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Understanding Countries' Tax Effort

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Understanding Countries' Tax Effort

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Abstract

This paper presents a model to determine the tax effort and tax capacity of 113 countries and the main variables on which they depend. The results and the model allow a clear determination of which countries are near their tax capacity and which are some way from it, and therefore, could increase their tax revenue. This paper also determines central factors on which tax capacity depends: the level of development, trade, education, inflation, income distribution, corruption, and the ease of tax collection.

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Contents

Acronyms

AVA	Value Added of Agriculture
COR	Corruption perception index of Transparency International
CPI	Consumer Price Index
FAD	Fiscal Affairs Department
GDP	Gross Domestic Product per capita
GNP	Gross National Product
HN	Half Normal Model
ML	Maximum likelihood
MREM	Mundlak REM
REM	Random Effects Model
TFE	True Fixed Effects Model
PE	Public Expenditure on Education
TN	Truncated Normal Model
TNH	Truncated Normal Heterogeneous Model
Tot	General government tax and social contributions revenue, percent of GDP
WDI	World Bank World Development Indicators

I. INTRODUCTION

1. **This paper estimates tax capacity—the maximum level of tax revenue that a country can achieve—and tax effort—the ratio between actual revenue and tax capacity for 113 countries from which data were available**. This paper uses the econometric model followed by Pessino and Fenochietto (2010) to build a 'stochastic tax frontier' for panel data. The results allow determining which countries are near their tax capacity and which are some way from it, and therefore could increase their tax revenue. An initial step before implementing new taxes or increasing the rate of the existing ones is to analyze how far actual revenue is from their tax capacity.

2. **Previous analysis (see Pessino and Fenochietto 2010) did not include countries in which revenue from natural resources represented more than 30 percent of total tax revenue**. To broaden the analysis, we include now 17 countries where revenue from natural resources represents more than 25 percent of total revenue (taxes plus revenue from natural resources excluding non tax-revenue and grants), and consider only non-resources tax revenue as percent of non-natural resources product. A sensitivity analysis was also carried out by running the model without a group of countries and by considering other values for certain variables. The analysis found that running the model with those changes does not have a significant impact on our results.

3. **This paper is organized as follows**. Section 2 presents a brief review of related literature. Section 3 develops the idea of stochastic tax frontier, the model utilized in this research. Section 4 explains the estimation strategy, including that for natural-resource dependent economies. Section 5 compares and analyses the most significant results. Section 6 discusses 'unobserved' heterogeneity and fixed effects under the stochastic tax frontier. Finally, Section 7 includes the main conclusions.

II. BRIEF REVIEW OF RELATED LITERATURE

4. **Only a few papers study tax effort**. Most of them employ cross-section empirical methods and hence ignore the variation over time. Some of these papers have aimed at identifying the determinants of the level of taxation, including per capita GDP, the composition of the economy, the degree of openness of an economy, the ratio of public debt to GDP, the level of education of a country, and institutional factors such as corruption and governance.

5. **The level of per capita income—a proxy for the degree of overall economic development—is expected to be positively correlated with tax revenues**, as is the extent of trade openness. The composition of the economy also matters to tax revenue performance because certain sectors are easier to tax than others; large industrial companies are usually easier to control than the agricultural sector, especially if the agriculture sector is dominated by a large number of small farmers.

6. **Lotz and Mors (1967) published one of the first articles to study the international tax ratio,** using as explanatory variables per capita Gross National Product (GNP) and trade (represented by the ratio of exports plus imports to total GNP). Gupta (2007) used regression analysis in a dynamic panel data model and also found that some structural factors, such as per capita GDP, the share of agriculture in GDP, trade openness, and foreign aid, significantly affect tax revenues. Davoodi and Grigorian (2007) on extended the conventional determinants of tax revenue potential to include measures of institutional quality and informal economic activity in a panel data framework and showed that institutional improvements as well as policy initiatives designed to reduce the size of informal economic activity are important in raising tax revenue performance. Alfirman (2003) analyzed tax capacity in only one country (Indonesia) to conclude that local governments were far from their tax capacity and could increase their tax revenue.

7. **Keen and Simone (2004) found that revenue may increase when trade liberalization comes** with an improvement in customs procedures; on many occasions the reduction of tariff and export taxes came with compensatory measures and revenue did not go down, at least abruptly. Baunsgaard and Keen (2010), using panel date for 117 countries, corroborated this argument finding (a) a positive and significant relationship between trade and revenue for high and middle income countries; but (b) a weaker relationship for low income countries.

8. **Pessino and Fenochietto (2010) corroborated previous analysis in finding a positive and significant relationship between tax capacity and the level of development, trade, and education**. The study also demonstrated the negative relationship between tax capacity and inflation, income distribution, the difficulty of tax collection, and corruption. The main innovation of this study was the use of a tax stochastic frontier model influencing time-varying inefficiency with two disturbance terms: one that allows distinguishing the existence of technical inefficiencies and the other the standard mean zero statistical error term.

III. STOCHASTIC TAX FRONTIER

9. **To estimate countries tax efforts, this paper employs the stochastic frontier tax analysis** using panel data and taking into account country-specific demographic, economic, and institutional characteristics that may change over time. We use a relative method with predictions of tax effort using a comparative analysis of data on these countries. That is to say, the method determines if a country's tax capacity is high or low in comparison with tax capacity of the other countries. The stochastic frontier tax function is an extension of the familiar regression model, based on the theoretical premise that a production function represents the maximum output (level of tax revenue) that a country can achieve considering a set of inputs (GDP per capita, inflation, level of education, and so on). The stochastic frontier model of Aigner, Lovell, and Schmidt (1977) is the standard econometric platform for this analysis (Box 1). Several researches and studies have used and reformulated this

model; Greene (2008) includes a revision of these papers and Pessino and Fenochietto (2010) a detailed description of the stochastic tax frontier model used in the current analysis.

10. **Tax frontier development is similar to production frontier development, with two main differences**. First, in the latter, the output is produced by specific inputs—labor, capital, and land. As Alfirman (2003) expresses, in this case the determinants of output are very clear. However, the underlying relationship is less clear in estimating the tax frontier. It is clear that per capita GDP and some related economic indicators, such as the level of education, are determinants (inputs) of revenue collection; however, it is not so clear that inflation and GINI coefficient are determinants (inputs), an issue that we will consider later.

Box 1. Stochastic Frontier Models

The stochastic frontier model of Aigner, Lovell, and Schmidt (1977) is the standard econometric platform for the analysis carried out in this paper. A panel version of this model can be written as

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + v_{it} - u_{it} \qquad [1]$$

Where,

y_{it} represents the log tax revenue to GDP ratio for country *i* at time *t*;

$\boldsymbol{x}_{it}$ is the vector that represents variables affecting tax revenue for country *i* at time *t*;

$\boldsymbol{\beta}$ is a vector of unknown parameters,

u_{it}, represents the inefficiency, the "failure" to produce the relative maximum level of tax collection or production. It is a non-negative random variable associated with country-specific factors which contribute to country *i* not attaining its tax capacity at time *t*.

v_{it} is the statistical noise (the disturbance or error term**.** It is a random (stochastic) variable which represents the independent variables that explain the dependent one but are not explicitly taken into account as well as measurement errors and incorrect functional form; *vit* can be positive or negative and so the stochastic frontier outputs vary on the deterministic part of the model.

It is usually assumed that:

- v_{it} has a symmetric distribution, such as the normal distribution,
- v_i and u_i are statistically independent of each other.

u_{it}, > 0, but v_{it} may take any value.

The analysis aims to predict and measure inefficiency effects. To do so, we use the tax effort, defined as the ratio between actual tax revenue and the corresponding stochastic frontier tax revenue (tax capacity). This measure of tax effort has a value between zero and one.

$$TE_{it} = \frac{\tau_{\text{it}}}{\exp(\alpha + \boldsymbol{\beta}^{\mathrm{T}}\mathbf{x}_{it} + v_{it})} = \frac{\exp(\alpha + \boldsymbol{\beta}^{\mathrm{T}}\mathbf{x}_{it} + v_{it} - u_{it})}{\exp(\alpha + \boldsymbol{\beta}^{\mathrm{T}}\mathbf{x}_{it} + v_{it})} = \exp(-u_{it}) \qquad [2]$$

11. **A second difference lies in the interpretation of the results**. In production frontier analysis, the difference between current production and the frontier represents the level of inefficiency, something that firms do not accomplish. In the case of the tax frontier, the difference between actual revenue and tax capacity includes the existence of technical

inefficiencies as well as policy issues (differences in tax legislation, for instance, in the level of tax rates): something that countries can modify.[2]

12. **While we use stochastic frontier approach to estimate countries' tax effort, most of the empirical literature has used OLS-based assessments**. The main conceptual difference between the stochastic frontier approach (used in this paper) and the Ordinary Least Squares (OLS) methodology (typically utilized in the empirical literature) is that the OLS approach assumes that all countries are technically efficient while the stochastic frontier approach includes a variable for different levels of inefficiency represented by the positive term u_{it} in equation 1. In a variant of the model, this is related to an observable variable which in this context is corruption (see Section V).

