (i.e. if $u_{it} = 0$, or equivalently, if effort $\xi = 1$). The inefficiency term u_{it} varies across both countries and time, and is influenced in part by observable factors $\boldsymbol{z}_{it,e}$.

Whether any given observed variable should be considered to be a direct input into the raising of tax revenues and thus included in vector **x**, to influence tax capacity as an environmental variable $\mathbf{z}_e$, or to influence tax effort as a component of $\mathbf{z}_p$ is often

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[4] The existence of internal conflict is one example of a candidate for inclusion in $\mathbf{z}_{it,p}$, as a factor that might reasonably be expected to shift the stochastic frontier inward. Development assistance grants are an example of a candidate for inclusion in $\mathbf{z}_{it,e}$, as they might influence policy choices on the level of taxes to levy.

[5] This is similar to the approach of Fenochietto and Pessino (2013). See also Greene (2008). In this model, the components of $\mathbf{z_{it,e}}$ do not need to be converted to logarithms, unlike the production function inputs $\mathbf{x_{it}}$.

[6] Greene (2008) notes that adopting alternative assumptions for the distribution of u_{it}, such as half-normal, gamma or exponential, tends to have minimal impact on the size of inefficiency estimates.

ambiguous.[7] For example, the extent of corruption has been found in a number of empirical studies[8] to have a significant negative impact on actual tax collection – but it is not clear where this should enter in a model for tax capacity: a reasonable case could be made for corruption entering (3) as an inward shift of the tax frontier, or as a determinant of effort.[9] Such uncertainty rests on conceptual questions, as well as empirical ones; for example, if corruption were incorporated in $\mathbf{z_p}$ and not $\mathbf{z_e}$, we would expect this to lead to lower estimates of tax capacity and accordingly-higher estimates for tax effort in higher-corruption countries – and imply a different interpretation for the meaning of 'effort'.

Following Battese and Coelli (1995), who introduced a panel data model with time-varying inefficiency that reflects observable heterogeneity, the parameters of the stochastic frontier and the inefficiency model are estimated simultaneously to avoid bias (Wang and Schmidt, 2002), using maximum likelihood.[10] Unobserved time-invariant heterogeneity is captured in a random effects (RE) framework (in terms of the model in (3): the random effect is captured within the estimate for u_{it}). Given that RE relies on the unlikely assumption that the effects are uncorrelated with the explanatory variables, we test a Mundlak adjustment,[11] by which we seek to account for this correlation by including the country-specific means of each time-varying explanatory variable as additional regressors in the specification.

The choice of how to model unobserved time-invariant heterogeneity in SFA can have a substantive impact on the estimated size of inefficiency and hence, in the present context, on the size of countries' measured tax effort. In particular, country-specific characteristics that cannot be measured explicitly could be treated as: differences in potential tax capacity; time-invariant aspects of inefficiency; or – perhaps most realistically – as some combination of the two. A simple RE approach would inherently incorporate all effects into the estimate of inefficiency. Greene (2004, 2005) proposes alternative means for handling time-invariant effects – a "true fixed effects" and a "true random effects" model. Both these models treat all time-invariant effects as unobserved heterogeneity in the stochastic frontier, rather than as any part of inefficiency. This is a similarly extreme assumption, and the reality probably

[7] Alfirman (2003) raises this point clearly in his seminal paper on tax capacity. More generally, Greene (2008) notes that there may be no obvious 'right' answer as to the precise placement of variables in SFA applications.
[8] Such as in Ghura (1998), Gupta (2007) and Le et al (2012).
[9] For example, an argument that corruption will reduce effectiveness in implementing tax policy would justify its inclusion as a determinant of inefficiency; an argument that corruption could be seen as a form of 'unofficial' taxation, that will reduce the size of the base for legitimate taxation, would justify its inclusion as a determinant of the stochastic frontier. One could even model corruption in both these ways; Greene (2008) illustrates an example of a single factor entering into an SFA model twice this way.
[10] Fenochietto and Pessino (2013) provide a useful overview of alternative models for tax capacity estimation. We conduct the estimation in Stata using the sfpanel command written by Belotti et al (2012).
[11] Mundlak (1978) shows – in a standard RE framework – that once explicit account is taken of the statistical dependence between the explanatory variables and the effects in this way, the 'RE' and 'FE' estimators are then identical (and thus RE is unbiased). Farsi et al (2005), however, note that the modification may not have quite the same effect in SFA models, due to the composite error term being asymmetric. Use of the Mundlak adjustment was introduced into the SFA literature by Farsi et al (2005), and with application to tax capacity by Fenochietto and Pessino (2013).

lies somewhere in the middle. In the context of a stochastic tax frontier, we choose a standard RE model and thus interpret unobserved heterogeneity as a lack of tax effort, suggesting that the influence of the unobserved factors could be overcome with tax policy and administration measures.

To determine our preferred specification we adopt a specific-to-general approach.[12] We first build up the content of **x**, then of $\mathbf{z_p}$, then of $\mathbf{z_e}$, adding the most significant variables each time, until no additional variable proves significant (assessed using robust standard errors, and at this stage without inclusion of a Mundlak adjustment). We also investigate the need for country, year, and even any individual observation dummies, to handle outliers. As the addition of significant variables to some parts of the specification can result in previously-included variables becoming insignificant, there is however a degree of iteration required in building the preferred specification.[13] The following section presents and discusses the results, including a variety of robustness tests.

3.2 Variables and data

The dependent variable we adopt in our estimations is total tax revenue expressed as a ratio to GDP,[14] excluding social contributions and natural resource revenues.[15] Our source for this tax data is the Government Revenue Dataset (GRD) – a new dataset constructed by the International Centre for Tax and Development (ICTD), which represents a major step forward in the quality and coverage of data available for cross-country empirical work (it provides tax data for 201 countries, for the years 1980-2010; full details are set out in Prichard et al, 2014). Improvements on previously-existing datasets include: a consistent treatment of resource revenues and social contributions across countries; the formulation and use of a consistent GDP series for each country; and the incorporation of a meticulous review, correction and combination of existing data, to expand coverage and ensure comparability.

