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Abstract*

This paper estimates short-run and long-run elasticities of tax revenue with respect to GDP in eight Latin American countries using quarterly data. Taxes considered are corporate income tax (CIT), personal income tax (PIT), value-added tax (VAT), and overall taxes. Results indicate that long-run elasticities are statistically and economically larger than 1, whereas short-run elasticities appear not to be statistically different from zero in the majority of cases. Tax systems seem very elastic in Argentina, Colombia, Ecuador, Peru, and Venezuela. The CIT exhibits the largest estimated long-run elasticity in most countries. Focusing on short-run elasticities that show statistical significance, only the CIT in Colombia and the PIT in Brazil and Colombia show larger fluctuations over the business cycle than growth potential in the long run. Overall, our results indicate that tax systems in Latin America are significantly more elastic than previous estimations.

JEL Classifications: E32, H24, H25, H29
Keywords: Tax revenue; Elasticities; Business cycles; Latin America.

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1. Introduction

A desirable characteristic of any tax system is elasticity. The elasticity coefficient measures the responsiveness of tax revenue with respect to national income or GDP growth, excluding any change in revenue induced by tax policy or administration modifications.[1] The more elastic tax revenue is with respect to income, the greater the magnitude of automatic fiscal stabilizers, and thus the weaker the case for discrete policy changes on the fiscal side to achieve macroeconomic stability in the presence of adverse external shocks such as a deterioration in the terms of trade. Baunsgaard and Symansky (2009) underscore that discretionary fiscal policies have two main shortcomings. First, they are afflicted by implementation lags, including political considerations inherent to the decision making process. Second, they are not automatically reversed when the economic context improves.

Tax elasticities are usually assumed to be constant over time (IDB, 2011). Nevertheless, these parameters can be expected to fluctuate over the business cycle. For instance, negative temporary shocks on household income may affect the demand for nonessential goods and services more than proportionally, thus increasing the short-run elasticity as these items tend to be taxed at higher rates than basic goods and services. Brondolo (2009) suggests that tax compliance deteriorates during sharp recessions, leading to a decline in tax revenue beyond the impact of the business cycle.

Therefore, the behavior of tax elasticities may vary in the short run as compared to the long run. By the same token, they may differ depending on the state of the economy, that is, whether a recessionary or expansionary phase of economic activity is in place. Moreover, the responsiveness of tax revenue with respect to output growth is expected to be different depending on the specific tax considered. This is of primary importance for economic policy design, as it informs policymakers about the expected fluctuations of tax revenue over the business cycle. However, these issues have not been addressed in Latin American countries. This paper aims at filling this gap, focusing on the three main categories of taxes in the region, namely, personal income tax (PIT), corporate income tax

[1] Total response of tax revenue with respect to national income or GDP growth including discretionary changes in tax policy and administration is termed the buoyancy of the tax system (Shome, 1988; Jenkins, Kuo, and Shukla, 2000).

(CIT), and value-added tax (VAT). These three taxes account for an important share of total tax revenue in Latin America in recent years. Overall tax revenue is also analyzed.

Estimations of short-run and long-run elasticities of taxes with respect to GDP for eight Latin American countries (LAC (8)) are undertaken using quarterly data over the last 11 to 21 years, depending on data availability. For Central American countries, which do not report quarterly data of tax revenue variables for long periods, estimations are carried out using panel data with annual frequency during 1990–2008. The countries included are Costa Rica, El Salvador, Guatemala, and Panama (CA (4)). In addition, social security contributions (SSC) are also addressed for the three countries of the sample where it was possible to build a long enough quarterly database, namely, Argentina, Brazil, and Peru.

The paper is organized as follows. The next section describes the tax panorama of Latin America and its evolution over the last years. Section 3 reviews previous studies that have undertaken econometric estimations of tax elasticities in other countries. Section 4 explains the estimation methodology, whereas Section 5 describes the data. Section 6 presents the econometric results. Section 7 reports estimations allowing for differences between bad times and normal times. The last section concludes.

2. Tax Panorama of Latin America

In order to provide a general overview of the current tax situation in Latin American countries and its evolution over recent decades, this section presents tax structures in 1990, 2000, and 2010, the evolution of rates of the main taxes since 1990 (or latest available year), and standard measures of productivity and efficiency of the main taxes, namely PIT, CIT, and VAT. The focus is on Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Venezuela. In 2010, the three taxes accounted for some 70 percent of total tax revenue in LAC (8) (simple average; excluding SSC), ranging from 40.6 percent in Brazil to 89.1 percent in Mexico. Including SSC, the latter figures decline to 32.2 percent and 71.6 percent, respectively.

Table 1 presents the composition of general government tax revenue and social security contributions in 1990, 2000, and 2010. A number of features stand out. First, with the exception of Mexico, in all countries the CIT collects more revenue than the PIT. The most extreme cases are Colombia and Venezuela, where the CIT generated nearly 13 times the revenue collected by the PIT in 2010. In Mexico and Brazil the combined revenue from the PIT and CIT surpasses the amount collected from the VAT, which signals progressivity. In the other countries, the PIT represents a small fraction of total revenues, even when the tax rates are comparable in level to those of the CIT. In many countries, minimum exempt income levels are very generous, and many workers are exempt from paying taxes. Thus, mostly dependent workers are paying the PIT through employer withholding. This highlights a pending issue related to tax reform: improvement of the PIT.

Table 1. Composition of General Government Tax Revenue and Social Security Contributions, 1990, 2000, and 2010 *(percent of total revenue)*

	1990	2000	2010
Argentina			
Income Tax	5.4	16.4	15.7
PIT	n.a.	5.4	n.a.
CIT	n.a.	10.9	n.a.
VAT	18.0	30.0	24.0
Excises	16.7	8.4	5.1
International trade	10.2	3.0	11.4
Other taxes	32.0	22.8	23.3
Social security contributions	17.6	19.4	20.4
Total	100.0	100.0	100.0
Total (percent of GDP)	13.6	24.0	34.6
Brazil			
Income Tax	15.9	14.6	17.8
PIT	n.a.	7.1	7.1
CIT	n.a.	7.5	10.8
VAT	12.0	14.0	14.4
Excises	7.4	5.3	3.8
International trade	2.3	2.4	1.7
Other taxes	43.8	45.7	41.6
Social security contributions	18.7	18.1	20.6
Total	100.0	100.0	100.0
Total (percent of GDP)	29.6	30.3	34.1
Chile			
Income Tax	19.3	17.3	30.4
PIT	5.2	7.4	5.7
CIT	14.1	9.8	24.7
VAT	29.9	34.1	31.9
Excises	8.2	8.4	5.9
International trade	10.2	5.7	1.0

Other taxes	17.5	31.3	24.0
Social security contributions	15.0	3.2	6.8
Total	100.0	100.0	100.0
Total (percent of GDP)	23.5	23.9	25.4
Colombia			
Income Tax	29.8	24.1	25.9
PIT	4.5	2.3	1.9
CIT	25.4	21.9	24.0
VAT	22.6	27.4	28.9
Excises	12.4	6.7	3.9
International trade	17.9	5.7	4.5
Other taxes	1.9	13.4	12.7
Social security contributions	15.4	22.7	24.0
Total	100.0	100.0	100.0
Total (percent of GDP)	11.5	14.9	19.8
Ecuador			
Income Tax	15.3	11.6	24.7
PIT	3.5	3.5	2.9
CIT	11.8	8.1	21.8
VAT	31.6	40.9	34.5
Excises	8.4	3.9	4.4
International trade	13.1	15.4	10.2
Other taxes	7.0	18.2	5.5
Social security contributions	24.7	9.9	20.7
Total	100.0	100.0	100.0
Total (percent of GDP)	10.0	13.0	16.6
Mexico			
Income Tax	34.6	34.9	40.9
PIT	14.9	14.2	20.7
CIT	19.6	20.7	20.2
VAT	27.9	25.6	30.7
Excises	6.9	2.7	4.0
International trade	6.8	4.4	1.5
Other taxes	9.0	13.2	3.3
Social security contributions	14.7	19.2	19.6
Total	100.0	100.0	100.0
Total (percent of GDP)	12.9	13.5	12.5
Peru			
Income Tax	5.4	17.8	32.8
PIT	n.d.	9.2	10.4
CIT	n.d.	8.6	22.4
VAT	12.0	41.5	45.2
Excises	35.5	12.2	6.1
International trade	17.2	10.3	2.3
Other taxes	22.7	2.2	-2.9
Social security contributions	7.2	16.0	16.7
Total	100.0	100.0	100.0

Total (percent of GDP)	12.6	15.5	18.1
Venezuela			
Income Tax	69.8	43.2	32.9
PIT	0.7	1.7	1.8
CIT	10.1	10.5	24.0
VAT [a]	0.0	30.2	46.4
Excises	8.9	7.1	6.2
International trade	8.2	9.5	2.6
Other taxes	6.5	4.6	4.8
Social security contributions	6.5	5.4	7.1
Total	100.0	100.0	100.0
Total (percent of GDP)	13.9	13.6	12.0

Source: Authors' elaboration based on IDB and ECLAC databases.
[a] The VAT was introduced in 1993 in Venezuela.

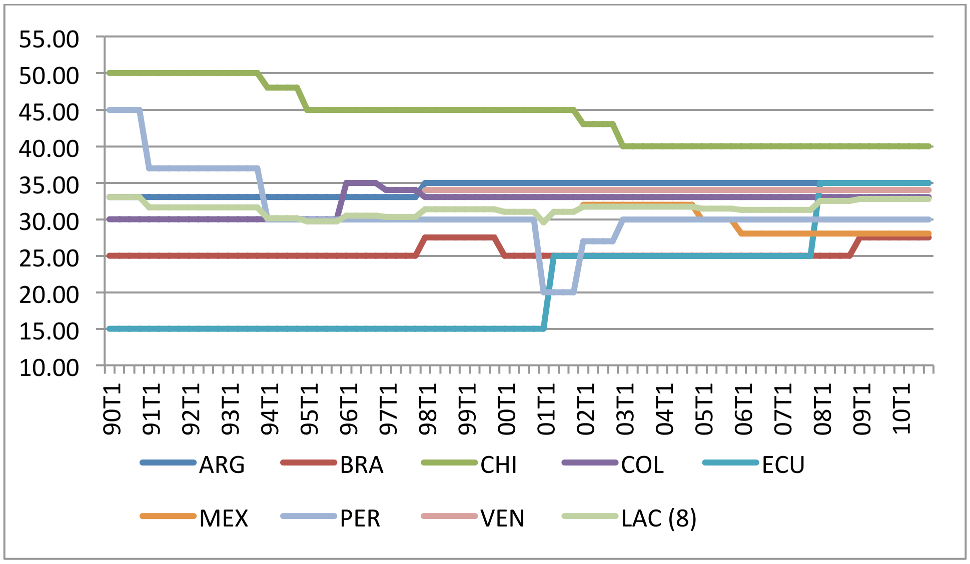
A second feature of tax revenue composition in LAC (8) is the preponderance of the VAT in most countries. It ranges from near 18 percent of total tax revenue in Argentina to more than 54 percent in Peru (excluding SSC). This confirms the role of the VAT as a revenue generator. On the other hand, in tune with the process of integration to the world economy in most countries, taxes on international trade have declined in recent decades. In most countries, taxes on international trade now account for less than 5 percent of total tax revenue. In the case of Argentina, taxes on exports of soybean and other agricultural products amounted to more than 14 percent of total tax revenue in 2010 (excluding SSC).