IV. Estimation Strategy

13. **We employ the stochastic frontier tax analysis using panel data to estimate tax effort for 113 countries** (first for 96 non-natural resource dependent countries, and then with the addition of 17 resource-dependent economies). Methods for estimating stochastic frontiers with panel data are expanding rapidly. These methods are expected to provide "better" estimates of efficiency than those that can be obtained from a single cross section, which serves to investigate changes in technical efficiencies over time (as well as underlying tax capacity). If observations on u_{it} and v_{it} are independent over time as well as across countries, then the panel nature of the data set is irrelevant; in fact, cross-section frontier models will apply to the pooled data set, such as the normal-half normal model of Aigner, Lovell and Schmidt (1977) that can be obtained through maximum likelihood estimates. The truncated normal frontier model is due to Stevenson (1980), while the gamma model is due to Greene (1990). The log-likelihood functions for these different models can be found in Kumbhakar and Lovell (2000). But, if one is willing to make further assumptions about the nature of the inefficiency, a number of new possibilities arise. Different structures are commonly classified according to whether they are time-invariant or time-varying.

14. **Time-invariant inefficiency models are somewhat restrictive**; one of the models that allows for time-varying technical inefficiency is the Battese and Coelli (1992) parametrization of time effects (time-varying decay model), where the inefficiency term is modeled as a truncated-normal random variable multiplied by a specific function of time:

[2] The model used in this paper does not allow determining what part of the 'gap' is due to inefficiency (say, evasion) and what part is due to policy issues because of the lack of data to represent both causes. For instance, tax rates as explanatory variables of policy issues must be analyzed with tax bases (regime of depreciation, exemptions, and deductions); a country can have a high CIT or VAT rate and a low level of revenue because of the high level of exemptions and deductions. For this reason, only effective rates could be used as explanatory variables. However, effective tax rates are only available for a very small group of developed counties and for a few years. The same happens with inefficiencies: we do not have a variable to represent inefficiencies in collection (of tax administrations): even the level of evasion is only available for a few countries, a few years, and a few taxes (sometimes the VAT, other times the PIT).

$$u_{it} = u_i * \exp[\eta * (t-T)]$$

where T corresponds to the last time period in each panel, η is the decay parameter to be estimated, and u_i are assumed to have a N(μ, σ) distribution truncated at 0.The idiosyncratic error term is assumed to have a normal distribution. The only panel-specific effect is the random inefficiency term.

15. **Battese and Coelli (1992) propose estimating their models in a random effects framework using the method of maximum likelihood**. This often allows us to disentangle the effects of inefficiency and technological changes. The prediction of the technical efficiencies is based on its conditional expectation given the observable value of (v_{it} -u_{it}) and it is computed by the residual using the formula provided by Jondrow and others (1982). Coelli and others (2005) suggest that the choice of a more general distribution, such as the truncated-normal distribution, is usually preferable. However, this is ultimately an empirical issue, and we estimate below this specification assuming first the half normal and then the truncated normal distribution for u_i.[3]

A. 'Observed' Heterogeneity

16. **In the development of the frontier model, an important question concerns how to introduce observed heterogeneity into the specification**. This paper assumes that there are covariates observed by the econometrician, which are not the direct inputs into tax collection that affect it from the outside, as environmental variables. For example, in the tax capacity case, inflation might impact tax collection and the inefficiency term; countries' ability to collect taxes is often influenced by exogenous variables that characterize the environment in which tax collection takes place.

17. **Some authors (e.g., Pitt and Lee, 1981) explored the relationship between environmental variables and predicted technical efficiencies using a two-stage approach.** The first stage involves estimating a conventional frontier model with environmental variables omitted. Firm-specific technical efficiencies are then predicted. The second stage involves regressing these predicted technical efficiencies on the environmental variables, usually variables that are observable at the time decisions are made (e.g., degree of government regulation, corruption, and inflation). Failure to include environmental variables in the first stage leads to biased estimators of the parameters of the deterministic part of the production frontier, and also to biased predictors of technical efficiency.[4]

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[3] Half normal and Truncated Normal models differ on the distributional assumption of the *'u'* term (the *'v'* term does not change between the two models). While the half normal distribution is a truncated version of a normal random having zero mean and variance σ^2_u, the Truncated Normal model relaxes an implicit restriction in the normal-half normal model assuming that the mean of the underlying variable is μ.

[4] For more details, see Caudill, Ford, and Gropper (1995); and Wang and Schmidt (2002).

18. **A second method for dealing with observable environmental variables is to allow them to directly influence the stochastic component of the production frontier**. It is up to the model builder to resolve at the outset whether the exogenous factors are part of the technology heterogeneity or whether they are elements of the inefficiency distribution. Battese and Coelli (1992, 1995) proposed a series of models that capture heterogeneity and that can be collected in the general form:

$$y_{it} = \beta' x_{it} + v_{it} - u_{it} \quad [3]$$

$$u_{it} = g(z\, u_{it})\, |U_i| \text{ where } U_i \sim N[\mu_i, \sigma_u^2],\ \mu_i = \mu_0 + \mu_1' w_i \quad [4]$$

Where,

w_i are variables that influence mean inefficiency;

y is the observed outcome (goal attainment); $\beta'x + v$ = the optimal frontier goal (e.g., maximal production output or minimum cost) pursued by the individual; $\beta'x$ = the deterministic part of the frontier; and $v \sim N[0,\sigma v^2]$ is the stochastic part. The two parts together constitute the 'stochastic frontier. The amount by which the observed individual fails to reach the optimum (the frontier) is u, where $u = |U|$ and $U \sim N[0,\sigma u2]$. In this context, u is the 'inefficiency.'

19. **First, this paper estimates countries' tax effort and capacity by using Battese and Coelli's original formulation without heterogeneity with the base specification $g(zit) = \exp[-\eta(t - T)]$** (columns I and II of Table 3). Second, we estimate a more general formulation (column III of Table 3), with $g(z_{it}) = \exp(\eta' z_{it})$ and the mean of the truncated normal depending on observable covariates $\mu_i = \mu_0 + \mu_1' w_i$ (notice that z variables influence time-varying inefficiency and w_i variables mean time-invariant inefficiency).

B. Variables and Data

20. **This paper uses a panel dataset for 113 countries covering the period 1991–2012** (although for some countries data was not available for all these years) and explores the relationship in a reduced form written as follows (Table 1 shows descriptive statistics and Appendix 1 data source):

$$Ltot = (lgd, NTR, TR, AVA, PE, GINI; CPI; lcor; Oil, Gov)$$
$$= f(LGD_t, TR_t, AVA_t, PE_t, GINI_t; CPI_t; LCOR_t; OIL_t; GOV_t)$$

Where

- *Ltot* denotes the log of the sum of tax and pension contributions revenue collected by central and sub national governments as percent of GDP;

- *Lgd* is the log GDP per capita (purchasing power parity constant 2005). The first and most common used explanatory variable is the level of development, based on the hypothesis that a high level of development brings more demand for public expenditure

(Tanzi 1987) and a higher level of tax capacity to pay for the higher expenditure. Therefore, the expected sign for the coefficient of this variable is positive;

- *Lgd*^{2} is lgd squared, which is included as an explanatory variable to capture the presumably non-linear elasticity between tax revenue and per-capita GDP; consequently, the expected sign of this variable is negative;

- *TR* is trade, imports plus exports as a percent of GDP, which reflects the degree of openness of an economy. In the medium term, it is expected that collection increases for more revenue from more economic activity (as previous studies found for high and middle income countries; Baunsgaard and Keen, 2010); therefore, the expected sign for the coefficient of this variable is positive.

Table 1. Descriptive Statistics

Variable	Mean	Std.Dev.	Minimum	Maximum
TOT	25.0	11.3	4.4	51.2
GDP	14232.7	13649.5	372.6	74113.9
GINI	38.0	9.0	24.7	67.4
COR	3.2	1.4	0.5	6.0
TR	82.4	51.4	13.2	460.5
AVA	12.7	12.6	0.1	65.1
CPI	6.8	11.4	-8.2	183.3
PE	4.5	1.5	1.3	9.5
GOV	0.6	0.5	0.0	1.0
lgd	8.9	1.3	5.9	11.2
lcor	1.1	0.5	-0.7	1.8
ltot	3.1	0.5	1.5	3.9
lgd2	81.1	22.7	35.1	125.7

- *AVA* is the value added of the agriculture sector as a percent of GDP. We use this variable to represent how easy (or not) it is to collect taxes. Some countries exempt agricultural products from VAT, and/or, agricultural producers from income tax. Moreover, this sector is very difficult to control particularly when it is composed of small producers. Therefore, the expected sign of this variable is negative

- *PE* is the total public expenditure on education as percent of GDP and represents the level of education. More educated people can understand better how and why it is necessary to pay taxes. With a higher level of education compliance will be higher. Therefore, it is expected a positive relationship between this variable and the level of tax effort.

- *GINI* coefficient measures the extent to which the distribution of income among individuals deviates from the equal distribution. A better income distribution should facilitate collection as well as voluntary taxpayer compliance (thus, the expected sign is positive);

- *CPI* is the percentage change of consumer price index. As a whole, countries that obtain resources from printing money have negative efficiency for collecting taxes. Therefore, the expected sign for this variable is negative;

- *Lcor* is the log of the corruption perception index; this paper uses this variable to represent inefficiencies in tax collection and, therefore, the expected sign is negative.

