Short- and Long-Run Fiscal Elasticities: International Evidence

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Abstract

Using dynamic heterogeneous panel data models, this paper estimates short- and long-run fiscal elasticities with respect to various cyclical factors for more than 90 countries. We find the terms of trade are significant in explaining primary fiscal revenues. Moreover, revenue elasticities with respect to real GDP on average are larger than one in the short-run and bigger in developing countries than in advanced economies both, in the short- and long-run. The analysis highlights the importance of considering short- and long-run elasticities with respect to other effects than the output gap, particularly terms of trade, when computing structural balances.

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Contents

Abstract 1

I. Introduction 4

II. Literature Review 7

III. The Econometric Methodology and Empirical Strategy 10
- A. The Econometric Model 10
- B. Empirical Strategy 14
- C. Data 17

IV. Model Estimation and Results 19
- A. Panel Unit Root and Co-integration Tests 19
- B. Elasticity Estimation Results 22
- C. Sub-sample Analyses 27
- D. Robustness Checks 30

V. Structural Fiscal Balances 32

VI. Concluding Remarks 34

References 37
Appendices 42

Tables

1. Summary of the Processed Panel Data 18
2. Pairwise Correlation Coefficients: Level and First-order Difference....19
3. Panel Unit Root Test: Levels 20
4. Panel Unit Root Test: First-order Differences 20
5. Panel Co-integration Tests: P-values....21
6. Fiscal Revenue Elasticities (Mean): Real GDP and GDP Deflator, Full Sample....23
7. Fiscal Revenue Elasticities (Mean): Baseline Model, Full Sample....24
8. Fiscal Revenue Elasticities (Mean): Equation (12), Full Sample....26
9. Fiscal Revenue Elasticities (Mean): Baseline Model, Sub-samples, Case 1 28
10. Fiscal Revenue Elasticities (Mean): Equation (12), Sub-samples, Case 1 29
11. Fiscal Revenue Elasticities (Mean): Baseline Model, Sub-samples, Case 2 29
12. Oil exporter countries (Oil CEC) and Trader 31

A1. List of variables and data source....42
A2. Summary of the Raw Panel Data 42
A3. Summary of the Raw Panel Data 43
A4. IMF FAD-specific Country Groupings....44
A5. Commodity Exporter Countries (CEC): 50 Countries....44
A6. Short-run Fiscal Revenue Elasticities: Model (2), PMG 45
A7. Short-run Fiscal Revenue Elasticities: Model (5), PMG 46
A8. Long-run and Short-run Fiscal Revenue Elasticities: Equation (12), Sub-samples....47
A9. Fiscal Revenue Elasticities for....48
A10. Financial Crisis Episodes for Model (5): IMF Database, 1970-2007....48
A11. Fiscal Revenue Elasticities (Mean): Equation (12), Robustness Check 1 49
A12. Fiscal Revenue Elasticities (Mean): Equation (12), Robustness Check 2 49
A13. Fiscal Revenue Elasticities (Mean): Equation (12), Robustness Check 3 50

Figures

1. Primary Fiscal Revenue and Terms of Trade, 1970–2012 6
2. US Structural Primary Fiscal Balance 33
3. Brazil Structural Primary Fiscal Balance....33

B.1.. Italy Structural Primary Fiscal Balance 51
B.2. China Structural Primary Fiscal Balance 51

I. INTRODUCTION

How large are fiscal revenue elasticities around the world? The fiscal effects of the global financial crisis (GFC) have sparked tax experts and policy makers to think more carefully about how to measure the fiscal stance and trends in fiscal balances. For that, an important factor is to have accurate estimations of fiscal elasticities—including those for the transitory and trend revenue components.

However, very few studies so far have attempted to estimate short- and long-run revenue elasticities for a broader country sample than the OECD countries. This is particularly the case for analyses controlling for other effects beyond the business cycle, such as terms-of-trade-, commodity price-, and asset price cycles. Such cyclical factors are also relevant for fiscal policies in other countries than the advanced economies (AEs) only.

This paper attempts to fill this gap by estimating short- and long-run revenue elasticities for an enlarged sample of 96 countries. It examines both possibilities of heterogeneous and homogeneous country elasticities with respect to a broad set of cyclical factors: output gap, GDP deflator, terms of trade, financial variables, and unemployment rate.[1] We then calculate structural fiscal balances with the elasticities estimated for selected cases, providing a trend-cycle decomposition for different economic variables.

The short- and long-run elasticities are estimated via dynamic heterogeneous vector error correction (VEC) panel models. Heterogeneous short-run sensitivities are estimated across countries. In turn, long-run elasticities are estimated either heterogeneously for each country, by using the mean-group (MG) estimator (Pesaran and Smith, 1995); or homogeneously for all countries, via the pooled mean-group (PMG) estimator (Pesaran et al., 1999).

Several reasons cause the revenue elasticities to differ in the short- and long-run (see Sobel and Holcombe, 1996; and Bruce et al., 2006). In one hand, long run elasticities measure the stable relationship between tax bases and an economic variable over an extended horizon. For example, the tax base sensitivity to income may tend to grow over time as income steadily grows. If such long run elasticity exceeds one, *ceteris paribus*, this implies that above-trend income steadily improves the overall balance through the revenue side of the budget. Long-run elasticities may further depend on the economic structure, improvements in revenue collection and other trends in an economy.