We investigate a broad range of explanatory variables that might feasibly influence tax capacity and effort, guided by the theoretical and empirical literature to date; IMF (2011) provides a useful summary of the range of candidates tested to date, and an overview of the underlying theoretical reasoning for each. These provide the core of the 26 variables tested

[12] This has the benefit of being much more computationally stable than a general-to-specific approach. Alfirman (2003) provides a detailed discussion about the potential sensitivity of SFA estimation to specification errors.

[13] This process, as in any regression investigation with many potential explanatory variables, incorporates an element of judgement – although we challenge this element, by testing appropriate alternative choices at different points in the iterative process.

[14] It must be acknowledged that inconsistencies in GDP measurement across countries – as demonstrated by a number of large recent GDP level revisions in African countries, such as an 89% revision made by the Nigerian statistical authorities in 2014 – represent a potentially-serious challenge for all cross-country empirical work, and demands appropriately guarded and cautious interpretation of its outputs.

[15] Social security revenues are excluded due to the significant differences in social security systems (including the balance between public and private provision) across countries. Resource tax revenues are excluded due to the significant differences in the nature of this form of revenue from other tax revenues, and its drivers (see for example Appendix VII of IMF, 2011).

here. We also trial three variables which have not (to our knowledge) been tested in the tax capacity literature before: MIT's economic complexity index; ethnic tension; and private sector credit. A higher value of MIT's economic complexity index (Hausmann et al, 2011) may reflect greater size, interlinkages and formality of firms – factors which should assist in tax collection. Higher ethnic tension may reflect less state cohesiveness, and thus reduce tax effort through lower demand for and willingness to pay tax (see for example Besley and Persson, 2013). Higher levels of private sector credit may reflect higher levels of formality and record-keeping, supporting tax administration.

Table 1 sets out the comprehensive set of variables we investigate, where we assume they enter in our model ($\mathbf{x}$, $\mathbf{z_p}$, or $\mathbf{z_e}$), summary statistics, and sources. We restrict our sample to include non-resource rich countries only – to account for the possibility that the determination of tax capacity in resource-rich countries may be structurally different to that in other countries – using the definition of 'resource rich' in IMF (2012). For our preferred specification, set out in the following section, the dataset contains a complete set of variables for 85 non-resource-rich countries, over the period 1984-2010.

3.3 Caveats

While cross-country estimation of tax potential and effort continues to be an active area of research, a number of methodological caveats are worthy of note. First are the set of issues inherent with any cross-country empirical work – including the potentially invalid assumptions implicit in imposing a common structure across countries, the difficulty of controlling for country-specific factors, and potential difficulties in data comparability. The quality and cross-country comparability of GDP data is of particular salience in cross-country tax work, where GDP is a natural (and in the present context, necessary) denominator, and yet is subject to significant measurement and comparability issues – as raised by Jerven (2013), and highlighted by various recent sizeable upward revisions amongst developing countries.[16]

[16] Such as recent upward revisions of 13% in Uganda, 25% in Kenya, 32% in Tanzania, and 89% in Nigeria.

Table 1: Summary of explanatory variables to be tested

Description	Source	Mean	S.d.	Min	Max	Corr. with tax:GDP[3]	Trialled location in specification: x	zp	ze
Tax:GDP ratio (excluding natural resource revenue and social security contributions)	ICTD	18.6	8.2	0.6	57.7	1			
Economic factors									
Ln GDP per capita, constant 2005 US$'000	WDI	8.0	1.7	4.7	11.4	0.71	x		
Ln of GDP per capita squared	WDI	67.4	26.9	22.4	129.1	0.72	x		
Agriculture value added as % GDP	WDI	17.2	15.1	0.0	72.0	-0.58	x		
Manufacturing value added as % GDP	WDI	14.9	7.8	0.3	45.7	0.18	x		
Services value added as % GDP	WDI	57.3	13.8	12.9	100.0	0.51	x		
Economic complexity index [4]	MIT	3.9	1.0	0.9	6.2	0.64	x		
Private sector credit (% GDP) [5]	WDI	44.2	36.4	0.8	150.0	0.48	x		
Imports (% of GDP) [5]	WDI	45.3	22.8	0.1	100.0	-0.08	x		
Exports (% of GDP) [5]	WDI	35.7	22.3	0.2	100.0	0.09	x		
Trade openness (% of GDP) [5]	WDI	81.0	42.4	0.3	200.0	0.01	x		
Inequality (GINI coefficient) [3]	IGC	42.4	9.2	19.4	74.3	-0.58	x		
Inflation (annual CPI inflation, %) [5]	WEO	11.1	18.2	-72.7	100.0	-0.30		x	
Real exchange rate, annual % change [5]	Bruegel	0.5	9.0	-30.0	30.0	0.07		x	
Extractive industry rents (% GDP)	WDI	1.0	2.3	0.0	39.5	-0.02			x
Non-tax revenues (% GDP) [6]	ICTD	4.6	4.3	-0.1	51.6	0.42			x
Grants (% GDP) [5]	ICTD	2.9	6.1	0.0	30.0	-0.29			x
Net Overseas Development Assistance (% GNI) [5]	WDI	6.4	9.5	-2.6	40.0	-0.37			x
Dummy = 1 if tax data refers to general government, 0 if central only	ICTD	0.4	0.5	0	1	0.69		x	
Demographic factors									
Education level (UN Education Index)	UN	61.9	19.5	6.7	100.0	0.68	x		
Age dependency ratio (15-64)	WDI	68.2	20.0	25.6	112.8	-0.53		x	
Urbanisation (% of population in urban centres)	WDI	51.2	24.6	4.3	100.0	0.53	x		
Population density	WDI	157.4	207.2	1.3	1000.0	-0.22			
Ethnic Tension [4]	ICRG	4.7	1.4	0.5	6.5	0.26			x
Institutional factors									
Corruption (6.5 = least corrupt) [4]	ICRG	3.8	1.4	0.5	6.5	0.64			x
Bureaucratic quality (4.5 = highest quality) [4]	ICRG	2.9	1.2	0.5	4.5	0.67			x
Law and Order (6.5 = highest quality) [4]	ICRG	4.5	1.5	0.5	6.5	0.67			x
Democratic accountability (6.5 = most accountable) [4]	ICRG	4.7	1.6	0.5	6.5	0.60			x
Dummy = 1 if internal conflict	PRIO	0.1	0.3	0	1	-0.28		x	
Time trend		14.6	7.5	1	27	0.10		x	
Year dummies				0	1			x	

Notes:

1/ The sample on which this table is based covers the period 1984-2010, and incorporates non resource-rich countries only. 2/ The Pearson's correlation coefficient of the variable in question with the tax-to-GDP ratio. 3/ The GINI coefficient dataset is generated using data from UNU-WIDER, the University of Texas Inequality Project, the OECD, the World Bank and Eurostat. 4/ Scale shifted to reduce distortion from logarithmic transformation. 5/ Variable truncated (for less than 5% of observations) to limit distortion from outliers. 6/ The non-tax revenue data, from ICTD, actually incorporates both revenue reported as "non-tax", and the resource component of reported tax revenue. The dataset authors advise that this measure of non-tax revenue can therefore be used as a proxy for resource revenues.