V. Empirical Findings

21. **First, we ran three different specifications for 96 countries pooled from 1991 to 2012 to obtain baseline specifications**. General government revenue was only available for 54 countries. For the remaining 42 countries, we included central government revenue (we used the dummy variable *Gov* to distinguish these two groups of countries). Table 2 shows the maximum likelihood estimation of the parameters of the stochastic frontier tax function for these specifications: the first assumes a half normal model (HN); the second a truncated normal model (TN); and the third a truncated normal with observed heterogeneity (TNH), such that corruption shifts mean inefficiency and inflation the decay in inefficiency.

Table 2. Parameters of the Stochastic Frontier Tax Function, Maximum Likelihood Method: Main Statistics Indicators

Variable	C I = Battese Coelli - Half Normal		C II = Battese Coelli - Truncated Normal		C III = Truncated Normal Heterogeneous in Mean and Decay Inefficiency	
	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error
	Frontier Model					
Constant	-1.38619***	0.312	-1.43757***	0.324	-1.98777***	0.295
LGD	1.0177***	0.069	1.03354***	0.072	1.15868***	0.070
AVA	-.00207***	0.000	-.00213***	0.000	-.00364***	0.001
PE	.03000***	0.002	.03003***	0.002	.03113***	0.002
TR	.00059***	0.000	.00062***	0.000	.00111***	0.000
GINI	-.00717***	0.001	-.00726***	0.001	-.00857***	0.001
GOV	.25867***	0.022	.25498***	0.023	.16669***	0.042
LGD^2	-.05229***	0.004	-.05321***	0.004	-.05904***	0.004
	Inefficiency					
Constant			.26038***	0.097	.66064***	0.120
Lcor					-.31809**	0.126
Lambda 1/	4.2025***	0.023	3.00723***	0.045	2.75871***	0.041
Sigma (u) 1/	.41954***	0.008	.30019***	0.004	.27891***	0.003
Eta 2/	.01074***	0.001	.01030***	0.001		
CPI					0.0010	0.001
Log-likelihood	1097.36		1123.02		1110.2	

***, **, * = significance 1%, 5%, 10% level.

1/ Parameters for compound error.

2/ Parameter for time varying inefficiency.

22. **All coefficients (except that for CPI) are statistically significant (different from zero) at 5 percent and have the expected signs**. Moreover, in the first and second models (HN and TN) the coefficients are quite similar (they included the same explanatory variables). In the three models, λi (σ_{ui}/σ_{vi}) the lambda parameter is quite large, larger than 2.8 and statistically significant, implying a large inefficiency component in the model.[5] The TNH model, where mean inefficiency depends on the level of corruption and the decay on the level of inflation, also maintains the significance, size and sign of the two previous models regarding the inputs to tax effort and capacity. The level of corruption, which is measured from 0.5 (high) to 6 (low), has a negative sign, meaning that a high level of this variable, that is less corruption, is associated with a lower level of inefficiency. CPI (inflation) also increases inefficiency; it has a positive sign, meaning that a high level of this variable, which is more inflation, is associated with a higher level of inefficiency.

23. **As expected, countries with a higher level of GDP per capita and public expenditure on education are near their tax capacity** (have a higher tax effort.) As also expected, the size of the agricultural sector, GINI index, and corruption are also significant variables but with an inverse relationship with tax capacity and tax effort. Most of the results are consistent with previous studies. For instance, the significance of per capita GDP is consistent, among others, with Lotz and Mors (1967) and Tanzi (1987). Tanzi and Davoodi (1997) and Davoodi and Grigorian (2007) had found that countries' institutional quality has a significant relationship with tax revenue as well as in this study corruption proxy for this quality.

A. Countries' Tax Effort

24. **Using the estimates of Table 2 we predict tax effort based on the Jondrow and others (1982) formula given the observable value of v_{it} -u_{it}.** Table 3, where countries are ranked in alphabetical order, shows countries' tax effort under the HN, the TN, and the TNH (columns I to III) and tax capacity under the TNH (column IV). Countries' tax effort under these three models is similar.

[5] *Lambda* ($\sigma u_i/\sigma v_i$) provides information of the relative contribution of v_{it} and u_{it} to the total error term and shows in this case that u_{it} or the inefficiency term is relatively large.

Table 3. Countries' Tax Capacity and Tax Effort

	Country	Year	Total Revenue /1	Percapita GDP, PPP 2005	Tax Effort			Tax Cap./3
					Half Normal	Truncated Normal	TNH /2	TNH /2
					I	II	III	IV
1	Albania	2011	22.8	7861.1	0.74	0.73	0.68	33.7
2	Argentina	2011	34.7	15501.4	0.67	0.67	0.66	52.2
3	Armenia	2011	16.1	5112.4	0.46	0.45	0.45	36.0
4	Australia	2011	26.1	35052.5	0.74	0.73	0.70	37.1
5	Austria	2011	42.1	36353.0	0.98	0.97	0.93	45.2
6	Bangladesh	2012	10.4	1622.9	0.43	0.43	0.41	25.4
7	Belarus	2011	39.0	13191.2	0.98	0.97	0.94	41.3
8	Belgium	2011	44.0	33126.5	0.95	0.94	0.87	50.6
9	Brazil	2011	29.7	10278.4	0.79	0.79	0.81	36.6
10	Bulgaria	2011	25.8	11799.5	0.70	0.69	0.65	39.7
11	BurkinaFaso	2012	14.1	1304.0	0.66	0.66	0.66	21.4
12	Canada	2011	31.4	35716.0	0.80	0.79	0.76	41.5
13	Chile	2011	19.5	15250.8	0.67	0.67	0.61	32.0
14	China,P.R.M.	2011	18.9	7417.9	0.49	0.48	0.48	39.1
15	Colombia	2011	19.0	8861.1	0.55	0.55	0.57	33.4
16	CostaRica	2012	20.0	11155.5	0.59	0.58	0.52	38.6
17	Croatia	2011	32.6	16162.2	0.82	0.81	0.78	41.8
18	Cyprus	2011	35.8	26045.4	0.70	0.69	0.65	55.3
19	CzechRepublic	2011	35.5	23966.6	0.79	0.78	0.72	49.3
20	Denmark	2010	48.2	32231.5	0.97	0.96	0.92	52.6
21	DominicanRepublic	2011	13.2	8650.6	0.53	0.52	0.46	28.4
22	Egypt	2011	16.7	5546.5	0.47	0.47	0.46	36.2
23	ElSalvador	2011	13.4	6031.9	0.49	0.48	0.43	30.9
24	Estonia	2011	32.8	17885.4	0.72	0.71	0.66	49.9
25	Ethiopia	2011	11.3	979.2	0.62	0.62	0.63	17.8
26	Finland	2011	42.8	32253.6	0.97	0.96	0.93	46.2
27	France	2012	42.6	29819.1	0.98	0.97	0.96	44.6
28	Gambia,The	2011	12.3	1872.8	0.60	0.59	0.58	21.3
29	Germany	2011	39.5	34436.8	0.84	0.83	0.79	49.9
30	Ghana	2011	16.9	1652.3	0.53	0.53	0.52	32.7
31	Greece	2011	33.4	22558.0	0.82	0.81	0.79	42.4
32	Guatemala	2011	10.6	4351.4	0.49	0.48	0.45	23.7
33	Guinea	2011	14.8	992.8	0.77	0.76	0.75	19.6
34	Guinea-Bissau	2011	9.0	1097.5	0.33	0.32	0.32	28.1
35	Guyana	2012	22.4	2929.7	0.81	0.79	0.72	30.9
36	Honduras	2011	18.7	3573.7	0.72	0.71	0.66	28.5
37	Hungary	2011	35.9	17295.4	0.87	0.86	0.81	44.5
38	Iceland	2011	33.7	33515.6	0.77	0.76	0.72	46.7
39	India	2011	15.8	3203.0	0.53	0.53	0.53	29.6
40	Indonesia	2011	11.9	4094.1	0.47	0.46	0.42	28.0
41	Ireland	2011	27.7	36144.7	0.68	0.67	0.61	45.2
42	Israel	2011	29.6	26720.0	0.94	0.93	0.83	35.6
43	Italy	2011	42.2	27069.2	0.99	0.99	0.98	43.1
44	Jamaica	2011	23.3	7073.6	0.80	0.78	0.71	33.0
45	Japan	2011	28.8	30660.4	0.68	0.67	0.64	45.2
46	Jordan	2011	14.9	5268.6	0.66	0.65	0.56	26.7
47	Kenya	2011	20.7	1509.6	0.76	0.75	0.76	27.4
48	Korea	2011	18.8	27541.3	0.53	0.52	0.47	39.7

1/ Tax and social contributions as percent of GDP.

2/ Truncated Normal Heterogeneous in Mean and Decay Inefficiency.

3/ Tax capacity (percent of GDP): tax and social contributions divided tax effort.