[1] Given the coverage of our country sample, no data on policy parameters or one-off measures are systematically available. Thus, we use a statistical procedure to correct for outliers and for discretionary changes in tax policy revenues, making the definition of tax elasticities here close to the one of tax buoyancy (Belinga et al, 2014).

Short-run elasticities, on the other hand, indicate how a tax base fluctuates over the cycle of the economic variable in analysis (e.g., business cycle). In this sense, short-run elasticities are related to the stabilization function of fiscal policy (Belinga et al., 2014). For instance, if short-run revenue elasticities to income are larger than one, the tax system is deemed as a good automatic stabilizer. However, if they are smaller than one, the tax revenue does not respond in tandem with the cycle and functions less as an automatic stabilizer.[2]

Therefore, understanding the dynamic (short- and long-run) properties of revenues structures is key. This way, tax structures can be adapted to ensure they generate appropriate revenue growth in the future sufficiently funding a publicly desired level of expenditures while stabilizing the economy in the short-run.

We estimate revenue elasticities for four economic variables: real GDP, GDP deflator, terms of trade, and a financial stress index (FSI). A dummy variable for financial crisis episodes is also introduced. When real GDP and GDP deflator are controlled for, the terms of trade and the FSI capture extra effects of international trade and financial markets on a country's nominal aggregate primary revenue.

Apart from our short- and long-run estimations, another main innovation of our analysis is to control for terms of trade (TOT) in a broad range of countries.[3] In countries which substantially depend from commodities exports and imports, TOT may have a significant effect on fiscal revenue. For oil exporter countries, for example, an increase in export prices and then in the terms of trade may augment the export-related fiscal revenue. However, if countries provide considerable tax incentives for exports, an increase in TOT may shift the production towards exporting sectors, having a negative effect on fiscal revenues. So the effect of TOT depends usually on three factors: (i) whether its movement mainly comes from export price or import price; (ii) the country's tax structure related to exports and imports; and (iii) how large is the world demand elasticity for the country's exports (see IMF, 2015a).

Figure 1 conveys the relationship between primary fiscal revenue and TOT in selected groups of countries. For emerging economies and, particularly, oil exporters, this relationship

[2] Swaying tax receipts with the cycle may be an important macroeconomic stabilization tool particularly in countries belonging to monetary unions (e.g., European Monetary Union) given the centralized monetary policy, limitation on the size of the budget deficit, no cyclical cross-country transfer system, and limited price and wage flexibility (Wolswijk, 2007). See also (Fatás and Mihov, 2001 and 2012).

[3] Some studies have already estimated the effect of TOT in selected countries. Turner (2006) considers the case for exceptional movements in TOT for those countries whose production of commodities is a substantial share of output when estimating the SFBs finding a significant positive effect. Rodriguez et al. (2007) study the impact of copper and molybdenum prices on Chile's SFBs. Aydin (2010) studies the case of South Africa, applying a disaggregated method for the calculation of fiscal balances with an emphasis on the effects of commodity and asset prices, and credit cycle as well. In turn, Adler and Magud (2015), Celasun et al. (2015), and Klemm (2015) discuss how important TOT booms are for fiscal performance in Latin America.

seems to be significant and positive; an improvement in TOT leads to larger primary revenues in those economies. In turn, for the full sample of countries the relationship appears to be negative.