There are also a number of specification issues to be borne in mind, including potential endogeneity, and variable selection. For example, there may well be reverse causality from the tax-to-GDP ratio to various regressors, including institutional factors such as law and order and corruption. This would induce bias into estimation – although the extent to which such structural factors are slow-moving, and may not be subject to a strong immediate, contemporaneous effect from tax revenues, would mitigate this potential problem. Our specification will likely suffer as well from omitted variables – with the level of informality, and any direct measure of preferences for taxation, both of which are notably omitted in Table 1.

Where possible, we try to control for such issues – such as by using the new, unprecedentedly high-quality ICTD tax dataset to address potential tax data quality and comparability issues – or to gauge their qualitative and quantitative importance, by running a number of sensitivity tests. Estimation of tax capacity will inherently necessitate cross-country comparison, and a number of problems this entails will be unavoidable. However, with sufficient care and sensitivity testing, the output should provide at least a meaningful, indicative guide to tax potential – albeit one that must be interpreted with an appropriate degree of caution and, in the context of individual countries, interpreted as part of a thorough assessment of country-specific conditions.

4. Results and discussion

4.1 Results

Our headline specification is displayed in column (I) of Table 2. In terms of the model in (3), the level of education, imports as a ratio to GDP, and the manufacturing share of GDP enter as part of tax frontier determinants **x**, and inflation, the dependency ratio and a general government data coverage dummy enter as environmental frontier shift factors $\mathbf{z_p}$. Corruption, democratic accountability, and law and order are found to be significant determinants of tax effort ($\mathbf{z_e}$). All coefficients are of the expected sign, and of statistically and economically[17] significant size. None of the three variables we test newly in this paper (the MIT economic complexity index, ethnic tension, and private sector credit) were found to be significant. The estimated stochastic error terms have a tight distribution about zero, with no major outliers (Annex 1 provides descriptive statistics and distribution plots for the estimates for v_{it}, as well as for u_{it} and ξ_{it}). The value of lambda, of around 2.3, indicates that lack of tax effort accounts for a large proportion of the composite error.

Our findings on determinants of tax capacity (**x** and $\mathbf{z_p}$) are broadly consistent with the existing literature. The significance of imports and inflation are common findings. The level of GDP per capita was not found to be significant, once the level of education is included. That finding contrasts with some studies in the tax determinants literature such as the seminal Lotz and Morss (1967), Adam et al (2001), Gupta (2007), and Drummond et al (2012), but is supported by others such as Tait et al (1979), Bird et al (2004) and Morrisey et al (2014), who also fail to find a significant impact when various other variables are included. This finding is probably driven by high correlation with the included explanatory variables. The education level, which is highly correlated with income and with the tax-to-GDP ratio, likely captures a variety of factors associated with a higher level of development that also support a higher tax capacity. In addition, a direct effect of higher education levels may be to raise citizens' appreciation of how and why to pay taxes. The significance of manufacturing as a share of GDP mirrors the regularly-found importance of sectoral share variables, and is likely to be picking up a variety of relevant inputs into tax collection – reflecting more concentrated, complex and formalised business activity, that is more amenable to tax collection. The positive impact of the age dependency ratio is likely to capture greater public demand for education and healthcare spending, and thus greater willingness to pay tax.[18] Finally, the small, negative coefficient on inflation suggests that macroeconomic instability, manifested in large CPI increases, constrains the capacity to tax.

The determinants of tax effort ($\mathbf{z_e}$) are of particular note, given the limited focus this has received in the literature to date. The detrimental impact of corruption on effort matches the findings of Fenochietto and Pessino (2013) and Cyan et al (2013), and may reflect its

[17] The judgement on economic significance is based on a simple assessment of the products of the coefficients with the mean and the standard deviation of the variables, relative to the mean of the tax-to-GDP ratio.

[18] The finding of a positive coefficient on the dependency ratio is in line with IMF (2013b) – although is in contrast to the negative coefficient reported by Le et al (2012) and Cyan et (2013).

deleterious effects on both policy choices and administrative implementation. The positive impact of law and order will capture the importance of a state's capacity to enforce tax policy, and mirrors a similar finding in Castenada and Pardinas (2012). The democratic accountability variable should partly capture the willingness of citizens to pay tax, and provides empirical backing to its theoretical importance as raised, for example, by Besley and Persson (2013) and Ali et al (2014). We do not find that measures of donor assistance significantly detract from tax effort. That result is in line with Carter (2014)'s study applying recent panel data techniques, and supports the view that donor resources neither impact tax potential nor collection efficiency when other factors are taken into account. In addition, we detect no time trend in the data, suggesting that changes in technology have shifted neither tax potential nor collection efficiency. We conclude that the introduction of more efficient taxes, advances in tax administration and digital technologies have been balanced by mitigating factors in the other direction, over the time period of our dataset (up to 2010). Whilst these findings are noteworthy, we also interpret the large and highly significant constant in the effort specification to in part indicate the limited extent to which this specification fully captures determinants of tax effort.