	Country	Year	Total Revenue /1	Percapita GDP, PPP 2005	Tax Effort: Half Normal	Tax Effort: Truncated Normal	Tax Effort: TNH /2	Tax Cap./3: THN /2
					I	II	III	IV
49	KyrgyzRepublic	2011	24.3	2118.5	0.81	0.80	0.76	31.9
50	Latvia	2011	27.7	13773.4	0.65	0.64	0.61	45.4
51	Lebanon	2012	16.8	12591.8	0.56	0.55	0.49	34.2
52	Lithuania	2011	27.3	17839.3	0.66	0.65	0.61	44.6
53	Luxembourg	2011	33.7	68458.7	0.86	0.85	0.73	46.0
54	Madagascar	2012	10.8	843.2	0.63	0.62	0.63	17.2
55	Malawi	2012	23.3	777.2	0.96	0.95	0.97	24.0
56	Mali	2012	14.4	1046.7	0.74	0.73	0.74	19.5
57	Moldova	2010	31.0	2793.5	0.79	0.78	0.79	39.4
58	Mongolia	2010	31.8	3620.2	0.82	0.81	0.76	41.8
59	Morocco	2012	24.3	4475.2	0.84	0.83	0.78	31.4
60	Mozambique	2011	18.2	861.3	0.81	0.80	0.84	21.7
61	Namibia	2011	25.3	5986.4	0.96	0.95	0.91	27.7
62	Netherlands	2011	37.8	37250.7	0.87	0.86	0.80	47.3
63	NewZealand	2011	31.7	24429.0	0.81	0.80	0.78	40.9
64	Nicaragua	2011	21.7	2579.3	0.81	0.80	0.76	28.7
65	Niger	2011	13.5	642.1	0.67	0.67	0.70	19.3
66	Norway	2010	43.0	46773.9	0.92	0.92	0.87	49.2
67	Pakistan	2011	9.9	2423.7	0.48	0.48	0.44	22.3
68	Panama	2012	16.9	14320.2	0.55	0.54	0.46	36.3
69	Paraguay	2011	15.2	4752.3	0.55	0.54	0.50	30.1
70	Peru	2011	17.2	9049.3	0.64	0.63	0.58	29.5
71	Philippines	2011	12.2	3630.9	0.58	0.58	0.52	23.7
72	Poland	2011	33.7	18087.4	0.79	0.78	0.76	44.5
73	Portugal	2011	32.4	21317.3	0.75	0.74	0.71	45.6
74	Romania	2011	28.2	10905.4	0.68	0.67	0.66	42.9
75	Senegal	2011	19.4	1737.1	0.76	0.75	0.72	26.8
76	SerbiaMontenegro	2011	34.1	9830.2	0.82	0.81	0.79	43.4
77	Singapore	2011	14.1	53591.1	0.43	0.42	0.30	46.8
78	SlovakRepublic	2011	28.9	20756.7	0.72	0.71	0.64	45.0
79	Slovenia	2011	35.9	24967.5	0.78	0.77	0.72	49.8
80	SouthAfrica	2011	27.8	9678.2	0.75	0.75	0.76	36.6
81	Spain	2011	32.7	26917.1	0.82	0.81	0.79	41.7
82	SriLanka	2011	12.5	4929.0	0.64	0.63	0.57	21.9
83	Sweden	2011	44.3	35170.1	0.98	0.98	0.94	47.0
84	Switzerland	2011	28.5	39384.7	0.70	0.69	0.64	44.5
85	Tanzania	2011	15.3	1334.1	0.58	0.57	0.57	27.0
86	Thailand	2011	17.7	7633.0	0.50	0.50	0.48	36.7
87	Togo	2011	15.9	926.6	0.76	0.75	0.76	21.0
88	Tunisia	2011	25.5	8257.7	0.79	0.78	0.70	36.2
89	Turkey	2011	26.7	13466.3	0.67	0.66	0.66	40.3
90	Uganda	2011	12.4	1187.7	0.64	0.63	0.64	19.5
91	Ukraine	2011	38.2	6365.2	0.81	0.80	0.78	48.9
92	UnitedKingdom	2011	35.8	32862.8	0.86	0.85	0.82	43.6
93	UnitedStates	2011	24.5	42486.0	0.71	0.71	0.68	36.0
94	Uruguay	2011	26.2	13314.9	0.92	0.90	0.84	31.1
95	Vietnam	2011	24.1	3012.7	0.66	0.65	0.65	36.8
96	Zambia	2012	16.6	1475.5	0.98	0.97	0.98	16.9

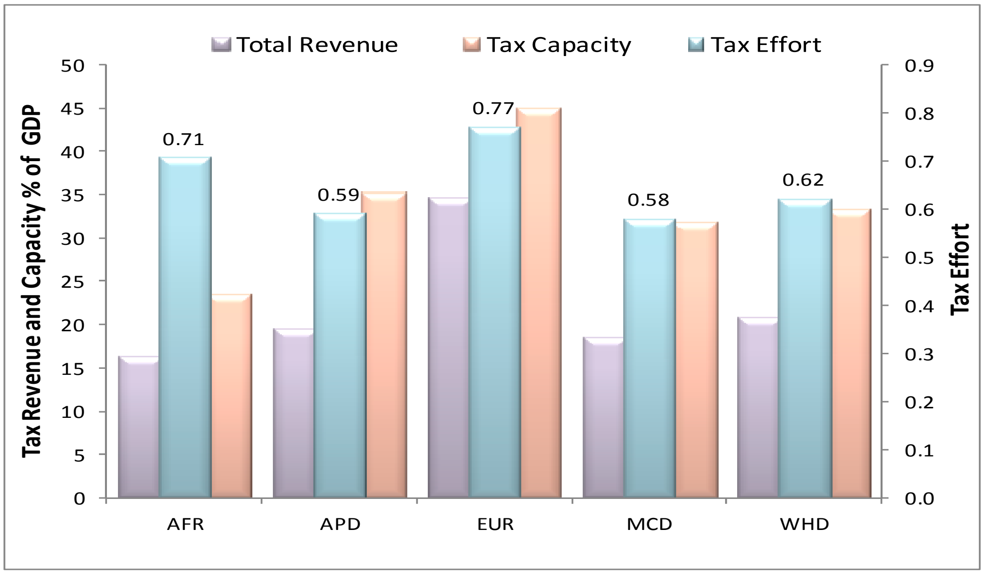
1/ Tax and social contributions as percent of GDP.

2/ Truncated Normal Heterogeneous in Mean and Decay Inefficiency.

3/ Tax capacity (percent of GDP): tax and social contributions divided tax effort.

26. **A very large level of exemptions** (in some cases established by constitutions, such as the case of Guatemala 0.46 under the TNH) **and low tax rates** (Panama (0.47) and Paraguay (0.51)[6]) **explain, in part, why some developing countries have a low level of tax effort**. In these cases, public choice explains at least a share of the distance between the actual revenue and the maximum level of revenue that these countries could achieve.

Figure 1. Countries' Tax Effort by Region



27. **The empirical analysis shows that most European countries with a high level of development are near their tax capacity** (that is, have a higher tax effort, Figure 1). This is particularly the case of Austria, Belgium, Denmark, Finland, France, Italy, and Sweden (with tax efforts higher than 90 percent). It is possibly here that the demand for public expenditure is a crucial determinant of the higher level of tax revenue (public choice issue). Given how near these countries are to their tax capacity, they also appear to be efficient in collecting taxes with low levels of evasion. As expected, the analysis also shows that tax effort is higher among developed countries (Table 4).

28. **Singapore (0.33 of tax effort under the THN model); Korea (0.49); and Japan (0.53) are exceptions,** with a very high level of per capita GDP, but operating far from their tax capacity. This is in part also explained by a matter of public choice. VAT rates in these countries are among the lowest in the world: between 3 percent (1994) and 7 percent (2011) in Singapore; 5 percent in Japan in 2011; and 10 percent in Korea in 2011. These three

[6] VAT standard rate is 7 percent in Panama and 10 percent in Paraguay, among the lowest in the world. In Paraguay, tax effort would be lower still if the country refunded the tax collected on the re-export trade (people who cross the border from neighbor countries to make purchases).

countries and Indonesia (where tax effort is 0.43) contribute to the fact that the Asia and Pacific region has the lowest level of tax effort (Figure 1).

Table 4. Countries' Tax Effort by Level of Development

Countries	Income		Average			
	Minimum	Maximum	Total Revenue	Per-capita GDP, PPP 2005	Tax Effort	Tax Capacity
Low Income	642.1	4752.3	17.0	2169.4	0.65	26.0
Middle Income	4929.0	17885.4	24.1	10554.1	0.64	37.3
High Income	18087.4	68458.7	34.2	32763.3	0.76	45.1

29. **Exceptions consisting of countries with low level of per capita GDP but operating near their tax capacity, include among others, Mali, Namibia, Senegal, and Zambia**. Various reasons could explain why these countries have this high level of collection and a low per capita GDP, including the recent increase of mining activity (but not enough to generate revenue from this sector higher than 25 percent) performed by large companies (easier to control than small producers). This group of countries contributes to explain why Africa is the region with the second highest level of tax effort.[7]

B. Tax Effort in Natural Resource Economies

30. **Natural resource dependent countries have very different economic structures that affect the comparison among them and with other countries**. When the natural resource sector is significantly large (for instance, more than 40 percent of total GDP), revenue from this sector (as a percent of total GDP) is usually very high, representing 72.5 percent of this aggregate in the case of Libya (2012) and 52.7 percent in Kuwait (2011). The high level of oil revenue as a percent of total GDP makes it very difficult to compare their tax capacities with those of other countries without natural resources. Moreover, the total tax capacity of natural-resource dependent countries usually depends on the level of reserves and oil production, while tax capacity in countries without natural resources depends on different factors (such per capita GDP, GINI, and the other variables that are described in this paper).