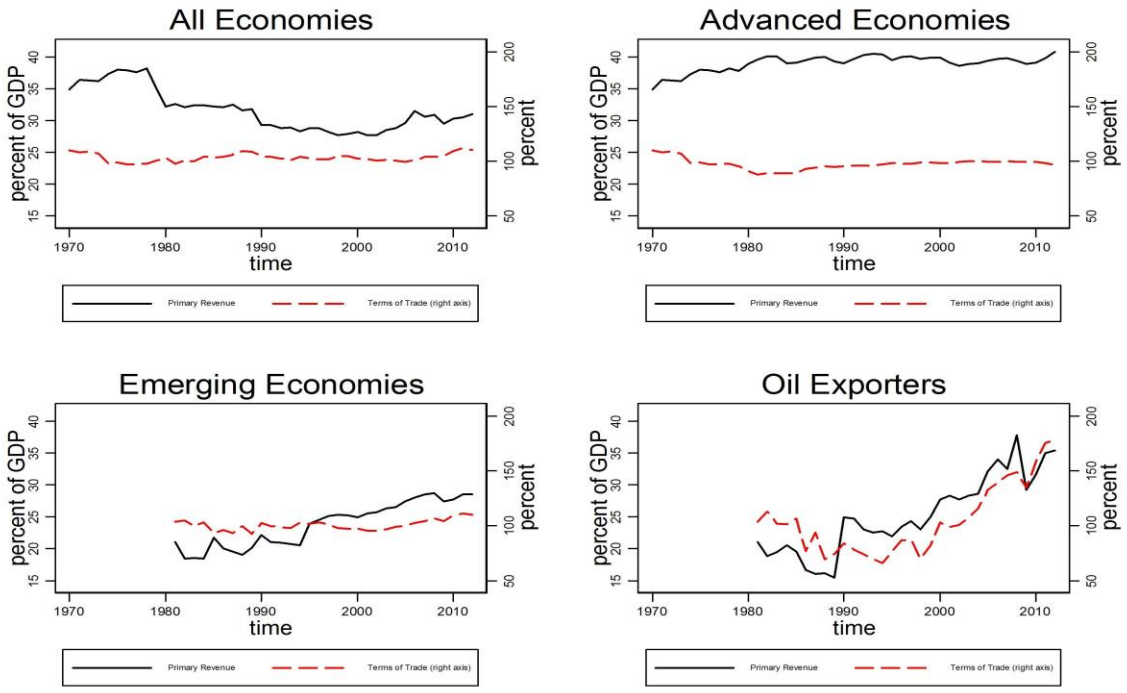

Figure 1. Primary Fiscal Revenue and Terms of Trade, 1970–2012
Source: *World Economic Outlook* database, International Monetary Fund.
Note: Primary fiscal revenue excluding interest earnings from total revenues and is presented in percent of nominal GDP.

Accordingly, our main result is that for the 96 economies covered the TOT elasticity is significant, indicating the importance of using this variable in the calculation of structural fiscal balances. For the total sample that elasticity is indeed negative, but for EMEs and oil exporters, the elasticity is highly significant and positive as expected.

Another important finding is that the short-run elasticity with respect to real GDP is significantly larger than one for our sample. This is particularly the case for low-income countries (LICs), as the subsample analysis indicates. This finding confirms for a broader sample of countries, including emerging economies (EMEs) and LICs, previous results on the importance of fiscal policy in the short-run (Galì, 1994; Fatás and Mihov, 2001; and Debrun and Kapoor, 2010). The estimations also evince that the bracket-creep inflation effect on the tax base exists only for AEs in the long-run. Moreover, financial stress and financial crisis have statistical significance but, on average, marginal influence on long-run revenues in our country sample.

Regarding the country groupings, our analysis indicates that revenue elasticities with respect to real GDP for EMEs and (particularly) LICs are larger than those for AEs both, in the short- and long-run. The long-run effect of terms of trade on revenue is negative for AEs, but positive for EMEs, potentially indicating the effects of TOT on these latter countries' tax bases and revenues. For oil producing and exporting countries the TOT have a strong positive effect on fiscal revenues in the long run. On the contrary, for countries whose taxes on international trade and transactions constitute a large proportion of their total fiscal revenue, TOT has a significant negative long-run effect on revenue, suggesting a shrinking of that tax base. Financial stress, on average, has a positive effect on fiscal revenues for AEs either in the short- or long-run, suggesting effects of taxes on financial and capital transactions in those economies (Matheson, 2011; Poghosyan et al., 2015). However, for EMEs that long-run elasticity is negative, hinting on permanent effects that financial crisis may have in those economies.

With the estimated elasticities, as example of our trend-cycle decomposition, we then calculate the structural fiscal balances for Brazil, China, Italy and the US. For these countries, we illustrate that while the real GDP cycle and GDP deflator cycle explain most part of the fluctuation in fiscal balances, adjusting the balances for cyclical fluctuation of their TOT is also important. Yet, financial stress conditions and crises seem to play a relatively small role in explaining the variability of their balances, even though again their long-run revenue elasticities are statistically significant.

Such findings, therefore, call (i) for an update of fiscal elasticities to include additional cycles beyond that of the output gap; and (ii) for the use of both short- and long-run elasticities in the calculation of structural balances.

The rest of this paper is organized as follows: Section II provides a brief review of the relevant literature; Section III explains the econometric model of dynamic heterogeneous panels, introduces our elasticity-trend methodology to calculate structural fiscal balances, and describes the data explored. Section IV presents and discusses the elasticity estimation results in detail, including those for the sub-sample analyses and robustness checks. The structural fiscal balances calculation for our selected countries is then performed in Section V. At last, Section VI concludes the paper.

II. LITERATURE REVIEW

Bornhorst et al. (2011) define structural fiscal balances as an extension of cyclically adjusted fiscal balances, correcting for a broader range of factors than only for the output gap effect such as asset prices, commodity prices and TOT, inflation effect, and so on. Normally there are three steps to estimate the structural fiscal balances: (i) identify and remove one-off fiscal operations such as public expenditure on a natural disaster; (ii) assess the impact of the

business cycle (output gap) on fiscal revenue and expenditure; and (iii) estimate the effects of other economic cycles or factors. In practice, the second and third steps can be done together, using the elasticity-trend approach.