Of greatest interest for the focus of this paper are estimates for tax capacity and tax effort. As reported in Table 2, the average estimated tax effort across countries and time is 0.63 – with a range from a low of 0.13 to a high of 0.97. Columns (I)(a) and (I)(b) in Table 3 report estimated tax potential and tax effort for each country, for the latest year available in the sample. Table 4 provides a summary of average actual tax revenues, estimated tax potential, and estimated tax effort, for low-income to lower-middle income countries, and upper-middle to high income countries; it is clear that whilst actual tax revenues are much smaller on average in lower income countries, this largely reflects estimated tax capacity – and on average over the sample as a whole, estimated tax effort is only 0.12 lower than in the higher income country group.

Column (II) in Table 2 reports the regression results for when a Mundlak adjustment is introduced into specification (I). A Wald test shows that the Mundlak terms are jointly highly significant (with a p-value of 0.003), suggesting that there is indeed a significant correlation between firm-specific effects and explanatory variables in (I). The inclusion of the Mundlak adjustment also disrupts a number of the coefficients in the tax frontier specification (as would be expected from multicollinearity). However, the most important point at issue in the present context is what impact this has on estimates of tax effort.

The coefficients in the effort specification are notably stable between regressions (I) and (II) and estimates of effort show considerable stability: average estimated effort across all observations rises marginally to 0.64, and the correlation between estimated effort for each observation in the two specifications is 0.98. Table 3, however, does highlight the existence of a number of sizeable changes for some specific observations: for example, the estimate for Mozambique in 2010 is 0.10 higher when the Mundlak adjustment is included; for the latest estimates for Jordan, it is 0.08 lower.

Table 2: Stochastic frontier coefficients

	(I) Main specification			(II) Mundlak specification		
	Coeffs.		p-value	Coeffs.		p-value
Frontier						
ln(mangva)	0.099	*	0.079	-0.068		0.277
ln(imports)	0.115	**	0.017	0.080		0.204
ln(educ)	0.399	***	0.000	0.175		0.115
gengov	0.235	***	0.002	0.236	***	0.003
cpi	-0.003	***	0.001	-0.002	**	0.062
depratio	0.004	*	0.094	-0.005	**	0.044
ln(mangva)-bar				0.198	**	0.023
ln(imports)-bar				0.031		0.693
ln(educ)-bar				0.302	*	0.069
cpi-bar				-0.002		0.359
depratio-bar				0.011	***	0.003
constant	0.672		0.219	0.127		0.853
Inefficiency						
laworder	-0.066	**	0.015	-0.079	***	0.009
corruption	-0.066	***	0.007	-0.063	**	0.013
democacc	-0.045	*	0.062	-0.038	*	0.093
constant	1.120	***	0.000	1.203	***	0.000
σ_u	0.269	***	0.000	0.278	***	0.000
σ_v	0.115	***	0.000	0.097	***	0.000
$\lambda = \sigma_u / \sigma_v$	2.346	***	0.000	2.868	***	0.000
Log-likelihood	-104.9			-41.4		
Mean effort	0.63			0.64		
Min effort	0.13			0.14		
Max effort	0.97			0.97		
Observations	1,664			1,664		
Countries	85			85		
Time period	1984-2010			1984-2010		

*Notes: * indicates significance at a 10% level, ** 5%, and *** 1%. Both specifications also include a dummy for Denmark, the estimated errors for which otherwise prove to be extreme outliers. Observations are only incorporated for cpi < 100%; when cpi is unrestricted, the coefficient on cpi is much smaller (being driven by outlier values), though still statistically significant.*

Table 3: Estimated tax capacity and effort (for latest available year in sample, based on specifications reported in Table 2)