The last important feature of tax revenue composition is the share of social security contributions (SSC) in Argentina, Brazil, Colombia, Ecuador and Mexico, where SSC account for between one fourth and one fifth of total tax revenue. Except for Argentina, Brazil, and Peru, no other Latin American country reports quarterly data on SSC revenue. Moreover, in Argentina, Brazil, and Peru, time series that report SSC rates are not available with quarterly frequency. This makes it very difficult to exclude SSC revenue changes due to modifications in rates or other reforms, rendering the estimation of elasticities with respect to output very difficult.

With respect to the evolution of PIT, CIT, and VAT rates, Figures 2 to 4 present their behavior in 1990–2010 in LAC (8). Figure 1 shows that there has been a trend toward convergence in PIT marginal rates. For instance, while in 1990 the difference between the maximum (Chile, 50 percent) and the minimum (Ecuador, 15 percent) was 35 percentage points, by 2010 the difference was only 12.5 percentage points (40 percent in Chile minus

27.5 percent in Brazil). However, the average marginal rate has been rather stable in LAC (8) over the period analyzed, with a minimum value of just below 30 percent in 1995 and a maximum of 33 percent in 1990. In 2010, the average marginal PIT rate was 32.8 percent.

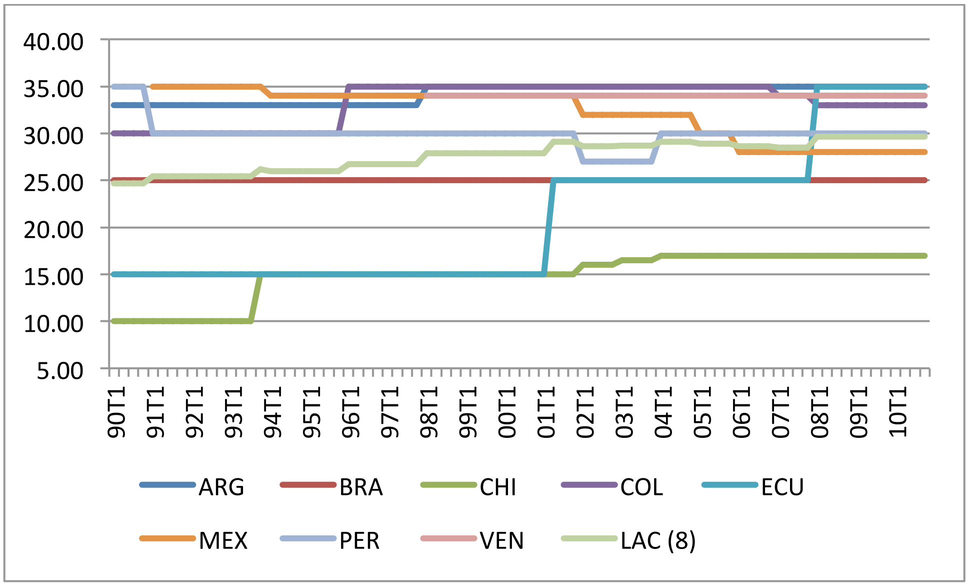
Figure 1. Marginal PIT Rates, 1990–2010[a] *(percent)*



Source: Authors' elaboration based on official figures.
[a] Maximum recorded rates in the scale of progressive rates.

Figure 2 shows the evolution of CIT rates since 1990. As can be seen, the convergence highlighted for the PIT rates are less apparent. Actually, the difference between the maximum (Peru, 35 percent) and the minimum rate (Chile, 10 percent) in 1990 was 25 percentage points. This gap was 18 percentage points in 2010 (35 percent in Argentina and Ecuador minus 17 percent in Chile). It is worth mentioning that in Brazil, the CIT rate was 25 percent during the whole period (including the additional rate of 10 percent applicable to corporations), whereas in Venezuela, the general CIT rate has stood at 34 percent since 1998 (first year available from the source used). Meanwhile, in Argentina, the CIT rate only changed once, from 33 percent to 35 percent starting in 1998. Overall, the simple average CIT rate for LAC (8) gradually increased from 24.7 percent in 1990 to 29.6 percent in 2010.

Figure 2. CIT rates, 1990–2010 *(percent)*

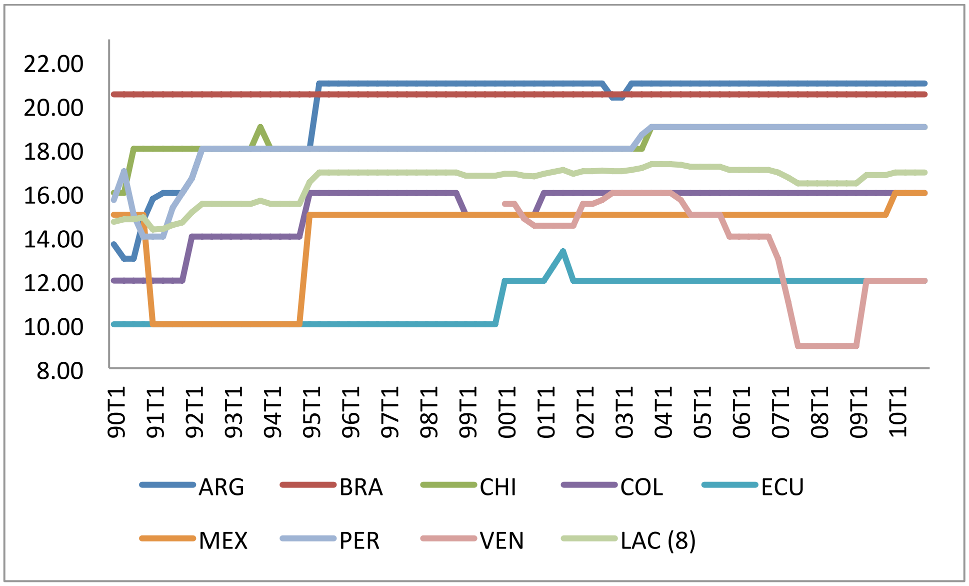


Source: Authors' elaboration based on official figures.
Notes: In Ecuador and Venezuela, the results correspond to the maximum recorded rates in the scale of progressive rates. In the other countries the rate is unique. In Brazil the result includes the additional rate applicable to corporations. In Chile the result corresponds to the rate applicable to capital (second category); the rate applicable to foreign enterprises and to national enterprises that distribute profits was 35 percent in the whole period. In Venezuela, the result corresponds to the general rate; the special rates applied to enterprises in the hydrocarbons and in the mining sector are higher (60 percent and 50 percent in 2010, respectively).

Last but not least, Figure 3 depicts the evolution of VAT rates in 1990–2010. In this case the difference between the maximum and the minimum rates across countries is smaller. In 1990, the gap was just above 10 percentage points (20.48 percent in Brazil minus 10 percent in Ecuador). By 2010, the difference was 8.48 percent (20.48 percent in Brazil minus 12 percent in Ecuador and Venezuela). The simple average for LAC (8) increased by just above 2 percentage points during the 21 years, gradually rising from 14.69 percent in 1990 to 16.94 percent in 2010. Again, as in the case of CIT tax rates, Brazil maintained the same CIT rate during the whole period.[2] The other countries modified the VAT rate more than once during the period analyzed.

[2] Venezuela maintained the same CIT rate since 1998, the first available figure in the official source used.

Figure 3. VAT Rates, 1990–2010 *(percent)*



Source: Authors' elaboration based on official figures.

3. Previous Studies

Some relevant research has differentiated between the impact of GDP growth on tax bases and the effect of changes in tax bases on tax revenue. Sobel and Holcombe (1996) (S&B, hereafter) highlight the importance of income elasticity of tax bases in both the long run and the short run. The long-run elasticity of tax bases with respect to output is an indicator of tax revenue growth, whereas the short-run elasticity is a measure of the cyclical behavior of tax revenues. Other studies have used different methodologies to estimate the income elasticity of taxes but have often failed to find unbiased and consistent estimates. Moreover, this literature has overlooked the key difference between short-run and long-run elasticities. As a consequence, the difference between how revenue from the tax base will grow as output grows (long-run elasticity) and how much revenue from that tax base will fluctuate over the business cycle (short-run elasticity) has not always been clearly stated.

The standard methodology to estimate the elasticity of tax revenue with respect to income was based on the following equation:

(1) $Ln(B_t) = \alpha + \beta Ln(Y_t) + \varepsilon_t$

where B_t is the level of the tax base at time t and Y_t is the level of aggregate income in that period. The coefficient β is the income elasticity of revenue from this tax base.

Depending on whether variables in equation (1) are stationary or not, the estimation of β may be problematic. Using adequate proxies for the bases of personal income tax, corporate income tax, sales tax, and excise taxes, as well as GDP for income, S&B find that all variables (in natural logs) are non-stationary according to standard Augmented Dickey-Fuller (ADF) tests. The main implication of this finding is that an equation like (1) would be useful to estimate the long-run relationship between Y and B, but that a stationary version of both variables is needed to estimate the short-run relationship. ADF tests still find evidence of non-stationarity in all variables after adjusting for a deterministic trend. However, all variables show stationarity in first (log) differences. Thus, the correct equation to estimate the short-run relationship between tax bases and GDP is:

(2) $\Delta Ln(B_t) = \alpha + \beta \Delta Ln(Y_t) + \varepsilon_t$

where Δ is the first difference operator.

Another problem stemming from the non-stationarity of the variables in equation (1) is that the estimates of the β coefficient (i.e., the long-run elasticity) will be asymptotically biased and its standard error will be inconsistently estimated.

In order to deal with these problems, S&B suggest the introduction of two econometric techniques. First, the use of Dynamic Ordinary Least Squares (DOLS) including leads and lags of the change in the independent variable so as to correct the estimated coefficient bias, as shown by Stock and Watson (1993). Second, the application of the Newey-West (1987) correction to obtain consistent estimated standard errors.