The elasticity-trend approach consists of three additional steps: (i) estimate the fiscal revenue and expenditure elasticities with respect to real output and other factors such as asset prices and TOT; (ii) perform the trend-cycle decomposition for real output and other factors; and (iii) calculate the trend levels of revenue and expenditure, and then the structural fiscal balances, using the estimated elasticities and trend levels of real output and other factors. Two main methods are used to implement the elasticity-trend approach according to the data availability and the aim of research. One is called the aggregated method for which elasticities are used to measure the sensitivity of total revenue and spending with respect to output gap and other cyclical factors. The other is the disaggregated method for which elasticities specific to various revenue and expenditure components (e.g., personal income taxes, corporate income taxes etc.) are estimated separately. Before applying these techniques, one has to determine what types of cyclical factors including and beyond output gap should be considered.

Another important issue is how to estimate the fiscal elasticities with respect to the different factors chosen to calculate the SFB. Among the existing literature, fiscal elasticities with respect to different factors, such as output gap, asset prices, commodity price and TOT, and inflation, are broadly investigated, either using an aggregated method or a disaggregated method. Girouard and André (2005) and, more recently Price, Dang, and Guillemette (2014) discuss the cyclically adjusted budget balances for OECD countries in detail, adopting a disaggregated method in which different tax categories' elasticities with respect to output gap are estimated separately. The relevant elasticity is then the product of two elasticities: the tax revenue elasticity relative to its base, and the base's elasticity relative to output gap.

When adjusting fiscal balances, inflation is an important factor to be considered. Inflation alters the distributive properties of nominally defined tax systems, and generates bracket-creep effects on tax revenues (Immervoll, 2000; Abiad and Ostry, 2005; Clayes, 2007; and Escolano, 2010). Zeng (2012) examines the determinants of the primary fiscal balances for a panel of countries, and finds that inflation appears to have a positive effect on real fiscal balances. Accordingly, Woo (2003) finds that inflation affects fiscal deficit for developing countries only.

Although not estimating revenue elasticities, Borio et al. (2013) discusses the relationship between financial cycle (represented by credit cycle and house price cycle) and the macroeconomics, including structural fiscal balances. These authors claim that neglecting the financial cycle can significantly mask underlying problems in fiscal policy given that financial booms can flatter the fiscal accounts as illustrated by the recent experiences of Spain and Ireland (see Benetrix and Lane, 2011). More recently, Poghosyan et al. (2015)

describe an operational approach for incorporating the impact of asset prices in the calculation of SFBs. Those authors discuss that not accounting for the fiscal impact of asset price cycles can encourage a procyclical stance if temporarily high revenues are passed through into expenditures. They further find that asset prices are imperfectly synchronized with the business cycle and are quantitatively significant with an average pre-crisis fiscal impact ranging from about ½ to 2 percent of GDP.

Closer to our analysis related to asset prices, Price and Dang (2011) explain the necessity of incorporating the asset prices effects when removing the transitory components of fiscal balances. These authors estimate SFBs correcting for house-price and equity-price cycles for OECD countries in a country-by-country basis. The econometric approach used is an auto-regressive-distributed-lag (ARDL) (1,1,1,…,1) model, which estimates both the short-run and long-run fiscal elasticities with respect to output and asset prices. After obtaining those short-run and long-run elasticities, they adjust the fiscal revenues for the asset price cycles effects measured in terms of deviations from the so-called "fundamental" and smoothed asset prices. Those authors also show that asset price movements are independent of and uncorrelated with the output cycle. Also looking at asset prices cycles Kanda (2010) performs a case study of Ireland, investigating the asset booms' effect on structural fiscal positions. Farrington et al. (2008) further adjust fiscal balances for equity and stock market effects.

Finally our approach follows the earlier papers on the estimation of short- vs. long-run revenue elasticities. Such literature was initiated by Dye and McGuire (1991) and started using time series techniques with Sobel and Holcombe (1996), who also examined more tax instruments. More recently, Bruce et al. (2006) analyze short- and long-run responses of state personal tax revenues and sales tax bases to changes in state personal income using the same techniques. These authors show that the average long-run elasticity for income taxes is more than double that for sales taxes in US states. Wolswijk (2007) provides estimates for short- and long-run base elasticities for the Netherlands for the period 1970–2005, finding that short-run elasticities often are lower than long-run ones in the Netherlands, particularly when taxes are subdued. Consequently, shocks to tax revenues tend to be aggravated by the dynamics of short-run elasticities. Thus, ignoring those differences between short- and long-run elasticities may contribute to negative revenue 'surprises' (tax receipts being below the long-run value) and an incorrect assessment of the fiscal stance. At last, Belinga et al. (2014) estimates short- and long-run tax buoyancy in OECD countries between 1965 and 2012. They find that, for aggregate tax revenues, short-run tax buoyancy does not significantly differ from one in the majority of countries; yet, it has increased since the late 1980s, indicating that tax systems have generally become better automatic stabilizers. Long-run buoyancy exceeds one in about half of their sample, implying that GDP growth has helped improve structural fiscal deficit ratios.

Overall, two points are important emphasizing about the existing literature. First of all, most of the existing papers study SFBs and estimate the relevant short- and long-run elasticities for only one country (case study), or a group of (advanced) economies (such as OECD countries). A general investigation of across a large sample of countries including emerging and developing economies is scarce. Second, few studies estimate the fiscal elasticities with respect to all the important cyclical factors, including TOT. This paper tries to close those gaps by estimating country-specific short- and long-run revenue and expenditure elasticities with respect to a broad set of business cycle and other transitory effects (including TOT), and to a large set of countries, as many emerging and developing countries. Both the heterogeneity and homogeneity of country-specific elasticities are examined in detail.