31. **Countries with a high level of revenue from natural resources frequently do not have well-developed tax structures and/or administrations.** A common characteristic for these countries is a very low level of tax revenue. The extent of natural resources dependency is different among these countries as well as the composition of their GDP. In previous

[7] The relative high level of tax effort in other developing countries can be explained by other factors. For instance, in the case of the Gambia (0.59) and the Kyrgyz Republic (0.78), by the tax collected on re-export trade (people who cross the border from neighboring countries to make purchases).

estimates, we did not include countries in which revenue from natural resources represented more than 30 percent of total tax revenue (see Pessino and Fenochietto, 2010). Now we try to broaden our analysis by adding a group of 17 countries where revenue from natural resources represents more than 25 percent of tax plus natural resource revenue without including other non-tax revenue and grants (on average in the period 2000–11)[8]. We created a dummy variable (oil) to distinguish countries in which revenue from natural resources (hydrocarbons and/or minerals) represents more than 25 percent of this revenue. For these countries, we considered only tax revenue (without revenue that comes from the oil and mining sectors) as a percent of non-natural resources product.

32. **As with the sample of 96 non-natural resource dependent countries, we ran first the HN, TN, and TNH models**. All coefficients (except those for CPI and corruption) are statistically significant (different from zero) at 10 percent (at least) and have the expected signs (Table 5). Coefficients are quite similar in the three models and λi, th*e lambda* parameter, is quite large, larger than 6.4 and statistically significant. Under this sample of countries (which includes natural resource dependent economies), the value of *lambda* is significantly larger than that of the first group of non-natural resource dependent countries, implying a larger inefficiency component in the model. In other words, the model shows that inefficiency in establishing or collecting taxes is higher when the sample includes natural resource dependent economies.

33. **The group of 17 natural resource countries included now in this analysis is very heterogeneous.** While some countries (such as Iran and Mexico) have developed, at least somewhat, their non-natural resource GDP and tax revenue, others (such as Kuwait and Libya) have not. Therefore, while some natural resource dependent countries have a very low tax effort (reaching only 0.05 for Kuwait and for 0.07 for Saudi Arabia under the THN model, Table 6, column III), others such as Papua New Guinea (where tax effort is 0.97 under the TNH model) and Bolivia (where it is 0.88) have a high one. This is explained because the latter two countries had developed their tax systems before exploiting their natural resources.[9]

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[8] In this group of countries, non-hydrocarbon tax revenues account for about 27.6 percent of total revenues on average (tax and oil revenues).

[9] Among natural-resource dependent economies, Bolivia is one of the exceptions: a developing country with also a significant level of tax revenue. In this country revenues from natural resources are significant since 2005, when a new government was elected and changed natural resource policies (revenue from natural resources increased from 1.6 to 7.7 percent of GDP between 2004 and 2008). That is to say, Bolivia had already developed its tax system and reached a relatively high level of tax revenue before collecting a significant level of revenue from natural resources.

Table 5. Parameters of the Stochastic Frontier Tax Function: Natural Resource and Non-Natural Resource Countries

Variable	Battese Coelli - Half Normal		Battese Coelli - Truncated Normal		Truncated Normal Heterogeneous in Mean and Decay Inefficiency	
	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error
	Frontier Model					
Constant	-2.54016***	0.309	-1.96594***	0.312	-2.20733***	0.314
LGD	1.26641***	0.072	1.13105***	0.073	1.19023***	0.073
AVA	-.00361***	0.001	-.00426***	0.001	-.00344***	0.001
PE	.02793***	0.002	.02783***	0.002	.02912***	0.002
TR	.00128***	0.000	.00122***	0.000	.00107***	0.000
GINI	-.00653***	0.001	-.00707***	0.001	-.00646***	0.001
OIL	0.022	0.046	.09782**	0.042	.07184*	0.044
GOV	.17240***	0.056	.16975***	0.039	.20670***	0.034
LGD^2	-.06496***	0.004	-.05716***	0.004	-.06122***	0.004
	Inefficiency					
Constant			-119.81	936.50	-20.21	266.45
Lcor					-42.1	531.4
Lambda 1/	6.75764***	0.007	70.0926***	0.05	48.2756***	0.13
Sigma (u) 1/	.76273***	0.020	7.92	1919.56	5.46	1019.96
Eta 2/	-.00203***	0.000	-.00251***	0.00		
CPI					0.0002	0.0005
Log-likelihood	1006.79		1019.94		1019.5	

***, **, * = significance 1%, 5%, 10% level.
1/ Parameters for compound error.
2/ Parameter for time varying inefficiency.

Table 6. Natural Resource Dependent Countries: Tax Capacity and Tax Effort

	Country	Year	Total Revenue / 1	GDP Percapita PPP 2005	Tax Effort: Half Normal	Tax Effort: Truncated Normal	Tax Effort: THN /2	Tax Effort: Mundalck REM	Tax Capacity 3/: THN /2	Tax Capacity 3/: Mundalck REM
					I	II	III	IV	V	VI
1	Algeria	2011	16.8	7296.4	0.46	0.44	0.47	0.84	36.1	19.9
2	Angola	2011	12.7	5227.4	0.59	0.58	0.60	0.87	21.2	14.6
3	Bahrain	2011	1.4	21729.4	0.05	0.05	0.06	0.07	24.5	20.0
4	Bolivia	2012	26.5	4551.7	0.88	0.86	0.88	0.98	30.0	27.0
5	Cameroon	2011	12.8	2083.0	0.53	0.51	0.52	0.68	24.4	18.9
6	Congo,Repof	2011	27.2	3884.9	0.70	0.68	0.71	0.97	38.5	28.1
7	Iran, I.R. of	2011	8.6	11414.8	0.22	0.21	0.22	0.35	38.4	24.3
8	Kuwait	2011	2.1	47935.0	0.05	0.04	0.05	0.10	40.6	20.2
9	Libya	2010	10.7	15361.2	0.31	0.30	0.32	0.59	33.6	18.1
10	Mexico	2011	13.2	12291.4	0.30	0.29	0.30	0.47	44.1	27.8
11	Nigeria	2012	11.0	2293.5	0.41	0.40	0.39	0.77	28.2	14.3
12	Oman	2011	8.2	25329.8	0.20	0.18	0.20	0.49	40.7	16.8
13	PapuaNewGuinea	2011	24.8	2363.3	0.98	0.97	0.97	0.98	25.5	25.3
14	Russia	2011	34.8	14808.5	0.83	0.81	0.81	0.97	42.8	36.1
15	SaudiArabia	2011	2.8	21430.2	0.07	0.06	0.07	0.22	41.8	12.8
16	Surinane	2011	10.6	8013.7	0.40	0.39	0.40	0.77	26.3	13.9
17	TrinidadandTobago	2011	24.5	22141.7	0.70	0.67	0.72	0.91	33.9	26.8

1/ Tax and social contributions as percent of non hydrocarbon GDP.
2/ Truncated Normal Heterogeneous in Mean and Decay Inefficiency.
3/ Tax capacity as percent of GDP: tax and social contributions divided tax effort.

C. Sensitivity Analysis

34. **We examined the sensitivity of our results by running the model without three countries**: (1) first, without the three countries with the highest per capita GDP (Luxemburg, Norway, and Singapore); (2) second, without the three countries with the lowest per capita GDP (Malawi, Mozambique, and Niger); and (3) finally, without the three countries with the lowest GINI coefficient. We found that running the model with these changes does not have a significant impact on our results. For instance, in running the model without the three countries with the highest level of per capita GDP, we found that, in average, tax effort changes 1.3 percent (with the maximum change being 5.6 percent and the minimum being 0.01 percent)[10]; in turn, in running the model without the three countries with the lowest per capita GDP, the average change in tax effort is only 0.4 percent (Table 7).

35. **We also carried out a sensitivity analysis by considering for all countries other values for GINI coefficient** (we increased its value by 15 percent) and randomly selecting in six countries (Armenia, Cameroon, France, Latvia, the Philippines, and Uruguay) other values for: CPI and TR (increasing their values by 30 percent). We also found that these changes do not have a significant impact on the estimated tax effort of the 113 countries included in the sample of this study.

Table 7. Sensitivity Analysis: Different Scenarios

Percentage of change in tax effort	Without three countries with the:		Increase TR and CPI 30 percent in six countries	Increase GINI 15 percent all countries
	Highest per-capita GDP	Lowest per-capita GDP		
Un-weighted average	1.3	0.4	0.02	0.01
Maximum	5.6	4.1	2.75	2.71
Minimum	0.0	-2.9	-1.39	-2.62

36. **Perhaps the most important test of the robustness of our results is presented in Appendix 2** that shows that the tax effort of the 96 non-natural resource countries does not change significantly when we consider in the estimates only these 96 countries (column VII) or when we run the analysis by including also the 17 natural resource countries (column VII). To strengthen the robustness checks we run a sensitivity analysis without including in the sample three countries (Chile, Norway, and Peru) with a significant level of revenue from natural resources (but not enough to generate revenue from this sector higher than 25 percent of total revenue) and the output did not change significantly. The low level of sensitivity of our results to alternative specifications increases the confidence in the results of our model.