			(I) Main specification		(II) Mundlak spec.					(I) Main specification		(II) Mundlak spec.	
Country	Year	Tax-to-GDP ratio	Tax potential	Tax effort	Tax potential	Tax effort	Country	Year	Tax-to-GDP ratio	Tax potential	Tax effort	Tax potential	Tax effort
Argentina	2009	24.7	33.9	0.73	33.8	0.73	Lebanon	2010	17.8	25.8	0.69	28.0	0.64
Armenia	2008	17.7	30.4	0.58	32.9	0.54	Lithuania	2009	17.4	35.5	0.49	37.1	0.47
Australia	2008	27.5	33.3	0.83	34.4	0.80	Luxembourg	2009	24.6	27.7	0.89	28.4	0.87
Austria	2010	27.5	35.6	0.77	35.3	0.78	Madagascar	2009	13.9	26.2	0.53	25.4	0.55
Bahamas	2010	14.3	21.8	0.66	22.5	0.64	Malawi	2010	20.9	28.9	0.72	27.1	0.77
Bangladesh	2010	9.0	20.8	0.43	21.6	0.42	Malaysia	2008	11.6	26.9	0.43	29.8	0.39
Belarus	2010	23.9	38.6	0.62	36.1	0.66	Malta	2008	27.2	30.6	0.89	31.0	0.88
Belgium	2010	29.4	37.9	0.78	39.7	0.74	Moldova	2010	20.6	32.0	0.64	33.4	0.62
Brazil	2009	23.5	31.5	0.75	31.4	0.75	Morocco	2010	23.4	26.7	0.88	27.8	0.84
Burkina Faso	2010	12.9	21.3	0.61	19.8	0.65	Mozambique	2010	18.1	26.6	0.68	23.2	0.78
Canada	2009	27.4	32.8	0.83	32.3	0.85	Namibia	2010	25.0	29.1	0.86	29.9	0.83
China	2010	18.2	31.7	0.57	31.4	0.58	Netherlands	2008	24.7	35.7	0.69	35.5	0.70
Colombia	2010	17.5	30.4	0.58	32.2	0.54	New Zealand	2009	32.1	36.4	0.88	37.5	0.86
Costa Rica	2010	13.1	25.1	0.52	27.7	0.47	Nicaragua	2010	18.1	26.6	0.68	28.0	0.65
Croatia	2009	21.9	33.2	0.66	32.7	0.67	Pakistan	2010	10.2	19.4	0.52	20.7	0.49
Cyprus	2008	30.9	32.5	0.95	32.2	0.96	Panama	2010	11.6	24.5	0.47	27.4	0.42
Czech Republic	2010	18.7	36.3	0.52	35.6	0.53	Paraguay	2010	13.1	26.7	0.49	27.8	0.47
Denmark	2010	46.9	57.3	0.82	56.2	0.83	Philippines	2010	12.2	25.5	0.48	28.7	0.42
Dominican Rep.	2010	13.4	25.3	0.53	28.4	0.47	Poland	2008	22.9	34.2	0.67	34.2	0.67
El Salvador	2009	12.6	26.5	0.48	29.8	0.42	Portugal	2008	23.8	34.3	0.69	34.4	0.69
Estonia	2010	20.9	37.0	0.56	36.7	0.57	Senegal	2010	18.8	25.5	0.74	24.9	0.75
Ethiopia	2009	8.6	19.8	0.44	17.9	0.48	Serbia	2010	24.5	34.2	0.72	33.5	0.73
Finland	2009	30.0	36.1	0.83	36.5	0.82	Sierra Leone	2010	11.7	18.2	0.64	18.2	0.64
France	2009	25.7	33.0	0.78	33.8	0.76	Singapore	2009	13.0	27.6	0.47	28.0	0.46
Germany	2009	22.9	34.7	0.66	34.4	0.66	Slovak Republic	2010	16.1	34.8	0.46	35.4	0.45
Ghana	2010	13.2	24.2	0.55	25.7	0.52	Slovenia	2009	22.0	37.0	0.60	36.7	0.60
Greece	2010	20.2	32.2	0.63	31.5	0.64	South Africa	2008	29.2	35.3	0.83	38.1	0.77
Guatemala	2009	10.0	26.5	0.38	28.9	0.35	Sri Lanka	2010	12.9	25.3	0.51	25.1	0.51
Honduras	2009	15.1	34.5	0.44	39.3	0.39	Sweden	2009	35.2	38.9	0.90	39.1	0.90
Hong Kong	2010	14.5	28.0	0.52	27.5	0.53	Switzerland	2009	22.6	35.1	0.64	35.1	0.64
Hungary	2010	26.1	38.3	0.68	36.9	0.71	Tanzania	2010	14.6	23.6	0.62	21.8	0.67
Iceland	2009	30.9	36.1	0.86	36.4	0.85	Thailand	2010	17.5	35.5	0.49	35.2	0.50
India	2010	16.6	28.4	0.58	28.5	0.58	Togo	2010	15.6	27.8	0.56	29.0	0.54
Ireland	2010	22.0	39.2	0.56	40.0	0.55	Tunisia	2010	19.0	28.2	0.67	29.7	0.64
Italy	2009	29.7	35.8	0.83	34.7	0.86	Turkey	2009	18.6	30.6	0.61	30.1	0.62
Jamaica	2010	24.1	28.0	0.86	28.4	0.85	Uganda	2010	11.7	26.2	0.45	22.7	0.51
Japan	2010	15.7	30.4	0.52	28.8	0.54	Ukraine	2010	26.1	35.4	0.74	34.6	0.75
Jordan	2010	15.9	29.1	0.55	33.9	0.47	United Kingdom	2010	28.2	34.4	0.82	35.6	0.79
Kenya	2010	18.3	27.2	0.67	29.9	0.61	United States	2010	18.2	30.1	0.60	30.8	0.59
Korea, Rep.	2009	19.7	35.4	0.56	35.2	0.56	Uruguay	2010	19.3	27.5	0.70	26.9	0.72
Latvia	2010	18.1	34.6	0.52	33.9	0.53	Zimbabwe	2010	27.7	31.4	0.88	30.9	0.90

Note: This table reports results for 82 countries (of the full sample of 85 countries) for which the latest available estimate is in 2008 or later.

Table 4: Average tax-to-GDP ratio, estimated tax capacity and estimated tax effort, by country income group (based on specification (I) in Table 2)

	Average, 1984-2010				*Latest year (2008 onwards)*			
Country income group	**n**	**Tax-to GDP ratio**	**Estimated tax capacity**	**Estimated tax effort**	**n**	**Tax-to GDP ratio**	**Estimated tax capacity**	**Estimated tax effort**
Low and lower-middle	593	13.0%	23.2%	0.55	27	15.7%	26.4%	0.59
Upper-middle and high	1071	21.8%	31.6%	0.67	55	22.5%	33.0%	0.68

4.2 Sensitivity testing

We submit the results to a number of sensitivity tests; the regression output from these tests is summarised in Annex 2, while the impact on the estimates for tax effort are summarised in Table 5 below. We base these sensitivity tests on specification (I), for clearer exposition of changes in the regression output.

Our first test is to run the specification using observations from only the last fifteen years of the sample – as a simple way to investigate the possibility that the determination of tax capacity may change over time. Column (III) in Annex 2 shows that there is some degree of parameter stability compared to the full sample – but the change in size of certain coefficients (such as that on education) is notable, and others (whilst all at least remaining of the same sign) are no longer statistically significant; this will in part be a function of the smaller sample size, though may also signify some structural change. Row (III) in Table 5 summarises the impact on estimates for tax effort; on average, there is a very small increase, of 0.02, and correlation with estimates based on the full sample are very high (0.98). However, in the minimum and maximum columns of row (III) in Table 2 highlight that for some select observations, the change can be quantitatively much more meaningful.

Table 5: Estimated tax effort from sensitivity tests

		Mean estimated tax effort	Correlation with estimations for tax effort in (I)	Differences from (I) in country-year tax effort estimates		
				Min	Max	S.d.
(I)	Main specification	0.63	1.00	-	-	-
(II)	Main specification w/Mundlak adjustment	0.64	0.98	-0.09	0.14	0.03
(III)	Shorter sample (1996-2010)	0.65	0.98	-0.14	0.14	0.03
(IV)	Corruption in $\mathbf{z_p}$ instead of $\mathbf{z_e}$	0.81	0.89	-0.01	0.32	0.07
(V)	Dependency ratio in $\mathbf{z_e}$ instead of $\mathbf{z_p}$	0.64	0.98	-0.04	0.11	0.03
(VI)	Inclusion of resource rich countries	0.77	0.85	-0.01	0.36	0.08
(VII)	GDP revisions of 20% or 40% in LICs	0.64	0.99	-0.08	0.11	0.03

We next investigate the sensitivity of results to changes in the specification. First, we investigate the effect of shifting corruption out of the effort specification, and treating it as an environmental determinant of tax capacity. Column (IV) in Annex 2 shows that corruption is also highly significant under this placement. However, as discussed above, this implies a very different interpretation of the meaning of capacity and effort – and as would be expected, Table 5 shows that average estimated tax effort would be much higher (and, equivalent, estimated tax capacity much lower) if corruption were to be treated as a determinant of capacity rather than effort.