III. The Econometric Methodology and Empirical Strategy

A. The Econometric Model

To estimate fiscal elasticities, we adopt a panel data version of the econometric model of Price and Dang (2011). We use an ARDL model distinguishing between short-run and long-run elasticities. Our *ARDL(p,q,q,...,q)* panel data model can be described as follows:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \boldsymbol{\delta}_{ij}^{'} \boldsymbol{X}_{i,t-j} + \mu_i + \varepsilon_{it}, \quad (1)$$

where $i = 1, 2, \ldots, N$, are the countries in our sample; $t = 1, 2, \ldots, T$, are the years in our sample; y_{it} is the logarithmic value of aggregate primary fiscal revenue PFR_{it} or primary expenditure PFE_{it} for country i in year t; $\boldsymbol{X}_{it} = (x_{it}^1, x_{it}^2, \ldots, x_{it}^k)'$ is a $k \times 1$ vector of explanatory variables for country i in time t; μ_i represents the country-specific fixed effects; the coefficient for the lagged depend variable; λ_{ij}, is a scalar; and the coefficient $\boldsymbol{\delta}_{ij}^{'}$ is a $1 \times k$ vector. T must be large enough such that for each country the dynamic model can be estimated separately. The dimension for the vector of explanatory variables, X_{it}, depends on the data availability and whether the dependent variable, y_{it}, is the fiscal primary revenue or fiscal primary expenditure (in logarithm).

When we consider the nominal aggregate primary fiscal revenue, PFR_{it}, we adjust it to various cyclical effects generated by the output gap, inflation, TOT and financial conditions (this latter indicated by indices of share price, house price or financial stress). Such effects can be denoted by the following set of variables Ω_{it}:

$$\Omega_{it} = \{ln\_RGDP_{it}, ln\_Def_{it}, ln\_TOT_{it}, ln\_SP_{it}, ln\_HP_{it}, FSI_{it}, Unemp_{it}\} \quad (2)$$

where ln_RGDP_{it}, ln_TOT_{it}, ln_SP_{it}, and ln_HP_{it} are the logarithms of real GDP, TOT index,[4] share price index, and house price index respectively. ln_Def_{it} is the logarithm of GDP deflator, FSI_{it} is the financial stress index (Balakrishnan et al., 2009), and $Unemp_{it}$ is the unemployment rate. Then $\boldsymbol{X}_{it} \subseteq \Omega_{it}$ is a subset of Ω_{it}, and how many variables it contains depends on the data availability and data properties.

Aggregate fiscal revenue can be viewed as the product of real fiscal revenue and an aggregate price index such as GDP deflator. Real GDP can be roughly regarded as the tax base of real fiscal revenue, capturing the real cyclical effect of output on fiscal revenue. GDP deflator is another independent variable in the regression, capturing the nominal effect of aggregate price and the bracket-creep effects of inflation on tax revenues.

In the literature, the effect of aggregate price is sometimes ignored when nominal aggregate fiscal revenue is cyclically adjusted, and only the effect of real output gap is considered. However, the aggregate price level of an economy also exhibits cyclicality, which is then transmitted to the cyclicality of the inflation rate (see IMF, 2015b). Hence, given that inflation is likely to alter the distributive properties of nominally defined tax systems and has the bracket-creep effects on tax revenues (Immervoll, 2000; Abiad and Ostry, 2005; and Escolano, 2010), we expect that the elasticity of nominal fiscal revenue with respect to GDP deflator is greater than one.

Given that we explore the general influence of financial markets as a whole on the aggregate fiscal revenue, the financial stress index (FSI_{it}) is a comprehensive measure capturing a broad part of stress in a country's financial system. It is calculated by Balakrishnan et al. (2009) and updated to the year 2012. In this methodology, financial stress captures the degree of how the financial system of a country is under strain and its ability to intermediate is impaired. It is associated with four fundamental characteristics of financial markets: (i) large shifts in asset prices, (ii) an abrupt increase in risk and uncertainty, (iii) liquidity droughts, and (iv) concerns about the health of the banking system. A value of zero for FSI_{it} implies neutral financial market conditions on average across the sub-indices; while positive values imply financial strain. A value of 1 indicates a one-standard-error deviation from average conditions across sub-indices. Thus, financial crisis is here defined when FSI_{it} is equal to or greater than 3 for any country *i* and period *t*.[5]

[4] Terms of trade index is calculated as 100 times the ratio of export price index over import price index, where export price index is the deflator of total exports of goods and services, and import price index is the deflator of total imports of goods and services.