S&H also include a standard error correction term—that is, the lagged residual obtained from the estimation of equation (1)—in equation (2) to capture the adjustment of the variables to the deviations from their long-run (equilibrium) relationship.[3] Including the error correction term, equation (2) is reformulated as:

[3]An alternative procedure would be to test for the existence of a long-run relationship between B and Y—that is, the existence of a co-integration vector—using standard tests such as the trace test. If this is not rejected,

(3) $\Delta Ln(B_t) = \alpha + \theta \Delta Ln(Y_t) + \phi e_{t-1} + \varepsilon_t$

where e_{t-1} is the lagged residual from the estimation of equation (1). Thus, the dynamics of tax revenue is determined by the short-run elasticity (θ) and the error correction term (ϕ).

S&B estimate long-run elasticities (equation (1)) using OLS and DOLS and short-run elasticities (equations (2) and (3)) for the United States in 1951–1991. Taxes considered include PIT, CIT, sales tax (ST), motor fuel tax (MFT), and alcohol tax (AT). Tax bases are proxied by personal taxable income and adjusted gross income, corporate taxable income, retail sales and non-food retail sales, motor fuel consumption, and liquor store sales, respectively. Results are shown in Table 2.

Table 2. Tax Base Elasticity Estimates in the United States

	Estimates of long-run elasticity		**Estimates of short-run elasticity**	
Dependent variable	**Levels - OLS[a]**	**Levels - DOLS[b]**	**Regular difference model[c]**	**Error correction model[d]**
Personal taxable income (PIT)	1.235	1.215	1.195	1.164
Adjusted gross income	0.977	0.945	1.015	0.970
Corporate taxable income (CIT)	0.691	0.670	3.562	3.369
Retail sales (ST)	0.691	0.660	1.084	1.039
Non-food retail	0.732	0.701	1.431	1.377
Motor fuel consumption (MFT)	1.098	0.996	0.731	0.729
Liquor store sales	0.259	0.254	-0.024	-0.011

Source: Sobel and Holcombe (1996), Table 2.
[a] Equation (1).
[b] Equation (1) including leads and lags of the change in the independent variable.
[c] Equation (2).
[d] Equation (3).
Note: All estimated elasticity coefficients are statistically significant at the 1 percent level, except for the short-run elasticity estimated for liquor store sales using both difference models.

the Johansen (1988) estimation method could be applied to estimate the long-run elasticity and its error correction model representation to estimate the short-run elasticity.

A first inspection of the results leads to the realization that both long-run and short-run elasticities estimated using different models are fairly close. But the fact that estimated long-run elasticities are practically identical does not mean that the corresponding short-run elasticities are also the same. For instance, comparing CIT to ST, while it is true that the two taxes would have similar long-run growth potential, it is incorrect to extrapolate this conclusion to their short-run behavior. Indeed, Table 2 shows that the CIT is much more volatile over the business cycle than the ST (estimated short-run elasticities well above 3 versus short-run elasticities just above 1, respectively). This has implications for the trade-off between long-run growth and short-run variability of tax bases. Figures presented in Table 2 show that it is possible to reduce revenue variability without sacrificing long-run growth. For instance, both the PIT and the MFT have a higher long-run growth rate and also a lower cyclical variability than the CIT. In addition, while the PIT has similar cyclical variability than the ST, it has significantly higher long-run potential. Thus, the trade-off between growth and variability is not automatic, as had been assumed in the past, that is, higher long-run elasticities (more growth potential) do not necessarily imply higher short-run elasticities (more variability over the business cycle).

Bruce, Fox and Tuttle (2006) (BFT, hereafter) extend the methodology of S&B to examine the relative dynamic responses of PIT and ST bases to changes in income for 52 states in the United States for the period 1967–2000. Their analysis permits the estimation of asymmetric short-run responses depending on the deviations from long-run equilibrium as pioneered by Granger and Lee (1989). Equation (4) shows how such asymmetries can be tested, by adding a dummy variable ($DRES_t$) that takes the value of 1 in case of a positive lagged residual and 0 otherwise:

$$(4)\ \Delta Ln(B_t) = \alpha + \Delta\beta_1 Ln(Y_t) + \Delta\beta_2 Ln(Y_t) * DRES_t + \phi_1 e_{t-1} + \phi_2 e_{t-1} * DRES_t + \varepsilon_t$$

Their results show that short-run elasticities of the ST and the PIT are significantly higher when the lagged residual of the long-term relationship is positive (above equilibrium). As regards the estimated error correction coefficient, it is also higher in the equilibrium case above (i.e., the adjustment process to long-run equilibrium is faster) for the PIT, but lower for the ST.

While S&B and BFT differentiate short-run and long-run responses of tax bases to changes in income, they implicitly assume that the elasticity of tax revenue with respect to the tax base is equal to 1. This means that tax collection efficiency remains constant over time, and it is therefore not affected by the business cycle.

Questioning this implicit assumption, Wolswijk (2009) estimates short-run and long-run elasticities of tax revenue with respect to the tax base for the period 1971–2005 in the Netherlands. Following standard procedures to differentiate between tax revenue buoyancy and tax revenue elasticity, he removes the effects of discretionary measures on the tax revenue series.[4] In order to evaluate the asymmetries in the response of tax revenue with respect to imbalances in the long-term relationships between tax revenue and the tax base, the following equation is estimated:

$$(5)\ \Delta Ln(T_t) = \alpha + \Delta\beta_1 Ln(B_t) + \Delta\beta_2 Ln(B_t) * DRES_t + \phi_1 e_{t-1} + \phi_2 e_{t-1} * DRES_t + \varepsilon_t$$

where T_t is the tax revenue in period t.

Wolswijk's results show that short-run elasticities are different from long-run elasticities, that short-run elasticities are state-dependent, and that the adjustment process is asymmetric (Tables 5 and 6). These findings strongly support the advisability of estimating tax revenue elasticities with respect to tax bases differentiating between the long-run and the short-run, as well as allowing for the possibility of asymmetries in the error correction parameters.

In the case of Latin American countries, Martner (2006) estimates short-run and long-run GDP buoyancies of tax revenue for six Latin American countries using quarterly data between some point in the 1990s up to 2004 or 2005, depending on the country.[5] The estimation is carried out using OLS based on the following dynamic formulation:

$$(6)\ Ln(T_t) = \alpha + \beta Ln(Y_t) + \gamma Ln(T_{t-1}) + \varepsilon_t$$

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[4] See, Jenkins, Kuo, and Shukla (2000) for the methodology to do so.

[5] Despite the fact that this paper refers to these estimations as "elasticities," they are actually buoyancies, as no adjustment is made to the series to exclude variations due to tax policy modifications.

where the subscript *t-1* refers to the corresponding variable lagged one period. In this setting, the estimate of β is the short-run buoyancy, while the long-run buoyancy corresponds to the static long-run solution $\beta/(1-\gamma)$.

Results are shown in Table 3. All estimates are statistically significant at standard levels. In all cases, long-run estimates are much higher than short-run estimates. The highest values are recorded by Colombia. Long-run buoyancy is close to unity in Costa Rica and Peru, and, to a lesser extent, in Chile.

Table 3. Long-run and Short-run Buoyancy of Total Tax Revenue in Latin American Countries

	Long-run buoyancy	Short-run buoyancy
Argentina	1.67	0.67
Chile	1.15	0.78
Colombia	2.66	1.95
Costa Rica	1.03	0.64
Mexico	1.30	0.31
Peru	1.05	0.41

Source: Martner (2006).
Notes: Estimation by OLS. All estimates are statistically significant at standard levels.

On the other hand, Vladkova-Holler and Zettlemeyer (2008) (VHZ, hereafter) estimate long-run elasticities of non-commodity tax revenue with respect to GDP for eight Latin American countries applying three alternative estimation methods. Results, presented in Table 4, show that all estimated long-run elasticities are statistically significant at the 1 percent level. Differences in the estimates of income elasticities of tax revenue using OLS and DOLS are consistent with the differences found by S&H in the estimation of income elasticities of tax bases shown in Table 1. A major shortcoming of these results is sample size, which ranges from 10 to 24 observations. Of course, this limits the number of leads and lags included in the DOLS estimation. Another shortcoming is that this paper does not provide estimations for short-run elasticities. Overall, according to the DOLS estimates, income elasticities of non-commodity tax revenues are different from 1 only for Argentina, Colombia, and El Salvador, but it is economically near unity in most cases. It would be interesting to extend the analysis undertaken by VHZ (2008) in two directions to overcome the shortcomings stated above, first, to use larger samples and second, to estimate both long-run and short-run income elasticities of tax revenue (see Table 4).

Table 4. Long-run Income Elasticity of Central Government Non-commodity Tax Revenue in Latin American Countries

Country	OLS	Johansen	DOLS	Observations	Period
Argentina	1.00	1.06	1.02	24	1980–2007
Brazil	1.03	1.14	1.03	15	1992–2007
Chile	0.96	0.85	0.94	13	1993–2007
Colombia	1.10	..	1.21	10	1993–2007
Costa Rica	1.11	..	1.01	14	1991–2007
El Salvador	1.36	..	1.27	14	1992–2007
Panama	0.80	..	0.67	13	1992–2007
Peru	1.11	..	0.85	16	1992–2007

Source: VHZ (2008), Table 2.

Note: All estimated long-run income elasticities are statistically significant at the 1 percent level.

Last but not least, following a totally different methodology—that is, calibration rather than econometric estimation—, Daude, Melguizo, and Neut (2011) (DMN, hereafter) calculate long-run elasticities of non-commodity tax revenue in eight Latin American countries, following the so-called OECD method presented by Giorno et al. (1995), van den Noord (2000), and Gourard and André (2005). Their calculations cover PIT, SSC, CIT, indirect taxes, and overall tax revenue.

As shown in Table 5, long-run elasticities of non-commodity tax revenue range from 1.13 in Mexico to 1.27 in Argentina and Costa Rica. At the individual country level, except for Colombia, these elasticities are larger than the ones estimated by VHZ (2008) using DOLS (Table 4). In most countries, the largest elasticity is exhibited by indirect taxes, whereas the smallest is presented by CIT. We shall return to these calculations in Section 6.

Table 5. Long-run Income Elasticity on Non-commodity Tax Revenue in Latin American Countries

	PIT	SSC	CIT	Indirect taxes	All taxes
Argentina	1.06	1.04	1.03	1.14	1.27
Brazil	1.01	1.06	1.04	1.14	1.25
Chile	1.04	1.01	1.00	1.10	1.15
Colombia	1.00	1.01	1.06	1.07	1.14
Costa Rica	1.06	1.12	1.01	1.09	1.27
Mexico	1.06	1.01	1.02	1.05	1.13
Peru	1.07	1.03	1.01	1.07	1.18
Uruguay	1.05	1.06	1.03	1.11	1.25

Source: DMN (2011).