We then experiment with treating the dependency ratio as a determinant of effort, rather than of capacity; this alternative treatment might be justified if it were seen as capturing policy choice, and thus influencing effort, rather than capacity, However, column (V) in Annex 2 shows that the dependency ratio is not statistically significant in this placement. In any case, mean estimated tax effort is on average very similar to under specification (I) – although again, certain country-year observations do see substantive shifts in estimated effort.

To confirm whether the common distinction between resource rich countries and others is important for our dataset, we run main specification (I) using observations on both resource and non resource rich countries. The coefficients in the frontier specification (see column VI in Annex 2) are broadly comparable to those estimated using non resource rich countries alone, suggesting that the determination of tax potential is of a similar form in both groups of countries. However, the fact that all regressors in the effort specification become highly insignificant suggests that the determination of tax effort is qualitatively different in resource rich countries – justifying the separate treatment of the two groups in quantitative investigation of tax effort.

To gauge the potential influence of mis-measured GDP, we also run a sensitivity test whereby we raise measured GDP in half of the low-income country observations by 20%, and in the other half by 40% - with the tax-to-GDP and imports-to-GDP ratios falling accordingly.[19] The estimated coefficients (see column VII in Annex 2) are reassuringly similar to those in the headline specification. Furthermore, average estimated effort is little changed (it rises by just 0.01) – although the average estimated stochastic error term (v_{it}) becomes 0.04,[20] rather than zero – highlighting a degree of model mis-specification. The estimated efforts for the low-income country observations fall by up to 0.08 compared to the headline specification, reflecting that GDP mis-measurement would lead to a distortion of estimated tax effort, even though the coefficients partly adjust to cushion the effect of the rebasing.

Overall, the results suggest that systematic mis-measurement of GDP in certain countries would indeed influence the validity of effort estimates for the affected observations. The high effort estimate of 0.88 for Zimbabwe is a good case. GDP was last rebased in 1990 (IMF, 2013a) and so-the-tax to GDP ratio is probably overestimated by a large amount, resulting in an artificially-inflated effort estimate. However, the robustness check suggests that such revisions should not raise fundamental questions about the validity of the results overall. It's worth noting that this robustness is the flipside of the result that GDP per capita plays an insignificant role in determining tax capacity when the other explanatory factors are included.

Finally, we note that neither Greene's TFE nor TRE estimators converge when applied to our root specification (I), and thus we do not report results here.[21] However, the indicative results that are produced tell a broadly similar story to the TRE results reported by Fenochietto and Pessino (2013): estimated tax effort is in general substantively higher, reflecting the fact that unobserved time-invariant heterogeneity is treated as shifting tax capacity, rather than as part of tax effort.

[19] Note that low income observations account for 309 of the 1,683 used in the regression.

[20] Whilst this result (not shown in the tables or figures) is non-negligible, it is nonetheless still small compared to the average ln(tottax) value of 2.82.

[21] Results would be happily supplied by the authors to interested parties on request.

5. Conclusion

This paper has estimated the scope for additional tax revenue mobilisation across 85 non-resource-rich countries. It builds on recent advances in the literature by applying SFA techniques to a new high-quality cross-country tax revenue dataset, and with an increased focus on the determinants of tax effort – where 'effort' captures unused tax capacity, encompassing policy choice as well as inefficiencies in collection. Our results suggest that corruption, law and order, and the level of democratic accountability all play a significant role in determining the extent to which a country's tax take reaches its potential.

We find wide variation in the estimated level of tax effort across our sample, ranging from a low of around 0.1 to a high of close to 1 across the sample period as a whole. The results suggest that the level of tax revenues collected by low and lower-middle income countries is close to 60% of their potential (as of the latest available year in our sample), compared to an effort of closer to 70% on average in upper-middle and high income countries.

Caution must be exercised in interpreting the results, given the variety of econometric issues faced in the cross-country methodology used, the inevitably wide range of omitted variables, and conceptual issues associated with the application of SFA techniques to tax capacity. Reflecting this, we subject our results to several sensitivity tests, including the addition of a Mundlak adjustment to control for potential unobserved heterogeneity bias. These tests highlight the need to guard against placing too much weight on the precise size of individual country-year tax effort estimates – but overall, the tests exhibit a degree of stability that lends comfort to the robustness of the results, and to the broad story they portray.

Overall, the analytic approach of this paper is to look at the big picture, determining tax potential and effort via comparison with the experience of other countries. On the basis of international experience over three decades, it seeks to estimate what maximum level of tax revenue could feasibly be raised for a given economic structure, and thus allows an estimate of how much more tax a country may hope to raise given prevailing conditions.

The factors identified as being related to tax capacity and tax effort point towards broad areas for reform in countries wishing to raise additional revenue. However, studies like the present one present correlations, rather than causation – and do not explicitly address how an individual country should go about raising its tax take. For this, we look optimistically to the burgeoning literature on taxation in developing countries, which promises new insights into the drivers of tax capacity and ways to improve tax effort through administrative and policy reform.

Annex 1: Distribution of stochastic frontier parameters

The Annex provides descriptive statistics and kernel density estimate plots for estimated 'inefficiency' (i.e. lack of tax effort, u_{it}), stochastic error (v_{it}) and tax effort (ξ_{it}),from the headline specification (I) as reported in Table 2 in the main text.