[5] FSI_{it} is constructed in a slightly different manner for AEs and EMEs. To capture three financial market segments (banking, securities markets, and exchange markets), FSI_{it} for EMEs comprises five components

(Continued…)

Thus, with the set of variables Ω_{it} , we can examine two aggregate effects and two compositional effects on nominal fiscal revenue. The two aggregate effects are respectively the real GDP aggregate effect and the GDP deflator nominal aggregate effect. By controlling these two aggregate effects, the two compositional effects from international trade and financial markets reveal the additional effects on trade related taxes and financial-markets related fiscal revenues.

Hence, we simplify the *ARDL(p,q,q,…,q)* in (1) to an $ARDL(1,1,1,\ldots,1)$ model as follows:

$$y_{it} = \lambda_i y_{i,t-1} + \boldsymbol{\delta}_{i0}^{'} \boldsymbol{X}_{it} + \boldsymbol{\delta}_{i1}^{'} \boldsymbol{X}_{i,t-1} + \mu_i + \varepsilon_{it}, \tag{3}$$

where $\boldsymbol{\delta}_{i0} = (\delta_{i0}^{1}, \delta_{i0}^{2}, \ldots, \delta_{i0}^{k})'$, and $\boldsymbol{\delta}_{i1} = (\delta_{i1}^{1}, \delta_{i1}^{2}, \ldots, \delta_{i1}^{k})'$. Equation (3) can be further inserted into an error correction model (ECM):

$$\Delta y_{it} = \phi_i (y_{i,t-1} - c_i - \boldsymbol{\theta}_i^{'} \boldsymbol{X}_{i,t-1}) + \boldsymbol{\delta}_{i0}^{'} \Delta \boldsymbol{X}_{it} + \varepsilon_{it}, \tag{4}$$

where $\phi_i = \lambda_i - 1$ is the equilibrium correction parameter, representing the error-correcting speed of adjustment between the short-run and long run effects of the fiscal policy; $c_i = -\mu_i / \phi_i$; and $\boldsymbol{\theta}_i = -(\boldsymbol{\delta}_{i0} + \boldsymbol{\delta}_{i1}) / \phi_i = (\theta_i^{1}, \theta_i^{2}, \ldots, \theta_i^{k})'$ links the short-run fiscal elasticities (δ_{i0}^{j} and δ_{i1}^{j}) and the long-run elasticities (θ_i^{j}) with respect to the relevant explanatory variable, x_{it}^{j}. The coefficient ϕ_i is expected to have a significantly negative value, as long as it is assumed that there is indeed a long-run equilibrium and the system will return to the long-run equilibrium when it deviates.

If $\phi_i = 0$, then there is no evidence for a long-run relationship. When $\phi_i = 0$ and the long-run elasticities are finite, Equation (4) degenerates to:

$$\Delta y_{it} = \mu_i + \boldsymbol{\delta}_{i0}^{'} \Delta \boldsymbol{X}_{it} + \varepsilon_{it}. \tag{5}$$

Equation (5) is frequently employed to estimate fiscal elasticities when one does not consider the long-run effects of cyclical factors (Bornhorst et al., 2011).

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related to "banking-sector beta", stock market returns, time-varying stock market return volatility, sovereign debt spreads, and an exchange market pressure index (EMPI). The overall index is a composite measure of these sub-indices and captures markets movements relative to averages or trends, as they are likely to signal strain in financial markets. In turn, FSI_{it} for AEs comprises seven components and has more information on banking sector and securities markets. For an empirical analysis using this index see Cimadomo et al. (2014).

However, we use an ARDL model in this paper for the following reasons. First of all, there may be compositional effects on the tax base (especially for the aggregated method), e.g., short-term shifts in the consumption towards higher-taxed goods, driving up the short run elasticity (Price and Dang, 2011). To capture this kind of compositional effect and its long-run influence, the ARDL model is a good option. Secondly, there are at least two kinds of lag effects of explanatory variables on fiscal revenues that cannot be captured by only estimating short-term elasticities. One is the lag effect due to the market incompleteness such as the stickiness in wages. For example, if the inflation rate is high in one period, nominal wages should increase as well, but due to the stickiness of nominal wages it usually takes one additional period to adjust it. This lag effect, therefore, also affects the personal income tax. Another lag effect is due to the revenue accounting and collection (Escolano, 2010; Price and Dang, 2011), which may indicate persistent effects on revenues of the change in the underlying economic variable, e.g., real GDP growth.[6]

With the short-run and long-run elasticities estimated and the one-off fiscal operations adjusted for each country, the trend levels of fiscal revenue can be calculated as follows:

$$(PFR_{it})^* = PFR_{it} \times \prod_{j=1}^{k} \{\exp[(1-L)\left((x_{it}^j)^* - x_{it}^j\right)]\}^{\delta_{i0}^j} \{\exp[(x_{i,t-1}^j)^* - x_{i,t-1}^j]\}^{-\phi_i \theta_i^j}, \quad (6)$$

where the stars denote the trend levels of the relevant variables, and L is the lag operator for time t. Equation (6) is intuitive, as long as we pay attention to the two short-run elasticities in Equation (3), δ_{i0}^j and δ_{i1}^j, and write Equation (6) in its equivalent form below:

$$(PFR_{it})^* = PFR_{it} \times \prod_{j=1}^{k} \{\exp[(x_{it}^j)^* - x_{it}^j]\}^{\delta_{i0}^j} \{\exp[(x_{i,t-1}^j)^* - x_{i,t-1}^j]\}^{\delta_{i1}^j}. \quad (7)$$