[10] The maximum difference of 5.6 percent belongs to Guyana, whose level of tax effort changes from 0.73 to 0.67.

VI. ‘UNOBSERVED’ HETEROGENEITY

37. **First, this paper estimated countries’ tax effort and capacity using Battese and Coelli’s original formulation (HN and TN models, Column I and II of Table 3) without heterogeneity**. Second, it estimated a more general formulation (TNH model, Column III of Table 3) including two variables (corruption and inflation) to distinguish ‘observable’ heterogeneity. Disentangling ‘unobserved’ heterogeneity or not could be a philosophical question: whether time-invariant countries-specific characteristics or fixed effects should be interpreted as heterogeneity that should be controlled before estimating the gap (the difference between tax capacity and tax effort). Half normal (HN) and truncated normal (TN) models do not aim to distinguish heterogeneity, which would be included in the gap.

38. **In using the TNH method, this paper aimed to distinguish ‘observed’ endogeneity by including two variables to represent inefficiency** (inflation and corruption). Nevertheless, some independent variables potentially related to the *‘u’* term could be missing and therefore the potential existence of ‘unobserved’ endogeneity of independent variables arises. An alternative source of identification would be to include independent missing variables which are correlated with the inefficiency but not with the heterogeneity. This would be a natural way to extend the model of this paper. However, this is not possible due to the lack of instruments to solve the problem.

39. **Greene (2005) developed two models to separate time-invariant inefficiency from unit specific time-invariant ‘unobserved heterogeneity’**. These models are known as ‘True Fixed Effects’ (TFE) and ‘Random Effects’ (REM), according to the assumptions on the unobserved unit-specific heterogeneity α_i (the country fixed or random effect) and they are introduced as country dummies in the following equation.

$$y_{it} = \alpha_i + \boldsymbol{\beta}'\mathbf{x}_{it} + v_{it} - u_{it} \qquad [5]$$

40. **When the gap term (tax capacity – tax effort) is constant over time, the TFE and REM models do not allow disentangling time invariant heterogeneity from inefficiency** (Belotti and Ilardi, 2012). In addition, the TFE model presents the incidental parameter problem (see Belotti and others, 2012), which modifies the post-estimation of inefficiencies since it leads to inconsistent variance parameter estimates (reducing the level of tax capacity of most countries). As discussed in Farsi, Filippini, and Kuenzle (2005) the TFE and REM approaches can also suffer from the ‘unobserved variables bias’, because the unobserved characteristics may not be distributed independently of the explanatory variables.

41. **In order to address these econometric problems, this paper follows the approach taken by Farsi, Filippini, and Kuenzle (2005) by using a Mundlak version of the REM** (originally proposed by Pitt and Lee, 1981). The Mundlak version of the REM (MREM) is based upon Mundlak’s (1978) modification of the REM for the general specification;

whereby the correlation of the individual specific effects (α_i) and the explanatory variables are considered in an auxiliary equation given by:

$$\alpha_i = \gamma \bar{x}_i + \delta_i$$
$$\bar{x}_i = \frac{1}{T}\sum_{i=1}^{T} x_i \qquad \text{and} \qquad \delta_i \sim iid(0, \sigma_\delta^2) \qquad [6]$$

where X_i is the vector of all explanatory variables. Equation [6] is readily incorporated in the main frontier equation (1, see Box 1) and estimated using the REM. The application of Mundlak's adjustment to the REM frontier framework decreases the bias in inefficiency estimates by separating inefficiency from unobserved heterogeneity.[11]

42. **Under the MREM, all coefficients and *lambda* are significant and statistically significant (different from zero) at 1 percent and have the expected signs** (Table 8). In running the MREM, we find that the results change improving tax capacity estimates for some specific countries. In general, for countries with the lowest level of per capita GDP and for natural resource dependent economies (with low level of revenue) the MREM reduces tax capacity (maximum level of revenue that the country could achieve).[12] MREM seems to adequately control for the 'short term' tax capacity of those two different groups of countries. That is to say, these countries could reach the TNH level of tax capacity only in the long term. This is particularly reasonable for natural resource dependent economies and the least developed countries with very low level of revenue and with unprepared institutions (tax administration and customs) to collect taxes.

Table 8: Mundlack Random Effects Model

Variable	Coefficient		St. Error
Constant	-2.6669		2.0250
LGD	1.4189	***	0.1499
AVA	-0.0036	***	0.0013
PE	0.0265	***	0.0044
TR	0.0011	***	0.0002
GINI	-0.0060	***	0.0016
GOV	0.2650	***	0.0585
LGD^2	-0.0732	***	0.0084
Inefficiency			
Lambda 1/	6.3094	***	0.0502
Sigma (u) 1/	0.7129	***	0.0502

***, **, * = significance 1%, 5%, 10% level.
1/ Parameters for compound error.
2/ Parameter for time varying inefficiency.

[11] In a few words, the model adds as explanatory variables the mean of every explanatory variable, which aim to identify the invariant or fixed characteristic of every country).

[12] Although some countries, such as Chile and Peru, are not considered in this paper as natural- resource dependent economies (because their mining-sector revenue is lower than 25 percent of total revenue), revenue from this sector is important and, perhaps, this is the main reason why their tax capacities under Mundlack are lower.

VII. CONCLUSIONS

43. **The initial step that a country should follow before implementing new taxes or increasing the rate of the existing ones is to analyze its tax effort**, to determine how far its actual revenue is from its tax capacity. If a country is near its tax capacity, then changes in the tax system should be oriented to improve its quality or only slightly increase tax rates. This paper uses the stochastic frontier tax analysis to determine the tax effort and tax capacity of 113 countries (initially we include in the study 96 non-natural resource dependent economies). This is a relative method with predictions of tax effort using a comparative analysis of data on these countries. That is to say, the method determines if a country's tax effort is high or low in comparison to that of other countries, taking into account some economic and institutional characteristics. While in production frontier analysis, the difference between current production and the frontier represents the level of inefficiency, in tax frontier analysis, the difference between actual revenue and tax capacity includes the existence of technical inefficiencies as well as public choice or policy issues (differences in tax legislation, for instance, in the level of tax rates)—things that countries can modify.

44. **This paper estimates different specifications of the stochastic frontier using panel data**: the Battese-Coelli half normal and truncated normal models, this last incorporating heterogeneity, and, to deal with 'unobserved' heterogeneity, the Mundlak version of the Random Effects Model (REM). This study corroborates previous analyses in finding a positive and significant relationship between tax revenue as a percent of GDP and the level of development (per capita GDP), trade (imports and exports as percent of GDP), and education (public expenditure on education as a percent of GDP). The study also demonstrates a negative relationship between tax revenue as a percent of GDP and inflation (CPI), income distribution (GINI coefficient), the ease of tax collection (agricultural sector value added as a percent of GDP), and corruption.

45. **The study also shows that**:

- High levels of exemptions and low tax rates explain, in part, why some developing countries have a low level of tax effort. Therefore, in the case of these countries, public choice explains at least a share of the distance between the actual revenue and the maximum level of revenue that these countries could achieve.

- Most European countries, with a high level of per capita GDP and education, open economies (particularly since the creation of the customs union), low levels of inflation and corruption, and strong policies of income distribution, are near their tax capacity. This is particularly the case for Austria, Belgium, Denmark, Finland, France, Italy, and Sweden (with tax efforts higher than 90 percent) where, probably, the demand for public expenditure is a crucial determinant of the higher level of tax revenue. Taking into account how near these countries are to their tax capacity, they appear to be very efficient in collecting taxes (with low levels of evasion).

- Singapore (0.33 of tax effort under the THN model); Korea (0.49); and Japan (0.53) are exceptions, with very high level of per capita GDP but lying far from their tax capacities. This is also explained, in part, by a matter of public choice. VAT rates in these countries are among the lowest in the world: between 3 percent (1994) and 7 percent (2011) in Singapore; 5 percent in Japan in 2011; and 10 percent in Korea in 2011. These three countries and Indonesia (where tax effort is 0.43) contribute to the fact that the Asia and Pacific region has the lowest level of tax effort.

46. **To broaden the analysis, this paper adds 17 natural resource dependent countries** (where revenue from natural resources represents more than 25 percent of tax and natural resource revenue).[13] For these countries, we consider only tax revenue (without revenue that comes from the oil and mining sectors) as a percent of non-natural resource products. As with the sample of 96 non-natural resource dependent countries, three models (HN, TN, and TNH) were run. All coefficients (except those for CPI and corruption) are statistically significant (different from zero) at 10 percent (at least); have the expected signs; and are quite similar in the three models. By adding the 17 natural resource countries to the initial sample of 96 countries, the value of the *lambda* parameter is significantly larger than that of the first group of non-natural resource dependent countries, implying a larger inefficiency component in the model. In other words, the model shows that inefficiency in collecting taxes is higher when the sample includes natural resource dependent economies.