4. Methodology

In order to estimate short-run and long-run elasticities of taxes with respect to GDP, the impact of output growth on tax revenue is estimated according to the equation:

$$(6)\ Ln(T_t) = \alpha_0 + \alpha_1 DBT_t + \beta Ln(Y_t) + +\varepsilon_t$$

where *T* is tax revenue (deflated by CPI and filtered to exclude changes due to tax policy and administration modifications), *Y* is real GDP and *DBT* is a dummy variable that takes the value of 1 during bad times, and 0 otherwise. Bad times are defined as years where GDP per capita declines.[6] Theoretically, there exists a long-run relationship between tax revenue and GDP.[7] Additionally, we implement co-integration tests below to further validate long-run elasticities estimations (equation (6)). The estimation of (6) using DOLS provides unbiased estimates of long-run elasticities. Standard errors are estimated using Heteroskedasticity and Autocorrelation Consistent Standard Errors (HACSE).[8] The number of leads and lags are chosen guided by the statistical significance of the associated parameters (Hendry and Doornik, 2001).[9] The maximum lead/lag is set to 5, the number chosen by Solbe and Holcombe (1996), whereas the minimum is set to 1. The corresponding short-run elasticities are estimated from:

$$(7)\ \Delta Ln(T_t) = \alpha_0 + \alpha_1 DBT_t + \beta \Delta Ln(Y_t) + +\phi_1 e_{t-1} + \phi_2 e_{t-1} * DRES_t + \varepsilon_t$$

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[6] In the exploration of the relationship between tax revenue efficiency and the output gap, Sancak, Velloso, and Xing (2010) define bad times as periods where GDP growth is below potential. Alternatively, they define bad times as periods where GDP growth is at least one percentage point below potential GDP growth. Here a much simpler definition is used avoiding the technicalities involved in the estimation of potential GDP, which is beyond the scope of this paper.

[7] Sobel and Holcombe (1996), Bruce, Fox, and Tuttle (2006), and Wolswijk (2009) seem to rely on this fact to estimate long-run elasticities in equations similar to (6).

[8] Andrews (1991) introduces a more general approach than Newey and West (1987) to deal with potential heteroskedasticity and autocorrelation in the residuals.

[9] Sobel and Holcombe (1996: 542) set the number of leads and lags at 5 on the basis that this is "what is typical." Bruce, Fox and Tuttle (2006) choose this number according to the Schwarz Bayesian Criterion. Wolswijk (2009) sets it at 1 to save on degrees of freedom. VHZ (2008) choose it according to the Wald test but with limitations due to the small size of their samples.

where *DRES* is a dummy variable that takes the value of 1 when the lagged residual of (6) – that is, e_{t-1} – is negative and 0 otherwise. The parameter ϕ_2 captures the potential asymmetric adjustment towards long-run equilibrium. The estimation of (7) gives unbiased estimates of short-run elasticities.

This approach is applied individually to LAC (8) using quarterly data from some year in the 1990s to 2007, 2008, or 2010 (depending on data availability) at the central or federal government level. The focus is on VAT, PIT, and CIT. These three taxes account for an important share of total tax revenue in LAC (8), as mentioned above (see Table 1). Seasonal dummy variables are included in all regressions. The same analysis is undertaken for SSC in countries that report quarterly data on revenue from these contributions, that is, Argentina, Brazil, and Peru.

In the case of Central American countries, which do not have quarterly data on revenue variables available for long enough periods of time, a panel data estimation of long-run elasticities is carried out using annual data for 1990–2008. The countries included are Costa Rica, El Salvador, Guatemala, and Panama (CA (4)). The same three taxes are evaluated, together with total tax revenue. The estimation method applied is fixed effects. The estimated equation is:

(8) $Ln(T_{it}) = \alpha_0 + \alpha_1 DBT_{it} + \beta Ln(Y_{it}) + \varepsilon_{it}$

where the subscript i denotes the country.

5. Data

All variables are taken from official national sources, and correspond to the central government (see Appendix 2). In the case of income tax revenue variables for Colombia, Mexico, and Venezuela, which do not disclose information about personal and corporate income tax, the annual share is applied to total income tax revenue quarters based on the Inter-American Development Bank (IDB) database. In the absence of any additional information regarding the share of each component of the income tax, this is the least arbitrary assumption. The inclusion of seasonal dummies in all quarterly regressions would capture all kinds of seasonality in tax collection. This procedure implies that the last observations of the CIT and PIT revenue series correspond either to 2007 or 2008, the last available observations in the IDB database. The same procedure is applied in the case of annual income tax revenue data in Costa Rica, El Salvador, and Guatemala, which do not disclose income tax revenue in CIT and PIT.

All revenue variables are filtered out so as to exclude changes associated with modifications of rates and/or bases and other tax administration reforms. The list of adjustments is presented in Table 6. Total tax revenue is filtered out according to the adjustments made to the revenue series of PIT, CIT, and VAT. No adjustments were made to exclude commodity-related tax revenue.

Table 6. Adjustments in Tax Revenue Variables in LAC (8)

	Corporate income tax	Personal income tax	VAT
Argentina	Step dummy from 2004Q1 for tax reform.	Step dummy from 2004Q1 for tax reform	Step dummy from 2004Q1 for tax reform
Brazil	No adjustment	Step dummy from 1998Q1	No adjustment
Chile	Adjustment from 2002Q1 for increase in rate from 15 percent to 16 percent Adjustment from 2003Q1 for increase in rate from 16 percent to 16.5 percent Adjustment from 2004Q1 for increase in rate from 16.5 percent to 17 percent	Adjustment from 2002Q1 for reduction in maximum rate from 45 percent to 43 percent Adjustment from 2003Q1 for reduction in maximum rate from 43 percent to 40 percent	Adjustment from 2004Q3 for increase in rate from 18 percent to 19 percent
Colombia	Adjustment from 2007Q1 for reduction in rate from 35 percent to 34 percent Adjustment from 2008Q1 for reduction in rate from 34 percent to 33 percent Step dummy from 2001Q1	Adjustment from 2007Q1 for reduction in maximum rate from 35 percent to 34 percent Adjustment from 2008Q1 for reduction in maximum rate from 34 percent to 33 percent	Adjustment from 1999Q1 for reduction in rate from 16 percent to 15 percent Adjustment in 2001Q1 for increase in rate from 15 percent to 16 percent Step dummy from 2003Q1
Ecuador	Step dummy from 2002Q1 for tax reform Adjustment from 2008Q1 for increase in maximum rate from 25 percent to 35 percent	Step dummy from 2002Q1 for tax reform Adjustment from 2008Q1 for increase in maximum rate from 25 percent to 35 percent	Step dummy from 2002Q1 for tax reform Adjustment from 2000Q1 for increase in rate from 10 percent to 12 percent
Mexico	Adjustment from 1994Q1 for reduction in rate from 35 percent to 34 percent Adjustment from 2002Q1 for reduction in rate from 34 percent to 32 percent Adjustment from 2005Q1 for reduction in rate from	Adjustment from 1999Q1 for increase in maximum rate from 35 percent to 40 percent Adjustment from 2003Q1 for reduction in maximum rate from 40 percent to 35 percent	Adjustment from 1995Q1 for increase in rate from 10 percent to 15 percent Adjustment from 2010Q1 for increase in rate from 15 percent to 16 percent

	32 percent to 30 percent Adjustment from 2006Q1 fro reduction in rate from 30 percent to 28 percent Step dummy from 2005T1	Adjustment from 2004Q1 for reduction in maximum rate from 35 percent to 33 percent Step dummy from 2003Q1 Step dummy from 2008T1 for reform that unified the rate at 17.5 percent	
Peru	Adjustment from 2002Q1 for reduction in rate from 30 percent to 27 percent Adjustment from 2004Q1 for increase in rate from 27 percent to 30 percent Step dummy from 2003Q1	Adjustment from 2001Q1 for reduction in maximum rate from 30 percent to 20 percent Adjustment from 2002Q1 for increase in maximum rate from 20 percent to 27 percent	Adjustment from 2003Q3 for increase in rate from 18 percent to 18.7 percent Adjustment from 2003Q4 for increase from 18.7 percent to 19 percent
Venezuela	Step dummy from 2002Q1 for tax reform	Step dummy from 2000Q1 Step dummy from 2002Q1 for tax reform	Adjustment from 2000Q3 for reduction in rate from 15.5 percent to 14.8 percent Adjustment from 2000Q4 for reduction in rate from 14.8 percent to 14.5 percent Adjustment from 2002Q1 for increase in rate from 14.5 percent to 15.5 percent Adjustment from 2002Q3 for increase in rate from 15.5 percent to 15.7 percent Adjustment from 2002Q4 for increase in rate from 15.7 percent to 16 percent Adjustment from 2004Q3 for reduction in rate from 16 percent to 15.7 percent Adjustment from 2004Q4 for reduction in rate from 15.7 percent to 15 percent Adjustment from 2005Q4 for reduction in rate from 15 percent to 14 percent Adjustment from 2007Q1 for reduction in rate from 14 percent to 13 percent Adjustment from 2007Q2 for reduction in rate from 13 percent to 11 percent Adjustment from 2007Q3 for reduction in rate from 11 percent to 9 percent Adjustment from 2009Q2 for increase in rate from 9 percent to 12 percent Step dummy from 2002Q1 for tax reform

Source: Authors' elaboration based on official data and information, and VHZ (2008).

Bad times are defined as any year where real GDP per capita declines. These are 1999–2002 and 2009 in Argentina; 1998–1999, 2001, 2003, and 2009 in Brazil; 1999 and 2009 in Chile; 1998–1999 in Colombia; 1999 and 2009 in Ecuador; 1995, 2001–2002, and 2009 in Mexico; 1998–1999, 2001, and 2009 in Peru; and 1998–1999, 2002–2003, and 2009–2010 in Venezuela. The bad times dummy variable (DBT) takes the value of 1 in all these years and 0 otherwise.

In the case of Central American countries, bad times years are 1996, 2000–2001, and 2009 in Costa Rica; 2009 in El Salvador; 2001 and 2009 in Guatemala; and 1995 and 2001 in Panama. The adjustments undertaken to tax revenue series are presented in Table 7.