Table A1.1: Descriptive statistics

	Mean	S.d.	Min	Max
u_{it}	0.50	0.27	0.03	2.03
v_{it}	0.00	0.05	-0.21	0.54
ξ_{it}	0.63	0.16	0.13	0.97

Figure A1.1: Distribution of estimated inefficiency (u_{it})

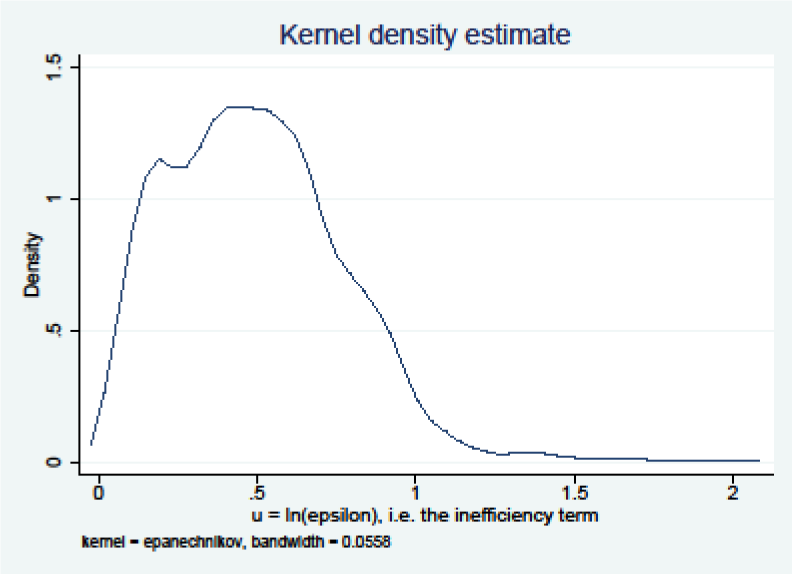


Figure A1.2: Distribution of estimated stochastic errors (v_{it})

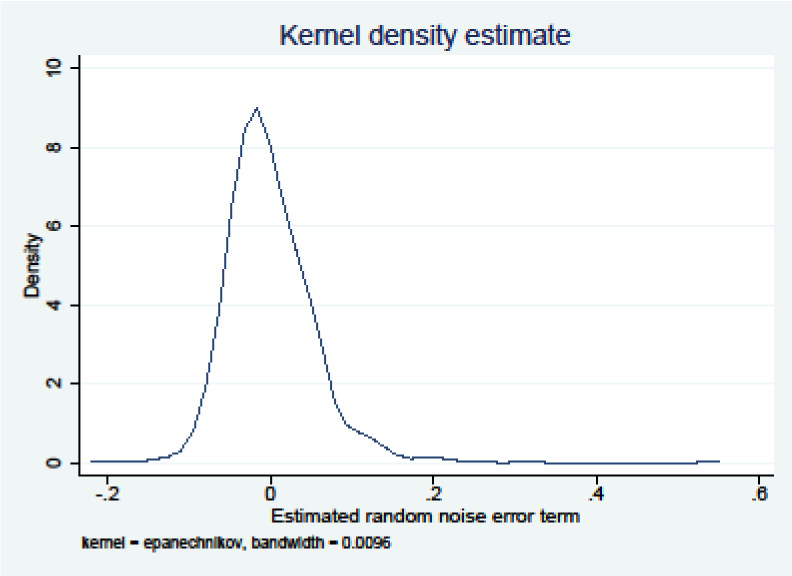
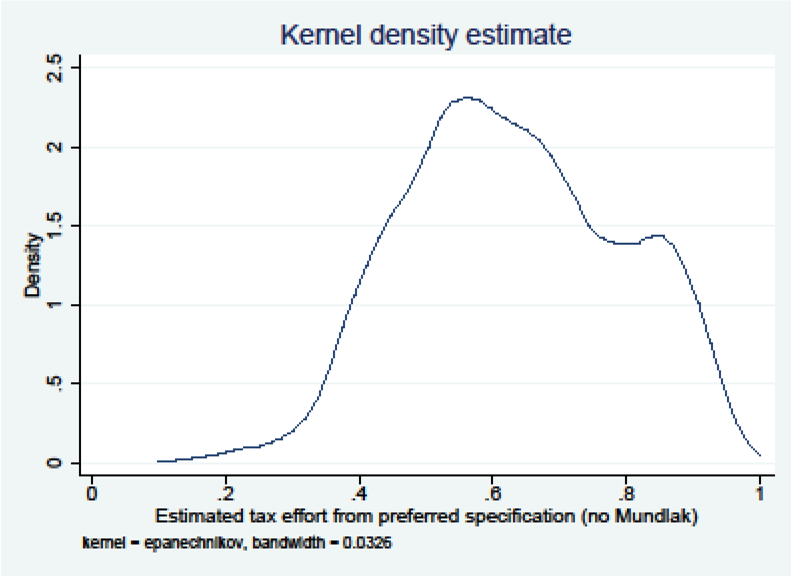


Figure A1.3: Distribution of estimated effort (ξ_{it})