47. **In running the MREM, we find that the results change, improving tax capacity estimates for some specific countries**. In general, for countries with the lowest level of per capita GDP and for natural resource dependent economies (with low levels of revenue) the MREM reduces tax capacity (maximum level of revenue that the country could achieve). MREM seems to adequately control for the 'short term' tax capacity of those two different groups of countries. That is to say, these countries could reach the TNH level of tax capacity only in the long term. This is particularly reasonable for natural resource dependent economies and the least developed countries with very low levels of revenue and with unprepared institutions (tax administration and customs) to collect taxes.

[13] In this group of countries, non-hydrocarbon tax revenues account for about 27.6 percent of total revenues on average (tax and oil revenues).

Appendix 1. Variables and Data Source

Ltot is the log of the sum of tax and pension contributions revenue collected by central and sub national governments as percent of GDP. General government revenue was only available for 52 countries; for the remaining 60 countries we used central government revenue. We created a dummy variable (*Gov*) to distinguish countries that report consolidated revenues (*Gov*=1) from those that report only revenues from the central government (*Gov*=0). A caveat is worth mentioning: we did not include social security revenue collected and administered by private institutions, but we did include social security revenue collected by the Government. As a consequence, countries such as the USA and Chile, with an important level of private social security collection might be closer to its maximum tax capacity than what our analysis shows. (Source: *World Economic Outlook* and official websites.)

Lgd is the log GDP per capita, purchasing power parity constant 2005. (Source: World Bank World Development Indicators (WDI).)

Lgd^2 is lgd square, which we include as explanatory variable to capture the presumably non-linear elasticity between tax revenue and per capita GDP.

TR is trade, imports plus exports as percent of GDP, which reflects the degree of openness of an economy. (Source: WDI.)

AVA is the value added of the agriculture sector as percent of GDP. We use this variable to represent how ease (or not) is to collect taxes. (Source: WDI).[14]

PE is the total public expenditure on education as percent of GDP and represents the level of education.[15] (Source: WDI and FAD statistics.)

GINI coefficient measures the extent to which the distribution of income among individuals deviates from the equal distribution. (Source: WDI.)

CPI is the percentage change of consumption price index. (Source: WDI.)

Lcor is the log of the corruption perception index. There are different inefficiencies that can mean that countries do not reach their tax frontier. Among them, corruption, weak tax administrations, government ineffectiveness, and low enforcement. We chose only one to represent inefficiencies: the corruption perception index. (Source: Transparency International.)

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[14] Due to political reasons, some countries exempt agricultural products from VAT as well as agricultural producers from the income tax. Moreover, this sector is difficult to control particularly when it is composed of small producers.

[15] Other variables could reflect better the level of people's education; however, data sometimes are not available for all countries. On other occasions, some variables are not useful for comparison. For instance, labor force with secondary education (percent of total) was not available for some countries, and secondary education significantly differs among countries.

Appendix 2. Natural Resource and Non-Natural Resource Countries: Tax Capacity and Tax Effort

	Country	Year	Total Revenue /1	Percapita GDP, PPP 2005	Natural Resource and Non-Natural Resource Countries: Tax Effort: Half Normal	Tax Effort: Truncated Normal	Tax Effort: TNH /2	Tax Effort: Mundalck REM	Tax Capacity / 3: TNH /2	Tax Capacity / 3: Mundalck REM	Non-Natural Resource Countries: Tax Effort TNH /2	Non-Natural Resource Countries: Tax Capacity TNH /2
					I	II	III		IV	VI	VII	VIII
1	Albania	2011	22.8	7861.1	0.67	0.71	0.71	0.78	32.0	29.4	0.68	33.7
2	Algeria	2011	16.8	7296.4	0.46	0.44	0.47	0.84	36.1	19.9		
3	Angola	2011	12.7	5227.4	0.59	0.58	0.60	0.87	21.2	14.6		
4	Argentina	2011	34.7	15501.4	0.64	0.67	0.65	0.60	53.2	58.0	0.66	52.2
5	Armenia	2011	16.1	5112.4	0.44	0.46	0.45	0.62	35.9	26.1	0.45	36.0
6	Australia	2011	26.1	35052.5	0.70	0.71	0.72	0.69	36.3	37.6	0.70	37.1
7	Austria	2011	42.1	36353.0	0.94	0.95	0.97	0.95	43.5	44.3	0.93	45.2
8	Bahrain	2011	1.4	21729.4	0.05	0.05	0.06	0.07	24.5	20.0		
9	Bangladesh	2012	10.4	1622.9	0.41	0.42	0.42	0.67	24.5	15.6	0.41	25.4
10	Belarus	2011	39.0	13191.2	0.95	0.97	0.97	0.98	40.4	39.8	0.94	41.3
11	Belgium	2011	44.0	33126.5	0.87	0.88	0.91	0.92	48.5	47.9	0.87	50.6
12	Bolivia	2012	26.5	4551.7	0.88	0.86	0.88	0.98	30.0	27.0		
13	Brazil	2011	29.7	10278.4	0.77	0.81	0.78	0.75	38.0	39.7	0.81	36.6
14	Bulgaria	2011	25.8	11799.5	0.64	0.67	0.66	0.78	38.8	32.9	0.65	39.7
15	BurkinaFaso	2012	14.1	1304.0	0.66	0.68	0.67	0.59	21.0	24.0	0.66	21.4
16	Cameroon	2011	12.8	2083.0	0.53	0.51	0.52	0.68	24.4	18.9		
17	Canada	2011	31.4	35716.0	0.76	0.77	0.78	0.83	40.1	38.0	0.76	41.5
18	Chile	2011	19.5	15250.8	0.58	0.60	0.62	0.85	31.5	23.1	0.61	32.0
19	China,P.R.M.	2011	18.9	7417.9	0.46	0.49	0.47	0.58	40.0	32.4	0.48	39.1
20	Colombia	2011	19.0	8861.1	0.54	0.57	0.55	0.84	34.7	22.5	0.57	33.4
21	Congo,Repof	2011	27.2	3884.9	0.70	0.68	0.71	0.97	38.5	28.1		
22	CostaRica	2012	20.0	11155.5	0.49	0.52	0.53	0.67	37.9	30.0	0.52	38.6
23	Croatia	2011	32.6	16162.2	0.77	0.80	0.80	0.91	40.8	35.9	0.78	41.8
24	Cyprus	2011	35.8	26045.4	0.65	0.66	0.67	0.72	53.2	49.9	0.65	55.3
25	CzechRepublic	2011	35.5	23966.6	0.72	0.74	0.75	0.82	47.3	43.1	0.72	49.3
26	Denmark	2011	48.1	32399.3	0.94	0.95	0.96	0.93	49.9	51.9	0.92	52.6
27	DominicanRepublic	2011	13.2	8650.6	0.44	0.46	0.47	0.51	28.2	25.6	0.46	28.4
28	Egypt	2011	16.7	5546.5	0.46	0.48	0.46	0.72	35.9	23.1	0.46	36.2
29	ElSalvador	2011	13.4	6031.9	0.41	0.43	0.44	0.56	30.7	24.1	0.43	30.9
30	Estonia	2011	32.8	17885.4	0.64	0.67	0.67	0.81	48.8	40.6	0.66	49.9
31	Ethiopia	2011	11.3	979.2	0.66	0.68	0.66	0.53	17.0	21.2	0.63	17.8
32	Finland	2011	42.8	32253.6	0.94	0.96	0.96	0.95	44.4	45.1	0.93	46.2
33	France	2012	42.6	29819.1	0.96	0.97	0.98	0.94	43.6	45.1	0.96	44.6
34	Gambia,The	2011	12.3	1872.8	0.56	0.59	0.58	0.70	21.1	17.5	0.58	21.3
35	Germany	2011	39.5	34436.8	0.80	0.81	0.83	0.84	47.9	47.0	0.79	49.9
36	Ghana	2011	16.9	1652.3	0.51	0.53	0.52	0.44	32.1	38.7	0.52	32.7
37	Greece	2011	33.4	22558.0	0.78	0.80	0.80	0.80	41.6	42.0	0.79	42.4
38	Guatemala	2011	10.6	4351.4	0.42	0.44	0.44	0.47	23.9	22.5	0.45	23.7
39	Guinea	2011	14.8	992.8	0.76	0.78	0.78	0.95	18.9	15.6	0.75	19.6
40	Guinea-Bissau	2011	9.0	1097.5	0.32	0.34	0.33	0.42	27.4	21.7	0.32	28.1
41	Guyana	2012	22.4	2929.7	0.70	0.74	0.74	0.71	30.0	31.4	0.72	30.9
42	Honduras	2011	18.7	3573.7	0.62	0.65	0.65	0.60	28.6	31.1	0.66	28.5
43	Hungary	2011	35.9	17295.4	0.80	0.83	0.83	0.86	43.1	41.6	0.81	44.5
44	Iceland	2011	33.7	33515.6	0.73	0.74	0.75	0.67	44.7	50.6	0.72	46.7
45	India	2011	33.7	33515.6	0.53	0.55	0.53	0.52	63.0	64.4	0.53	29.6
46	Indonesia	2011	11.9	4094.1	0.42	0.43	0.44	0.69	27.0	17.2	0.42	28.0
47	Iran, I.R. of	2011	8.6	11414.8	0.22	0.21	0.22	0.35	38.4	24.3		
48	Ireland	2011	27.7	36144.7	0.60	0.61	0.63	0.75	43.7	36.9	0.61	45.2
49	Israel	2011	29.6	26720.0	0.83	0.85	0.88	0.94	33.5	31.5	0.83	35.6
50	Italy	1992	40.2	24263.7	0.98	0.98	0.98	0.97	40.8	41.3	0.98	43.1
51	Jamaica	2011	23.3	7073.6	0.68	0.72	0.73	0.78	31.9	29.9	0.71	33.0
52	Japan	2011	28.8	30660.4	0.64	0.65	0.66	0.71	43.4	40.8	0.64	45.2
53	Jordan	2011	14.9	5268.6	0.54	0.56	0.58	0.68	25.6	22.0	0.56	26.7
54	Kenya	2011	20.7	1509.6	0.75	0.78	0.76	0.65	27.1	31.9	0.76	27.4
55	Korea	2011	18.8	27541.3	0.47	0.48	0.49	0.49	38.8	38.2	0.47	39.7

1/ Tax and social contributions as percent of GDP.