Table 7. Adjustments in Tax Revenue Variables in CA (4)

	Corporate income tax	Personal income tax	VAT
Costa Rica	Adjustment from 2003 for increase in rate from 30 percent to 36 percent Adjustment from 2004 for reduction in rate from 36 percent to 30 percent	No adjustment	Adjustment from 1991 for increase in rate from 10 percent to 13 percent Adjustment from 1992 for reduction in rate from 13 percent to 12 percent Adjustment from 1993 for reduction in rate from 12 percent to 11 percent Adjustment from 1994 for reduction in rate from 11 percent to 10 percent Adjustment from 1995 for increase in rate from 10 percent to 11.25 percent Adjustment from 1996 for increase in rate from 11.25 percent to 15 percent Adjustment from 1997 for reduction in rate from 15 percent to 13.5 percent Adjustment from 1998 for reduction in rate from 13.5 percent to 13 percent
El Salvador	No adjustment	Adjustment from 2002 for increase in maximum rate from 30 percent to 50 percent	Adjustment from 1991 for increase in rate from 10 percent to 13 percent Adjustment from 1992 for reduction in rate from 13 percent to 12 percent Adjustment from 1993 for reduction in rate from 12 percent to 11 percent Adjustment from 1994 for

			reduction in rate from 11 percent to 10 percent Adjustment from 1995 for increase in rate from 10 percent to 11.5 percent Adjustment from 1996 for increase in rate from 11.25 percent to 13 percent
Guatemala	Adjustment from 1993 for reduction in rate from 34 percent to 25 percent Adjustment from 1995 for increase in rate from 25 percent to 30 percent Adjustment from 1999 for reduction in rate from 30 percent to 27.5 percent Adjustment from 2000 for reduction in rate from 27.5 percent to 25 percent Adjustment from 2001 for increase in rate from 25 percent to 31 percent	Adjustment from 1993 for reduction in maximum rate from 34 percent to 25 percent Adjustment from 1995 for increase in maximum rate from 25 percent to 30 percent Adjustment from 1998 for reduction in maximum rate from 30 percent to 25 percent Adjustment from 2011 for increase in maximum rate from 25 percent to 31 percent	Adjustment from 1996 for increase in rate from 7 percent to 10 percent Adjustment from 2003 for increase in rate from 10 percent to 12 percent
Panama	Adjustment from 1992 for reduction in rate from 47.5 percent to 45 percent Adjustment from 1993 for reduction in rate from 45 percent to 42 percent Adjustment from 1994 for reduction in rate from 42 percent to 34 percent Adjustment from 1995 for reduction in rate from 34 percent to 30 percent Adjustment from 2006 for reduction in rate from 30 percent to 29 percent Adjustment from 2007 for reduction in rate from 29 percent to 27 percent	Adjustment from 1992 for reduction in maximum rate from 56 percent to 30 percent Adjustment from 2005 for reduction in maximum rate from 30 percent to 27 percent Adjustment from 2010 for reduction in maximum rate from 27 percent to 25 percent	Adjustment from 2010 for increase in rate from 5 percent to 6.2 percent Adjustment from 2011 for increase in rate from 6.2 percent to 7 percent

Source: Authors' elaboration based on official data and information, and VHZ (2008).

To give a sense of the order of magnitude of the adjustments made to tax revenue series using the procedure described above, Table 8 presents changes in PIT, CIT, and VAT revenue as a share of original series in LAC (8). No adjustment was made to any series in Argentina and Brazil, as changes in revenue induced by tax policy modifications were isolated by the inclusion of step dummy variables in the estimation of the corresponding elasticities, as indicated in Table 6. In Colombia, adjustments made in revenue series amounted to less than one percentage point of original series in the three taxes considered. The largest adjustment was undertaken in the VAT revenue in Mexico (32.6 percent), followed by Venezuela (30.6 percent). Evidently, the magnitudes of these adjustments are positively related to changes in the corresponding tax rates. For instance, in Mexico the VAT rate was increased from 10 percent to 16 percent during the analyzed period.

Table 8. Adjustments to Tax Revenue Series *(change as a share of original series)*

	CIT	PIT	VAT
Argentina	0.0	0.0	0.0
Brazil	0.0	0.0	0.0
Chile	9.8	10.1	3.6
Colombia	0.55	0.55	0.54
Ecuador	13.1	14.6	15.4
Mexico	11.4	0.9	32.6
Peru	0.8	11.5	3.9
Venezuela	0.0	0.0	30.6

Source: Authors' estimations.
Notes: No adjustments were made for Argentina and Brazil. Changes in revenue induced by tax policy changes were filtered out including step dummies in the estimation of the corresponding elasticities as indicated in Table 6.

6. Econometric Results

Estimations of long-run and short-run elasticities from equations (6) and (7) are undertaken. Despite the non-stationary nature of both GDP and tax revenue, the estimation of (6) would be valid as theoretically there exists a long-run relationship between GDP and tax revenue. Appendix 3 shows unit root tests of the residuals of estimations of equation (6) for LAC (8) countries. These tests confirm a co-integration relationship between GDP and tax revenue (in natural logs) in most cases. [10] All estimations of equations (6) and (7) include seasonal dummy variables.[11]

[10] Should the residuals are found to be stationary, this is an indication of co-integration between Ln(GDP) and Ln(Tax revenue). This is called the Engle-Granger methodology to test for co-integration (see Enders (2004), chapter 6). As noted above, Sobel and Holcombe (1996), Bruce, Fox, and Tuttle (2006) and Wolswijk (2009) indirectly appeal to the existence of a theoretical long-run relationship between output and tax revenue to estimate long-run elasticities, as they do not present any co-integration test.

[11] Appendix 4 presents an alternative treatment of seasonality, namely, the estimation of the equations with seasonally adjusted series of GDP and tax revenue variables. Results are fairly robust.

A general inspection of the results shown in Table 9 reveals that most long-run elasticities estimates are statistically significant at standard levels, whereas short-run elasticities are statistically different from 0 in only three countries in the case of VAT (Argentina, Brazil, and Venezuela), two countries in the case of total taxes and PIT (Brazil and Colombia), and one country in the case of CIT (Colombia). Argentina, Brazil, Colombia, and Venezuela present two short-run elasticities estimates that are statistically significant, whereas Chile, Ecuador, Mexico, and Peru do not exhibit any. In the absence of any previous study that has attempted to estimate short-run elasticities of taxes in Latin American countries, no comparison is possible. Surprisingly, in Chile only the long-run elasticity of PIT is statistically significant. Overall, tax systems are more elastic in the long-run than in the short-run in all countries, which is in tune with the estimates of tax buoyancies provided by Martner (Table 3).

Table 9. Long-run and Short-run Elasticities of Taxes with Respect to GDP in LAC (8)

	Total taxes		CIT		PIT		VAT	
	Long-run[a]	Short-run	Long-run[a]	Short-run	Long-run[a]	Short-run	Long-run[a]	Short-run
Argentina	1.97***	1.21***	1.33***	2.45	1.27***	-2.15	1.94***	1.31**
Brazil	1.14***	0.04	3.26***	-1.79	2.99***	5.87***[b]	0.33	1.20**
Chile	0.59	0.31	2.00	0.36	1.57*	0.16	0.47	-0.21
Colombia	1.68***	1.03	2.44***	3.80***	2.25***	3.91*	1.61***	-2.79
Ecuador	2.23***	0.97	2.86***	-5.76	1.70***	-6.55	1.74***	0.28
Mexico	0.91***	0.73	1.50***	0.28	0.72***	-0.50	1.53***	0.66
Peru	1.40***	0.50	2.68***	2.01	1.60***	-0.67	1.36***	0.30
Venezuela	2.06***	1.05***	3.59***	0.49	0.97	0.92	2.65***	1.04***

Source: Authors' estimations.

Notes: All regressions for long-run elasticities estimated by DOLS using quarterly data including seasonal dummy variables. Estimation periods vary among countries, depending on data availability. Leads and lags orders chosen according to the statistical significance of the associated parameters. Standard errors of estimated parameters are HACSE. The program used is PcGive 10.1.

*** statistically significant at the 1 percent level.

** statistically significant at the 5 percent level.

* statistically significant at the 10 percent level.

In order to compare our long-run elasticities estimates to those reported by other papers, Table 11 shows our estimates, together with those from VHZ (2008) and of DMN (2011). As can be seen, our long-run total tax revenue elasticity estimates are larger than those estimated by VHZ (2008) for non-commodity tax revenue, except for Chile. Although these authors also use DOLS in their estimations, the differences in the estimated elasticities suggest that the commodity component of CIT revenue is more sensitive to GDP growth than the non-commodity component.[12] The comparison of the long-run elasticities estimates herein with long-run non-commodity tax revenue elasticities calculated by DMN (2011) provides mixed results, as in some cases our estimates are larger than the ones of these authors (Argentina, Colombia, and Peru), whereas in other cases, the opposite is true (Brazil, Chile, and Mexico). Considering the three sets of estimates, on average, the more elastic tax systems appear to be in Argentina, Colombia, and Brazil. On the contrary, Chile seems to have the less responsive tax system to GDP growth. The latter seems surprising, as this country is usually deemed as a good example of adequate economic policy management in Latin America.

Table 10. Comparison of Long-run Elasticities of Tax Revenue with Respect to GDP[a]

	Total tax revenue	Non-commodity tax revenue	CIT	PIT
Argentina				
Own estimations	1.97	…	1.33	1.27
VHZ (2008)	…	1.02	…	…
DMN (2010)	…	…	0.83	3.61
Brazil				
Own estimations	1.14	…	3.26	2.99
VHZ (2008)	…	1.03	…	…
DMN (2010)	…	…	1.17	2.72
Chile				
Own estimations	0.59[b]	…	2.00[b]	1.57
VHZ (2008)	…	0.94	…	…
DMN (2010)	…	…	0.66	3.51
Colombia				
Own estimations	1.68	…	2.44	2.25
VHZ (2008)	…	1.21	…	…
DMN (2010)	…	…	0.96	2.65
Mexico				
Own estimations	0.91	…	1.50	0.72
VHZ (2008)	…	…	…	…
DMN (2010)	…	…	0.69	2.95
Peru				
Own estimations	1.40	…	2.68	1.60
VHZ (2008)	…	0.85	…	…
DMN (2010)	…	…	0.38	5.33

Source: Table 10, VHZ (2008) and DMN (2010).
[a] VHZ (2008) and DMN (2010) do not include either Ecuador or Venezuela.
[b] Not statistically significant.

[12] These authors do not make any adjustment to the PIT or the VAT revenue to exclude the commodity-related component.

With respect to individual taxes, the comparison of our estimates with those from DMN (2011) reveals that ours are higher in the case of CIT, but lower in the case of PIT, with the exception of Brazil. In many cases the differences are quite significant in magnitude. This is presumably associated with the different methods applied, as these authors used the so-called OECD method to estimate elasticities of taxes, as mentioned in Section 3.