When the aggregate nominal fiscal primary expenditure, PFE_{it}, is under consideration, we only adjust it one-to-one to the cyclical effect of the aggregate price level but not to the real output gap or unemployment rate gap. That is because the unemployment-related expenditure is only a small part of social security expenditure, which itself is less than 20 percent of total expenditure for most countries. This is consistent with a rule of thumb for the aggregated method: zero-elasticity assumption for real aggregate fiscal primary expenditure. So its trend level is calculated as below:

[6] Regarding accounting effects, for example, even though the system of national accounts (SNA) and the OECD Revenue Statistics data in principle record taxes on an accrual basis, in some cases the liability to pay can only be determined in a later accounting period than when the income accrues.

$$(PFE_{it})^{*} = PFE_{it} \times \exp(\left(ln\_Def_{it}\right)^{*} - ln\_Def_{it}\right), \tag{8}$$

With these two trend levels estimated, we can calculate the structural primary fiscal balances for country i ($SPFB_{it}$) as follows:

$$SPFB_{it} = (PFR_{it})^{*} - (PFE_{it})^{*}. \tag{9}$$

B. Empirical Strategy

We estimate Equation (3) and (4) in a panel data set up. For that at least three alternative estimation methods can be used based on the extent to which they assume and account for the heterogeneity of fiscal elasticities. One possibility is the mean group (MG) estimation in which country-specific equations are estimated separately and the averages of the estimated elasticities are investigated. This method assumes heterogeneity for both the short-run and long-run fiscal elasticities across countries. In fact the MG model is a Random Coefficients Model (RCM) with the coefficients following the random models below:

$$H_a : \lambda_i = \lambda + \eta_{1i}, \boldsymbol{\delta}_{i0} = \boldsymbol{\delta}_0 + \boldsymbol{\eta}_{2i}, \boldsymbol{\delta}_{i1} = \boldsymbol{\delta}_1 + \boldsymbol{\eta}_{3i},$$

where η_{1i}, η_{2i}, and η_{3i} are assumed to have zero means and constant covariances, and their higher-order moments and cross moments are assumed to exit and be finite; the coefficients λ, δ_0, δ_1 are the mean values of the relevant heterogeneous coefficients. The above RCM can be characterized in an alternative way, using short-run and long-run elasticities, and the error correction parameter:

$$H_b : \phi_i = \phi + \xi_{1i}, \boldsymbol{\delta}_{i0} = \boldsymbol{\delta}_0 + \boldsymbol{\xi}_{2i}, \boldsymbol{\theta}_i = \boldsymbol{\theta} + \boldsymbol{\xi}_{3i}. \tag{10}$$

Pesaran and Smith (1995) show that the MG approach provides consistent estimates for the mean of the coefficients when the data's time series dimension is large enough. The mean values of the heterogeneous country-specific fiscal elasticities can be viewed as the average sensitivity of fiscal revenue with respect to explanatory variables.[7]

[7] For the estimation of long run elasticities (co-integrating vectors), one could also employ group mean FMOLS (fully modified OLS) method (Pedroni, 2000), for which each individual FMOLS estimator corrects for endogeneity and for serial correlation. If one cares about cross-section dependence problem, CCEMG (common correlated effects mean group estimator) (Pesaran, 2006) could also be employed. However, the cross-section dependence problem is not likely to exist in our model, since real GDP and GDP deflator are always included as explanatory variables and they can capture the influence of potential global common factors.

Another option is the traditional dynamic fixed effects (DFE) model in which both δ_{i0}, and δ_{i1} are assumed to be the same for all the countries. In this case both the short-run and long-run fiscal elasticities exhibit homogeneity across countries. This assumption is not completely realistic, especially for the short-run fiscal elasticities. Different countries are on the different levels of development and have different economic structures and business cycle properties. For example, the fiscal revenue elasticity with respect to TOT for an export oriented economy may be different from that of a more closed economy, at least in the short run. Econometrically, Pesaran and Smith (1995) show that if heterogeneity does exist in a dynamic panel data model, the pooled estimation of traditional DFE model would yield inconsistent and misleading parameter estimates.

Besides the above two options, there is an intermediate approach called pooled mean-group (PMG) method (Pesaran et al., 1999). The PMG approach assumes that the short-run fiscal elasticities (δ_{i0}), intercepts (c_i), error-correction parameters (ϕ_i), and error variances are heterogeneous across countries; whereas the long-run elasticities (θ_i) are restricted to be homogeneous over the cross sections.

Similarly to the MG method, the PMG approach also yields consistent estimate for the mean of short-run fiscal elasticities by taking the arithmetic average of country-specific short-run elasticities. As explained previously, it is reasonable to assume that different countries should have different short-run fiscal elasticities with respect to different types of cyclical effects. The adjustment speed, indicated by the error-correction parameter, could be different as well. However, if the assumption of long-run homogeneity is not true, the PMG estimator would be not consistent, and a downward bias for error-correction parameter would be generated (Robertson and Symons, 1992; Pesaran and Smith, 1995).