2/ Truncated Normal Heterogeneous in Mean and Decay Inefficiency.

3/ Tax capacity (percent of GDP): tax and social contributions divided tax effort.

	Country	Year	Total Revenue /1	Percapita GDP, PPP 2005	Natural Resource and Non-Natural Resource Countries: Tax Effort: Half Normal	Tax Effort: Truncated Normal	Tax Effort: TNH /2	Tax Effort: Mundalck REM	Tax Capacity / 3: TNH /2	Tax Capacity / 3: Mundalck REM	Non-Natural Resource Countries: Tax Effort TNH /2	Non-Natural Resource Countries: Tax Capacity TNH /2
					I	II	III		IV	VI	VII	VIII
56	Kuwait	2011	2.1	47935.0	0.05	0.04	0.05	0.10	40.6	20.2		
57	KyrgyzRepublic	2011	24.3	2118.5	0.77	0.81	0.80	0.83	30.5	29.3	0.76	31.9
58	Latvia	2011	27.7	13773.4	0.60	0.62	0.62	0.73	44.8	38.0	0.61	45.4
59	Lebanon	2012	16.8	12591.8	0.47	0.49	0.50	0.67	33.3	25.0	0.49	34.2
60	Libya	2010	10.7	15361.2	0.31	0.30	0.32	0.59	33.6	18.1		
61	Lithuania	2011	27.3	17839.3	0.60	0.62	0.62	0.73	43.8	37.4	0.61	44.6
62	Luxembourg	2011	33.7	68458.7	0.72	0.72	0.77	0.78	43.5	43.3	0.73	46.0
63	Madagascar	2012	10.8	843.2	0.62	0.64	0.63	0.70	17.0	15.4	0.63	17.2
64	Malawi	2012	23.3	777.2	0.98	0.98	0.98	0.96	23.8	24.2	0.97	24.0
65	Mali	2012	14.4	1046.7	0.75	0.78	0.77	0.79	18.8	18.3	0.74	19.5
66	Mexico	2011	13.2	12291.4	0.30	0.29	0.30	0.47	44.1	27.8		
67	Moldova	2010	31.0	2793.5	0.78	0.82	0.79	0.82	39.0	37.6	0.79	39.4
68	Mongolia	2010	31.8	3620.2	0.76	0.80	0.80	0.87	39.7	36.6	0.76	41.8
69	Morocco	2012	24.3	4475.2	0.77	0.80	0.80	0.80	30.4	30.3	0.78	31.4
70	Mozambique	2011	18.2	861.3	0.85	0.86	0.85	0.78	21.4	23.5	0.84	21.7
71	Namibia	2011	25.3	5986.4	0.86	0.91	0.91	0.90	27.8	28.0	0.91	27.7
72	Netherlands	2011	37.8	37250.7	0.80	0.81	0.83	0.82	45.4	46.1	0.80	47.3
73	NewZealand	2011	31.7	24429.0	0.77	0.79	0.79	0.72	40.0	43.9	0.78	40.9
74	Nicaragua	2011	21.7	2579.3	0.74	0.78	0.78	0.94	27.7	23.2	0.76	28.7
75	Niger	2011	13.5	642.1	0.72	0.73	0.72	0.72	18.8	18.6	0.70	19.3
76	Nigeria	2012	11.0	2293.5	0.41	0.40	0.39	0.77	28.2	14.3		
77	Norway	2011	43.2	46733.4	0.90	0.90	0.92	0.87	46.8	49.6	0.87	49.2
78	Oman	2011	8.2	25329.8	0.20	0.18	0.20	0.49	40.7	16.8		
79	Pakistan	2011	9.9	2423.7	0.45	0.46	0.46	0.63	21.3	15.8	0.44	22.3
80	Panama	2012	16.9	14320.2	0.43	0.45	0.47	0.54	35.9	31.0	0.46	36.3
81	PapuaNewGuinea	2011	24.8	2363.3	0.98	0.97	0.97	0.98	25.5	25.3		
82	Paraguay	2011	15.2	4752.3	0.48	0.51	0.51	0.63	30.1	24.1	0.50	30.1
83	Peru	2011	17.2	9049.3	0.55	0.58	0.59	0.71	29.3	24.2	0.58	29.5
84	Philippines	2011	12.2	3630.9	0.50	0.52	0.53	0.54	23.2	22.5	0.52	23.7
85	Poland	2011	33.7	18087.4	0.75	0.78	0.77	0.87	43.7	38.7	0.76	44.5
86	Portugal	2011	32.4	21317.3	0.70	0.72	0.72	0.71	45.0	45.6	0.71	45.6
87	Romania	2011	28.2	10905.4	0.65	0.68	0.67	0.83	42.1	33.8	0.66	42.9
88	Russia	2011	34.8	14808.5	0.83	0.81	0.81	0.97	42.8	36.1		
89	SaudiArabia	2011	2.8	21430.2	0.07	0.06	0.07	0.22	41.8	12.8		
90	Senegal	2011	19.4	1737.1	0.72	0.75	0.75	0.85	26.0	22.8	0.72	26.8
91	SerbiaMontenegro	2011	34.1	9830.2	0.79	0.83	0.82	0.96	41.7	35.4	0.79	43.4
92	Singapore	2011	14.1	53591.1	0.28	0.28	0.32	0.47	44.0	30.0	0.30	46.8
93	SlovakRepublic	2011	28.9	20756.7	0.63	0.65	0.67	0.79	43.5	36.8	0.64	45.0
94	Slovenia	2011	35.9	24967.5	0.72	0.74	0.75	0.83	48.0	43.4	0.72	49.8
95	SouthAfrica	2011	27.8	9678.2	0.71	0.75	0.73	0.77	38.2	35.9	0.76	36.6
96	Spain	2011	32.7	26917.1	0.78	0.80	0.80	0.79	40.7	41.3	0.79	41.7
97	SriLanka	2011	12.5	4929.0	0.55	0.58	0.59	0.62	21.3	20.1	0.57	21.9
98	Surinane	2011	10.6	8013.7	0.40	0.39	0.40	0.77	26.3	13.9		
99	Sweden	2011	44.3	35170.1	0.96	0.97	0.98	0.98	45.3	45.4	0.94	47.0
100	Switzerland	2011	28.5	39384.7	0.64	0.64	0.66	0.63	43.1	45.5	0.64	44.5
101	Tanzania	2011	15.3	1334.1	0.58	0.60	0.59	0.67	26.0	23.0	0.57	27.0
102	Thailand	2011	17.7	7633.0	0.46	0.49	0.48	0.54	37.1	32.7	0.48	36.7
103	Togo	2011	15.9	926.6	0.77	0.80	0.79	0.81	20.1	19.6	0.76	21.0
104	TrinidadandTobago	2011	24.5	22141.7	0.70	0.67	0.72	0.91	33.9	26.8		
105	Tunisia	2011	25.5	8257.7	0.69	0.72	0.74	0.91	34.6	27.9	0.70	36.2
106	Turkey	2011	26.7	13466.3	0.65	0.67	0.66	0.84	40.4	31.7	0.66	40.3
107	Uganda	2011	12.4	1187.7	0.64	0.66	0.65	0.74	19.1	16.8	0.64	19.5
108	Ukraine	2011	38.2	6365.2	0.78	0.82	0.80	0.89	47.7	43.0	0.78	48.9
109	UnitedKingdom	2011	35.8	32862.8	0.82	0.83	0.84	0.81	42.6	44.2	0.82	43.6
110	UnitedStates	2011	24.5	42486.0	0.68	0.68	0.69	0.61	35.4	39.9	0.68	36.0
111	Uruguay	2011	26.2	13314.9	0.81	0.85	0.86	0.90	30.4	29.3	0.84	31.1
112	Vietnam	2011	24.1	3012.7	0.64	0.68	0.66	0.73	36.7	33.1	0.65	36.8
113	Zambia	2012	16.6	1475.5	0.96	0.98	0.98	0.97	17.0	17.1	0.98	16.9

1/ Tax and social contributions as percent of GDP.

2/ Truncated Normal Heterogeneous in Mean and Decay Inefficiency.

3/ Tax capacity (percent of GDP): tax and social contributions divided tax effort.

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