Table 11 presents F tests, which evaluate the null hypotheses that estimated parameters are equal to 1, and that long-run estimated elasticities are equal to the corresponding short-run ones. As can be seen, most long-run estimated elasticities that are statistically significant are also statistically different from 1. Thus, in Argentina, Colombia, Ecuador, Peru, and Venezuela, long-run estimated elasticities of total taxes are indeed greater than 1. They are statistically not different from 1 in Brazil and Mexico. In all cases where short-run estimated elasticities are statistically significant, they are also different from the corresponding long-run estimated parameters. Finally, with the exception of PIT short-run estimated elasticity in Brazil, in all other cases where these estimated coefficients appear as statistically different from 0, it is not possible to reject the null hypothesis that they are equal to 1.

Table 11. Statistical Tests of Estimated Elasticities

	Null hypothesis: long-run estimated elasticity is equal to 1	**Null hypothesis: short-run estimated elasticity is equal to 1**	**Null hypothesis: long-run estimated elasticity is equal to the short-run estimated elasticity**
Argentina			
Total taxes	F(1,47) = 51.720***	F(1,48) = 0.40188	F(1,47) = 31.844***
CIT	F(1,38) = 2.1850	…	…
PIT	F(1,41) = 0.46317	…	…
VAT	F(1,35) = 32.743***	F (1,42) = 0.25659	F(1,35) = 14.726***
Brazil			
Total taxes	F(1,49) = 1.1414	…	…
CIT	F(1,54) = 121,08***	…	…
PIT	F(1,49) = 73.312***	F(1,52) = 10.665***	F(1,49) = 154.64***
Chile			
PIT	F(1,36) = 0.39521	…	…
Colombia			
Total taxes	F(1,32) = 29.653***	…	…
CIT	F(1,28) = 101.89***	F(1,28) = 2.0165	F(1,28) = 89.780***
PIT	F(1,26) = 54.260***	F(1,28) = 1.9995	F(1,26) = 96.418***
VAT	F(1,30) = 28.823***	…	…

Ecuador			
Total taxes	F(1,32) = 49.554***	…	…
CIT	F(1,32) = 3.4471	…	…
PIT	F(1,32) = 3.2187	…	…
VAT	F(1,32) = 17.399***	…	…
Mexico			
Total taxes	F(1,59) = 0.10692	…	…
CIT	F(1,48) = 8.0292***	…	…
PIT	F(1,48) = 1.2153	…	…
VAT	F(1,55) = 10.737***	…	…
Peru			
Total taxes	F(1,31) = 10.452***	…	…
CIT	F(1,39) = 25.547***	…	…
PIT	F(1,40) = 25.595***	…	…
VAT	F(1,28) = 21.382***	…	…
Venezuela			
Total taxes	F(1,34) = 37.987***	F(1,37) = 0.018465	F(1,34) = 34.477***
CIT	F(1,28) = 11.795***	…	…
VAT	F(1,23) = 169.10***	F(1,32) = 0.045829	F(1,23) = 161.02***

Source: Authors' calculations.
*** rejects the null hypothesis at the 1 percent level of significance.

Going back to Table 9, regarding long-run elasticities of total tax revenue, the estimated parameters range from 0.91 in Mexico to 2.23 in Ecuador. In Argentina and Venezuela, the only countries where short-run elasticities of total taxes are statistically significant, these are smaller than their corresponding long-run estimates. This means that total tax revenue fluctuates less over the business cycle than in the long run in these two countries.

The estimated parameters for long-run elasticities of CIT range from 1.33 in Argentina to 3.59 in Venezuela. In Colombia, the short-run elasticity estimate of CIT (3.80) is larger than the long-run estimate (2.44), indicating more volatility over the business cycle than tax revenue growth potential as output grows.

Regarding long-run elasticities of PIT, the minimum estimated value is 0.72 in Mexico, whereas the maximum is 2.99 in Brazil. In Brazil, the short-run elasticity is larger, reaching a value of 5.87. In Colombia, the other country where the short-run elasticity of PIT is statistically significant, its value is also above the long-run estimate (3.91 and 2.25, respectively). Therefore, in both Brazil and Colombia the short-run fluctuations of PIT revenue over the business cycle are larger than in the long run.

Last but not least, long-run elasticities estimates of VAT range from 1.36 in Peru to 2.65 in Venezuela. Long-run elasticities estimates in Venezuela and Argentina (1.94) are above short-run estimated coefficients (1.31 and 1.04, respectively). Therefore, similar to total tax revenue but contrary to the cases of CIT and PIT (in countries where short-run elasticities estimates prove to be statistically significant), VAT shows lower variability over the business cycle than in the long run.

Analyzing one country at a time, a number of issues arise in terms of the comparison both between taxes (total, CIT, PIT, VAT) and within taxes (long-run and short-run elasticities). In Argentina, total tax revenue exhibits the greatest long-run elasticity of the four categories considered (1.97), closely followed by VAT (1.94). Both taxes exhibit smaller variability over the business cycle than in the long run.

This contrasts with the Brazilian case, where the largest long-run estimated elasticity is that of CIT (3.26) followed by PIT (2.99). The latter tax shows greater variability over the business cycle (short-run elasticity of 5.87) than in the long run. The short-run elasticity of VAT is 1.20, but the long-run estimated parameter is not statistically different from 0.

Colombia also presents larger long-run estimated elasticities for the CIT (2.44) and the PIT (2.25). In both cases, the corresponding short-run elasticities are larger (3.80 and 3.91, respectively), revealing more variability over the business cycle than in the long run.

In Ecuador, the largest long-run estimated elasticity corresponds to CIT (2.86), followed by total taxes (2.23). No short-run estimated elasticity showed statistical significance at standard levels.

In the case of Mexico, the largest long-run estimated elasticities correspond to VAT (1.53) and CIT (1.50). In addition, this country shows the smallest long-run estimated elasticities of total taxes (0.91) and PIT (0.72) of all countries. No short-run estimated elasticity proved to be statistically different than 0.

Peru is another country where no short-term estimated elasticity is statistically significant. Similarly to Brazil and Colombia, the largest long-term estimated parameters correspond to CIT (2.68) and PIT (1.60).

Finally, Venezuela exhibits the largest long-term estimated elasticities in CIT and VAT (3.59 and 2.65, respectively). In the VAT tax as well as in total taxes, the short-run estimated coefficients (1.04 and 1.05, respectively) reveal that their revenue fluctuations over the business cycle are lower than in the long run.

Overall, most countries exhibit long-run elasticities well above 1 for most tax categories, except for Mexico, where neither the estimated elasticities of total taxes nor the PIT are statistically different from 1 (in Chile, no long-run elasticity appears to be statistically different from 0 at conventional significance levels). The largest long-run estimated elasticities correspond to CIT, with the exception of Argentina and Mexico, where VAT long-run estimated coefficients are larger. PIT long-run estimated elasticities are below the corresponding CIT and VAT parameters, except for Colombia and Peru, where the corresponding VAT parameters are smaller. In cases where short-run estimated elasticities are statistically significant (Argentina and Venezuela), total taxes and VAT exhibit larger long-run estimated parameters than the corresponding short-run ones. In contrast, CIT and PIT show larger estimated elasticities in the short run than in the long run in countries where they exhibit statistical significance at standard levels (Colombia, and Brazil and Colombia, respectively).

Results found for LAC (8) individual countries are consistent with the long-run elasticities estimated for CA (4) as a whole, using panel data. As can be seen in Table 13, all long-run estimated elasticities are both statistically different from 0 and from 1 at standard significance levels. The largest long-term estimated elasticity corresponds to PIT (2.10), followed by VAT (1.94).

Table 12. Long-run Elasticities of Taxes with Respect to GDP in CA (4)[a]

Total taxes	CIT	PIT	VAT
1.44*** F(1,70) = 31.8[b]	**1.47***** F(1,70) = 12.8[b]	**2.10***** F(1,70) = 28.1[b]	**1.94***** F(1,70) = 52.3[b]

Source: Authors' estimations.
[a] Includes Costa Rica, El Salvador, Guatemala, and Panama. Estimation method is fixed effects. Sample period is 1990–2008 with annual frequency. The program used is STATA 8.0.
[b] Statistically different from 1 at the 1 percent level.
*** statistically different from 0 at the 1 percent level.

With respect to SSC, results for Argentina, Brazil, and Peru are presented in Appendix 5. They reveal long-run elasticities above 1 for the three countries, and short-run elasticity below 1 for Argentina. Short-run elasticities in Brazil and Peru turned to be not statistically significant at conventional levels.

7. Elasticities of Tax Revenue in Bad Times and Normal Times

An interesting extension of the previous analysis is to explore whether long-run and short-run elasticities vary during bad times and normal times. This analysis is conducted by including a multiplicative dummy variable that takes the value of 1 during bad times and 0 otherwise in equations (6) and (7). As before, bad times are defined as any year where GDP per capita declines. The modified equations become, respectively:

$$(9)\ Ln(T_t) = \alpha_0 + \alpha_1 DBT_t + \beta_1 Ln(Y_t) + \beta_2 Ln(Y_t) * DBT + \varepsilon_t$$

$$(10)\ \Delta Ln(T_t) = \alpha_0 + \alpha_1 DBT_t + \beta_1 \Delta Ln(Y_t) + \beta_2 \Delta Ln(Y_t) * DBT + \phi_1 e_{t-1} + \phi_2 e_{t-1} * DRES_t + \varepsilon_t$$

Thus, the key parameter is β_2. It captures the difference between long-run and short-run elasticities of tax revenue during bad times and normal times. When it is not statistically different from 0, then the respective elasticity does not vary. In this case, the parameter β_1 becomes the elasticity in all times. But when β_2 is statistically significant, the elasticities of tax revenue are affected by the stage of the economy. Results for LAC (8) are presented in Table 13.