Annex 2: Coefficient estimates for alternative specifications

	(I)			(II)			(III)			(IV)			(V)			(VI)			(VII)		
	Main specification			*Mundlak specification*			*Lead, 1996-2010*			*Corrupt in zp*			*Depratio in ze*			*Resource rich included*			*GDP revisions*		
	Coeffs.		p-value	Coeffs.		p-value	Coeffs.		p-value	Coeffs.		p-value	Coeffs.		p-value	Coeffs.		p-value	Coeffs.		p-value
Frontier																					
ln(mangva)	0.099	*	0.079	-0.068		0.277	0.058		0.310	0.070		0.424	0.102	*	0.081	0.094		0.104	0.129	**	0.033
ln(imports)	0.115	**	0.017	0.080		0.204	0.106	*	0.068	0.110	**	0.011	0.117	**	0.020	0.136	***	0.003	0.132	***	0.005
ln(educ)	0.399	***	0.000	0.175		0.115	0.577	***	0.000	0.409	***	0.000	0.358	***	0.000	0.321	***	0.000	0.492	***	0.000
cpi	-0.003	***	0.001	-0.002	*	0.062	0.001		0.455	-0.002	***	0.008	-0.003	***	0.003	-0.004	***	0.000	-0.003	***	0.001
depratio	0.004	*	0.094	-0.005	**	0.044	0.005	**	0.042	0.003		0.311				-0.001		0.705	0.003		0.244
gengov	0.235	***	0.002	0.236	***	0.003	0.175	*	0.056	0.239	**	0.011	0.227	***	0.004	0.280	***	0.001	0.220	***	0.007
corruption										0.062	***	0.001									
ln(mangva)-bar				0.198	**	0.023															
ln(imports)-bar				0.031		0.693															
ln(educ)-bar				0.302	*	0.069															
cpi-bar				-0.002		0.359															
depratio-bar				0.011	***	0.003															
constant	0.672		0.219	0.127		0.853	0.000		0.999	0.250		0.659	1.043	**	0.016	0.919	*	0.055	0.157		0.803
Inefficiency																					
laworder	-0.066	**	0.015	-0.079	***	0.009	-0.086	**	0.015	-0.146		0.480	-0.064	**	0.015	0.929		0.214	-0.060	*	0.078
corruption	-0.066	***	0.007	-0.063	**	0.013	-0.044		0.145				-0.064	***	0.009	-1.151		0.387	-0.083	**	0.011
democacc	-0.045	*	0.062	-0.038	*	0.093	-0.052	*	0.052	-0.132		0.630	-0.047	*	0.070	-2.612		0.202	-0.052	*	0.080
depratio													-0.003		0.249						
constant	1.199	***	0.000	1.203	***	0.000	1.234	***	0.000	0.977	**	0.044	1.365	***	0.000	1.066		0.483	1.224	***	0.000
σ_u	0.269	***	0.000	0.278	***	0.000	0.273	***	0.000	0.352		0.018	0.262		0.000	1.615	*	0.033	0.296	***	0.000
σ_v	0.115	***	0.000	0.097	***	0.000	0.080	***	0.000	0.190	***	0-003	0.125		0.040	0.226	***	0.000	0.122	***	0.002
$\lambda = \sigma_u / \sigma_v$	2.339	***	0.000	2.872	***	0.000	3.430	***	0.000	1.853	***	0-003	2.096		0.040	7.146	***	0.000	2.426	***	0.000
Log-likelihood	-104.9			-71.7			4.3			-87.8			-113.9			-810.4			-181.1		
Mean effort	0.63			0.64			0.65			0.81			0.64			0.77			0.64		
Min effort	0.13			0.14			0.11			0.21			0.15			0.03			0.11		
Max effort	0.97			0.97			0.98			0.96			0.97			0.96			0.96		
Correln with (I)	1.00			0.98			0.98			0.89			0.98			0.85			0.99		
Observations	1664			1664			1129			1664			1664			2445			1668		
Countries	85			85			85			85			85			127			85		
Time period	1984-2010			1984-2010			1996-2010			1984-2010			1984-2010			1984-2010			1984-2010		

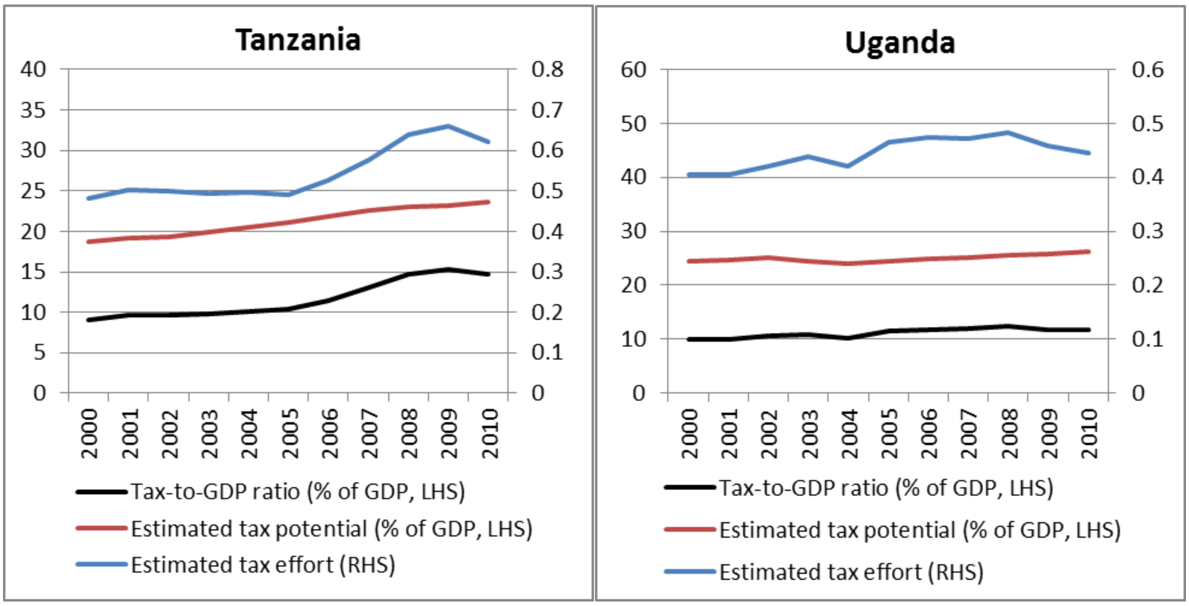
Annex 3: Tax capacity and effort over time: Tanzania and Uganda as examples

Estimates of tax capacity and time-varying effort can be used to shed additional light on the drivers behind trends in the tax-to-GDP. A comparison between Tanzania and Uganda's experiences over the last decade provides an interesting example.

Tanzania achieved a considerable increase in its tax-to-GDP ratio over the 2000's – rising around 5 percentage points, from below 10% to around 15% of GDP. The estimates in this paper (based on the headline specification (I))[22] suggest that this was the result of both an increase in Tanzania's tax potential and in its tax effort – with both these factors making an approximately equal contribution to the increase in tax collection.[23]

In contrast, Uganda's tax-to-GDP ratio increased only marginally over the decade. The estimates in this paper suggest that this reflects a broadly flat trend in Uganda's tax potential, and only a small increase in tax effort.

Figure A3.1: Tax-to-GDP ratio, and estimated tax capacity and effort, in Tanzania and Uganda, 2000-10



Note: Estimates are from specification (I).Tax to GDP figures are from the ICTD GRD, and excludes natural resource-related revenues.

[22] The trends are very similar if estimates from specification (II) are used instead. The one substantive difference is that under (II), slightly more of Tanzania's increased tax-to-GDP ratio over the period is attributed to improved effort, and slightly less to an increase in tax potential.

[23] Estimated tax capacity rose by around 5 percentage points over the period; if effort had remained at a little below 0.5, this would have translated into just below a 2.5 percentage point increase in tax revenues to GDP. The increase in effort of more than 0.1, however, contributed approximately an additional 2.5 percentage point increase in tax revenue.

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