Table 13. Long-run and Short-run Elasticities of Taxes with Respect to GDP in LAC (8) During Bad Times and Normal/All Times

	Long-run elasticities[a]		Short-run elasticities	
	All/normal times[b]	Bad times[c]	All/normal times[b]	Bad times[c]
Argentina				
Total tax revenue	1.99***	-0.03	1.36***	-0.25
CIT	1.22***	0.27	3.05*	-0.96
PIT	0.83**	2.09***	-2.99	-1.85
VAT	1.75***	0.37	0.71	0.65***
Brazil				
Total tax revenue	1.20***	-0.15	0.16	0.07
CIT	3.14***	3.72**	...	0.80
PIT	3.03***	-0.11	5.23***	-0.42
VAT	0.43	0.08	0.75	1.00
Chile				
Total tax revenue	0.52	2.03**	0.30	-1.02
CIT	2.00	...	0.24	-15.00
PIT	1.57*	…	0.19	0.37
VAT	0.27	5.49***	-0.21	-0.39

Colombia				
Total tax revenue	1.67***	-3.23	0.82	5.96
CIT	2.35***	5.24	3.70	4.23
PIT	2.24***	6.36	3.91*	...
VAT	1.46***	1.20	…	...
Ecuador				
Total tax revenue	2.23***	11.75	1.06	14.45
CIT	2.86***	-51.00	-5.83	21.29
PIT	1.70***	81.46	-3.69	38.16
VAT	1.74***	...	0.28	...
Mexico				
Total tax revenue	0.52***	1.83***	0.01	1.31*
CIT	1.25***	2.77***	-0.92	1.88*
PIT	0.56**	1.26*	-0.97	-0.23
VAT	1.27***	2.14***	...	1.53***
Peru				
Total tax revenue	1.53***	-0.24	0.64	0.23
CIT	2.99***	-0.87	2.47*	-0.97
PIT	1.71***	-0.24	-0.65	-1.29
VAT	1.30***	0.05	0.40	0.60
Venezuela				
Total tax revenue	2.22***	-0.24	0.83	1.12
CIT	3.31***	1.39	-1.37	0.81
PIT	0.38	5.27*	0.57	2.34
VAT	2.97***	-0.55	1.39***	-0.35

Source: Authors' estimations.
[a] All regressions estimated by DOLS using quarterly data including seasonal dummy variables. Leads and lags orders chosen according to the statistical significance of the associated parameters. Standard errors of estimated parameters are HACSE. The program used is PcGive 10.1. When estimated parameters are statistically significant but have implausible values in the original regression (equation (6) or (7)), the corresponding variable is dropped from the model and the regression is re-estimated. Implausible values are either negative or positive above 6 that are statistically significant.
[b] All times when the estimated parameter for bad times is statistically not different from 0; normal times when the parameter is statistically significant during bad times.
[c] Equals $\beta_1 + \beta_2$ when both parameters are statistically different from 0 or when both are not significant. Equals β_2 when it is not statistically different from 0, but β_1 does; or when it is statistically significant, and β_1 does not. Bad times are defined as any year when GDP per capita declines.
*** statistically significant at the 1 percent level.
** statistically significant at the 5 percent level.
* statistically significant at the 10 percent level.

Results shown in Table 14 reveal that, with the exception of Chile, in the other countries four or three long-run elasticities in all/normal times are statistically significant at standard levels, and in some cases with values above 2 or 3. On the contrary, in most cases short-run elasticities appear to be not statistically different from 0 during both all/normal times and bad times. These results are fully consistent with the estimations shown in Table 10, which do not include the multiplicative dummy variable for bad times.

In terms of long-run elasticities, Mexico is the country where the values for bad times are statistically significant for all four tax categories analyzed. The elasticities in bad times more than double those during normal times in the cases of CIT and PIT and are more than three times larger for total tax revenue. The difference is nearly 70 percent in the case of VAT. This indicates much more responsiveness of tax revenue with respect to GDP during the rainy days, making the authorities' capacity to implement counter-cyclical fiscal policies much more difficult, as revenue associated with the main tax categories (CIT, PIT, and VAT) would suffer a rather significant drain in these circumstances. This phenomenon would be similar in Argentina and Venezuela in the case of PIT only and, to a much lesser extent, in Brazil for CIT.

The distinction of long-run elasticities between normal times and bad times seems to explain why no such elasticities were found to be statistically significant in Chile (with the exception of PIT) as shown in Table 9 in the last section. As Table 13 shows, long-run elasticities are statistically significant both for total tax revenue and for VAT during bad times in Chile. In the latter case, elasticity exhibits a value as high as 5.49. Thus, one would expect a substantial reduction in VAT revenue during bad times, which demands attention, as this category represented more than 40 percent of total tax revenue in 2010 (Table 1).

Moving on to short-run elasticities, Mexico is the country where most estimated short-run elasticities during bad times are found to be statistically significant, which is consistent with what is found for long-run elasticities. For the four tax categories, the elasticities are higher in the long run than in the short run (the short-run elasticity of PIT is statistically not different from 0), indicating that the fluctuation of revenue is lower over the business cycle during bad times. Comparing these results with those shown in Table 10, which do not make any distinction between normal times and bad times, it is found that short-run elasticities are statistically significant for total tax revenue, CIT, and VAT during bad times only.

Overall, estimations differentiating between normal times and bad times shown in Table 13 are consistent with those presented in Table 9, which do not include the multiplicative dummy variable for bad times. More importantly, these estimations indicate that Chile exhibits significant long-run elasticities for total taxes and VAT during bad times. This provides an explanation for the puzzling result found in the last section, namely, that these long-run elasticities (along with that of CIT) were not statistically different from 0 in Chile. In addition, Mexico presents long-run elasticities for the four tax categories that are much larger during bad times than normal times. Finally, short-run elasticities in Mexico are statistically different from 0 in the cases of total tax revenue, CIT, and VAT only during bad times. In all cases, short-run elasticities during bad times are smaller than the corresponding long-run elasticities.

8. Concluding Remarks

The main purpose of this paper was to find out whether elasticities of taxes with respect to GDP in Latin American countries are different in the long run than in the short run. Although the econometric results (Section 6) show that most short-run elasticities in LAC (8) countries are not statistically different from 0 at standard significance levels, they lead to interesting conclusions. First, and contrary to what is usually assumed, tax systems in most Latin American countries are fairly elastic. This is true in Argentina, Colombia, Ecuador, Peru, and Venezuela, where the estimated long-run elasticities of total taxes are statistically and economically well above 1. The same is true in the case of the CA (4) countries as a whole.

Second, from the three individual taxes considered, CIT shows the largest estimated long-run elasticities in most LAC (8) countries, namely Brazil, Colombia, Ecuador, Peru, and Venezuela, although in Ecuador the estimated coefficient is not statistically different from 1. On the other hand, in Argentina the most elastic tax appears to be the VAT. In Mexico, the estimated long-run elasticities of CIT and VAT are almost equal, and statistically different from 1. At this level of analysis, the Chilean case seems puzzling, as no estimated elasticity proves to be statistically significant at conventional levels, with the exception of the long-run elasticity of PIT. This time the general result for LAC (8) countries is not consistent with what is found in CA (4), where PIT exhibits the largest estimated long-run elasticity.

Third, despite all short-run elasticity estimates that show statistical significance at standard levels, they do not appear to be statistically different from 1 (with the exception of the short-run elasticity of PIT in Brazil), and based on the estimated coefficient values alone, total taxes as well as VAT exhibit smaller fluctuations over the business cycle (short-run elasticities) than revenue potential as GDP grows (long-run elasticities) in Argentina and Venezuela. On the contrary, CIT shows greater variability over the business cycle than in the long run in Colombia, while the same is true for PIT in Brazil and Colombia. Nothing can be said in this regard for Chile, Ecuador, Mexico, and Peru, as no estimated short-run elasticity shows statistical significance at usual levels. Short-run elasticities could not be estimated for CA (4).

Extending the analysis by allowing changes in elasticities during bad times and normal times (Section 7), the fourth conclusion of the paper is that Mexico exhibits significantly larger long-run elasticities during bad times than in normal times. By the same token, all long-run elasticities are larger than the corresponding short-run ones during bad times.

Fifth, long-run elasticities of total tax revenue and VAT in Chile are statistically different from 0 during bad times, but not in normal times, nor when no distinction is allowed between these two situations in the economy. No short-run elasticity proved to be significant in either bad times or normal times.

Finally, with respect to the elasticity of tax systems in different countries, considering our estimates together with those of VHZ (2008) and DMN (2011), the more elastic tax systems in the countries considered in the three papers are in place in Argentina, Colombia, and Brazil, whereas the least elastic appears to be in Chile. The latter seems surprising, as this country is deemed to be an example of good economic policies throughout Latin America.

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Appendix 1

Table 1.1. Tax Revenue Sources

	Period	Frequency	Taxes	Source	Web page
Argentina	1996Q1–2010Q4	Quarterly	Total, CIT, PIT, VAT	Administración Federal de Ingresos Públicos (AFIP)	www.afip.gob.ar
Brazil	1990Q1–2010Q4	Quarterly	Total, CIT, PIT, VAT	Banco Central de Brasil	www.bcb.gov.br
Chile	1999Q1–2010Q4	Quarterly	Total, CIT, PIT, VAT	Tesorería General de la República de Chile	www.tesoreria.cl
Colombia	1998Q1–2010Q4	Quarterly	Total, IT, VAT	Dirección de Impuestos y Aduanas Nacionales (DIAN)	www.dian.gov.co
Ecuador	1997Q1–2010Q4	Quarterly	Total, CIT, PIT, VAT	Servicio de Rentas Internas de Ecuador	www.sri.gob.ec
Mexico	1990Q1–2010Q4	Quarterly	Total, IT, VAT	Secretaría de Hacienda y Crédito Público	www.shcp.gob.mx
Peru	1998Q1–2010Q4	Quarterly	Total, CIT, PIT, VAT	Superintendencia Nacional de Administración Tributaria (SUNAT)	www.sunat.gob.pe
Venezuela	1998Q1–2010Q3	Quarterly	Total, IT, VAT	Ministerio de Planificación y Finanzas	www.mf.gov.ve
Costa Rica	1990–2009	Annual	Total, IT, VAT	Banco Central de Costa Rica	www.bccr.fi.cr
El Salvador	1990–2009	Annual	Total, IT, VAT	Portal de Transparencia Fiscal, Ministerio de Hacienda	www.transparenciafiscal.gob.sv
Guatemala	1990–2009	Annual	Total, IT, VAT	Ministerio de Finanzas	www.minfin.gob.gt
Panama	1990–2009	Annual	Total, CIT, PIT, VAT	Dirección General de Ingresos	www.dgi.gob.pa

Source: Authors' elaboration.

Appendix 2

Unit Root Tests of the Residuals of Long-run Estimations

Table A2.1. Augmented Dickey-Fuller Tests

(Null hypothesis: The residual has a unit root)

	Test with constant	Test with constant and trend	Test with constant, trend and seasonal dummies
Argentina			
Total	-1.71 (1)	-1.92 (1)	-1.85 (1)
CIT	-6.19 (1)***	-6.24 (1)***	-6.02 (1)***
PIT	-5.13 (1)***	-5.06 (0)***	-4.87 (0)***
VAT	-5.65 (1)***	-5.62 (0)***	-5.42 (0)***
Brazil			
Total	-3.18 (2)**	-3.15 (2)*	-3.07 (2)*
CIT	-5.88 (0)***	-5.81 (0)***	-5.61 (0)***
PIT	-5.38 (0)***	-5.32 (0)***	-5.16 (0)***
VAT	-2.52 (0)	-2.48 (0)	-2.38 (0)
Chile			
Total	-1.82 (1)	-1.57 (1)	-2.56 (0)
CIT	-4.35 (0)***	-5.38 (0)***	-4.86 (0)***
PIT	-1.96 (0)	-2.95 (0)	-2.74 (0)
VAT	-1.76 (0)	-0.45 (0)	-0.23 (0)
Colombia			
Total	-6.34 (1)***	-6.16 (1)***	-5.91 (1)***
CIT	-6.22 (0)***	-6.10 (0)***	-5.85 (0)***
PIT	-5.01 (0)***	-4.93 (0)***	-4.66 (0)***
VAT	-8.43 (0)***	-8.32 (0)***	-7.88 (0)***
Ecuador			
Total	-4.35 (0)***	-4.34 (0)***	-4.09 (0)***
CIT	-6.98 (0)***	-6.89 (0)***	-6.44 (0)***
PIT	-7.40 (0)***	-7.05 (0)***	-7.79 (0)***
VAT	-2.76 (0)	-2.72 (0)	-2.56 (0)
Mexico			
Total	-3.28 (0)**	-3.26 (0)*	-3.18 (0)*
CIT	-4.12 (0)**	-4.08 (0)**	-3.97 (0)**
PIT	-5.21 (0)***	-5.19 (0)***	-5.05 (0)***
VAT	-2.47 (0)	-2.52 (1)	-2.43 (1)
Peru			
Total	-3.64 (0)***	-3.64 (0)**	-3.49 (0)*
CIT	-2.35 (0)	-2.22 (0)	-2.02 (0)
PIT	-3.50 (1)**	-3.39 (1)*	-3.30 (1)*
VAT	-4.19 (0)***	-4.18 (0)**	-3.99 (0)**
Venezuela			
Total	-4.03 (0)***	-4.02 (0)**	-3.82 (0)**
CIT	-5.78 (1)***	-6.27 (1)***	-5.97 (1)***
PIT	-5.62 (1)***	6.15 (1)***	-5.86 (1)***
VAT	-3.47 (0)**	-3.41 (0)*	-3.25 (0)*

Source: Authors' estimations.
*** = statistically significant at the 1 percent level.
** = statistically significant at the 5 percent level.
* = statistically significant at the 10 percent level.
Note: Rejection of null hypotheses implies stationary residuals and hence co-integration between GDP and tax revenue in natural logs. Figures in parenthesis indicate the number of first difference residuals lags used to undertake ADF tests.

Appendix 3

Estimation of Long-run and Short-run Elasticities using Seasonal Dummy Variables and Seasonally Adjusted Series

Table A3.1. Long-run and Short-run Elasticities of Tax Revenue with Respect to GDP in LAC (8) using Seasonal Dummy Variables

	Total taxes		CIT		PIT		VAT	
	Long-run[a]	Short-run	Long-run[a]	Short-run	Long-run[a]	Short-run	Long-run[a]	Short-run
Argentina	1.97***[b]	1.21***	1.33***	2.45	1.27***	-2.15	1.94***[b]	1.31**
Brazil	1.14***	0.04	3.26***[b]	-1.79	2.99***[b]	5.87***[b]	0.33	1.20**
Chile	0.59	0.31	2.00	0.36	1.57*	0.16	0.47	-0.21
Colombia	1.68***[b]	1.03	2.44***[b]	3.80***	2.25***[b]	3.91*	1.61***[b]	-2.79
Ecuador	2.23***[b]	0.97	2.86***	-5.76	1.70***	-6.55	1.74***[b]	0.28
Mexico	0.91***	0.73	1.50***[b]	0.28	0.72***	-0.50	1.53***[b]	0.66
Peru	1.40***[b]	0.50	2.68***[b]	2.01	1.60***[b]	-0.67	1.36***[b]	0.30
Venezuela	2.06***[b]	1.05***	3.59***[b]	0.49	0.97	0.92	2.65***[b]	1.04***

Source: Authors' estimations.

[a] All regressions estimated by DOLS using quarterly data. Estimation periods vary among countries, depending on data availability. Leads and lags orders chosen according to the statistical significance of the associated parameters. Standard errors of estimated parameters are HACSE. The program used is PcGive 10.1.

[b] Statistically different from 1.

*** statistically significant at the 1 percent level.

** statistically significant at the 5 percent level.

* statistically significant at the 10 percent level.

Table A3.2.Long-run and Short-run Elasticities of Tax Revenue with Respect to GDP in LAC (8) using Seasonally Adjusted Series

	Total taxes		CIT		PIT		VAT	
	Long-run	Short-run	Long-run	Short-run	Long-run	Short-run	Long-run	Short-run
Argentina	2.02***[b]	1.18***	1.39***	2.21	1.29***	2.05	1.96***[b]	1.90***
Brazil	1.18***[b]	0.68	3.23***[b]	-0.49	3.49***[b]	4.09***[b]	0.37	2.03***
Chile	0.55	0.33	-0.53	2.61	1.65	-0.09	0.45	0.06
Colombia	1.77***[b]	0.83	2.18***[b]	3.36**	2.32***[b]	2.50*	1.59***[b]	0.35
Ecuador	2.20***[b]	0.73	2.99***	1.84	1.81***[b]	0.45	1.60***[b]	0.50
Mexico	1.55***[b]	1.01	2.22***[b]	0.64	0.92***	0.13	2.24***[b]	1.61***
Peru	1.15***[b]	1.93***	2.72***[b]	3.19***	1.60***[b]	0.82	1.35***[b]	0.91***
Venezuela	2.39***[b]	1.08**	4.74***[b]	1.15	0.33	2.40*	2.66***[b]	1.01***
Chile1	0.55	0.33	-0.53	2.61	1.65	-0.09	-7.15***	-0.41
Chile2	0.45	0.25	-2.55	13.74***	1.65	-0.09	0.45	0.06

Source: Authors' estimations.
[a] All regressions estimated by DOLS using quarterly data. Estimation periods vary among countries, depending on data availability. Leads and lags orders chosen according to the statistical significance of the associated parameters. Standard errors of estimated parameters are HACSE. All series were seasonally adjusted using the Census X-12 methodology. The program used is E-views 7.1.
[b] Statistically different from 1.
*** statistically significant at the 1 percent level.
** statistically significant at the 5 percent level.
* statistically significant at the 10 percent level.

Results shown in Table A3.1 and A3.2 are fairly consistent in terms of both values and statistical significance. The main differences are in the following cases:

i. The estimated long-run elasticity of total tax revenue in Mexico is statistically significant and higher than 1 using seasonally adjusted series. It is statistically different from 0 but not statistically different from 1 using seasonal dummy variables.
ii. The estimated short-run elasticity of VAT in Mexico is significant at the 1 percent level using seasonally adjusted series. It is not statistically different from 0 using seasonal dummy variables. Its value (1.61) is lower than its corresponding long-run value, but it is not statistically different from 1. It is the only short-run elasticity that shows statistical significance in this country.
iii. The estimated short-run elasticities of total tax revenue, CIT and VAT in Peru turned out to be statistically significant at the 1 percent level using seasonally

adjusted series, but they are not statistically different from 1 at standard significance levels. On the contrary, the corresponding long-run elasticities are statistically larger than 1 in total taxes, CIT, PIT and VAT. No short-run elasticity proved to be statistically different from 0 using seasonal dummy variables.

iv. In Venezuela, the estimated short-run elasticity of PIT is statistically significant at the 10 percent using seasonally adjusted series, but it is not statistically different from 1 at conventional significance levels. It is not statistically different from 0 using seasonal dummy variables.

v. The only long-run elasticity that showed statistical significance using seasonal dummy variables in Chile is that of PIT. However, no long-run estimated elasticity is statistically different from 0 using seasonally adjusted series in this country. No short-run elasticity is statistically significant at standard levels using either seasonal dummy variables or seasonally adjusted series.

Appendix 4

Elasticities of Social Security Contributions

A similar analysis as the one in Section 6 for CIT, PIT, VAT, and total tax revenue is conducted for SSC in Argentina, Brazil, and Peru using quarterly data. In Argentina and Brazil, SSC include both pensions and health care contributions, whereas in Peru SSC include pensions contributions only. Sample periods are 1996Q1 to 2010Q4 in Argentina and Brazil, and 1999Q3 to 2010Q4 in Peru. Table A4.1 presents the adjustments made to the SSC series to filter out all policy-induced changes in revenue.

Table A4.1. Adjustments in SSC in Argentina, Brazil, and Peru

Argentina	Adjustment in 2002Q1 for decrease in rate from 35 percent to 29 percent Adjustment from 2002Q2 for increase in rate from 29 percent to 30 percent Adjustment in 2003Q2 for increase in rate from 30 percent to 32 percent Adjustment in 2003Q3 for increase in rate from 32 percent to 34 percent Adjustment from 2003Q4 for increase in rate from 34 percent to 36 percent
Brazil	No adjustment as rate of 28 percent remained constant during the whole period
Peru	Adjustments according to changes in the weighted average rate Weights given by the relative importance of the contributions collected from the private system and from the public system

Source: Authors' elaboration based on official information and IDB database.

Table A4.2 shows long-run and short-run elasticity estimations of SSC from equations (6) and (7). In all three countries, long-run elasticities are statistically significant and are also statistically different from 1. These results are consistent with those found for total taxes, CIT, PIT, and VAT shown in Table 10, confirming the highly elastic tax systems in these three countries in the long run. Regarding short-run elasticities, only Argentina exhibits statistical significance. In this country, the estimated short-run elasticity is also statistically different from 1 at standard significance levels. Estimated long-run and short-run elasticities are statistically different from one another at the 1 percent level.[13]

Table A5.2 Long-run and Short-run Elasticities of SSC with Respect to GDP

	Long-run[a]	Short-run
Argentina	2.58*** $F(1,44) = 131.02$[b]	0.53** $F(1,46) = 3.56$[c]
Brazil	2.12*** $F(1,44) = 81.22$[b]	0.67
Peru	1.80*** $F(1,34) = 57.03$[b]	0.44

Source: Authors' estimations.

[a] Estimated by DOLS using quarterly data including seasonal dummy variables. Leads and lags orders chosen according to the statistical significance of the associated parameters. Standard errors of estimated parameters are HACSE. The program used is PcGive 10.1.

[b] Statistically different from 1 at the 1 percent level.

[c] Statistically different from 1 at the 10 percent level.

*** statistically significant at the 1 percent level.

** statistically significant at the 5 percent level.

[13] $F(1,46) = 68.19$.