The PMG method used to estimate the dynamic heterogeneous panel data model is represented by Equation (3) with the following assumption on the long-run fiscal elasticities:

$$H_0 : \boldsymbol{\theta}_i = \boldsymbol{\theta}, i = 1, 2, \ldots, N. \tag{11}$$

The PMG model is estimated using a maximum likelihood methodology: either the Newton-Raphson algorithm; or the "back-substitution" algorithm (Pesaran et al., 1999). The null hypothesis of long-run homogeneity is tested via a Hausman statistic. Due to omitted group specific factors or measurement errors the country estimates could however be severely biased (Pesaran et al., 1999). Hence, it is necessary to do "poolability" tests based on long-run pooling restrictions.

The Hausman test relies on the result that an estimate of the long-run elasticities in the PMG approach could also be derived from the average (mean group) of the country regressions.

This means that the average of the MG long-run elasticities estimates are consistent under both $H_0 : \boldsymbol{\theta}_i = \boldsymbol{\theta}$ and $H_b : \boldsymbol{\theta}_i = \boldsymbol{\theta} + \boldsymbol{\xi}_{3i}$. But for the PMG approach, the elasticities estimates are only consistent under H_0. When the long-run elasticities are homogeneous (H_0 holds), the PMG approach will yield more efficient estimates. This Hausman test statistic can be described as:

$$Hausman = \hat{q}' \left[\text{var}\left(\hat{q}\right) \right]^{-1} \hat{q} \sim \chi_k^2,$$

where $\hat{q}$ is a $k \times 1$ vector of the differences between the average long-run elasticities of the MG estimation and the PMG long-run elasticities estimates; and $\text{var}\left(\hat{q}\right)$ is the corresponding covariance matrix. Under the null hypothesis $\left(H_0\right)$ that both of the two estimators are consistent, but one (PMG) is efficient, then $\text{var}\left(\hat{q}\right)$ can be easily calculated as the difference between the covariance matrices of the two estimators. If the pooling assumption of long-run elasticities is not correct, the estimates of PMG approach will no longer be consistent and the Hausman test statistic will reject the null. On the other hand, if the Hausman test is not rejected, the economies in the panel are homogeneous enough from a statistical perspective to assume common long-run elasticities.

The homogeneity assumption of long-run fiscal revenue elasticities with respect to some factors, such as real GDP and GDP deflator, can be justified by theoretical predictions. In a typical DGSE model with economic growth and taxes, such as in Liu (2014), the economy nominal fiscal revenue and nominal GDP normally exhibit balanced growth properties at the steady state. This indicates that in the long run the growth rate of nominal fiscal revenue is equal to the growth rate of real GDP plus the growth rate of GDP deflator. In other words, the long-run elasticities of nominal fiscal revenue with respect to real GDP and GDP deflator both should be one.

These DSGE models usually do not feature progressive taxation, issues with revenue collection, or a bracket-creep effect of inflation, which would suggest that the long-run elasticity with respect to GDP deflator could be larger than one. In this case, assuming the homogeneity of long-run fiscal revenue elasticities with respect to real GDP and GDP deflator for all the economies appears reasonable. Later on, we implement a Kao homogenous panel co-integration test to examine the long-run homogeneity assumption across countries. In turn, assuming that in the long run the relevant elasticities of different economies may vary around a common constant favors the MG approach (or random coefficients model).

Before estimating the MG or PMG model, panel unit root tests and panel co-integration tests are also performed. First of all, all the series including y_{it} and $x_{it}^j (j = 1, 2, \ldots, k)$ should be at

most $I(1)$ process. We apply the IPS (Im, Pesaran and Shin, 2003) panel unit root test. Secondly, there should exist co-integration relationship between the dependent variable y_{it} and the vector of explanatory variables, X_{it}. We thus perform the traditional Kao homogeneous test (Kao,1999) together with the heterogeneous panel co-integration test introduced by Pedroni (1997, 1999), under the null hypothesis of no co-integration.

At last, besides examining country specific elasticities, this paper also investigates mean elasticities for certain country groupings. The country-specific elasticities can be used to evaluate the country-specific influence of explanatory variables on fiscal revenue and then to calculate structural fiscal balances. The mean elasticities help us judging the average effects of influencing factors for certain country groups and the comparison among different groupings.

C. Data

The data used in this paper is an annual unbalanced panel dataset covering the years from 1970 to 2012 for 147 countries. Table A1 in the Appendix provides the data sources and Table A2 describes the raw panel data. Since we use an aggregated method to estimate fiscal elasticities,[8] fiscal revenue, expenditure, and fiscal balance respectively refer to general government primary revenue (GGPR), general government primary expenditure (GGPE),[9] and net operating balance, i.e., the difference between GGPR and GGPE.

Given that we are also interested in whether the fiscal elasticities behave differently among different country groupings, we divide our sample (147 countries) into three groups. These groups are defined according to the IMF Fiscal Affairs Department's grouping method: 30 advanced economies (AEs), 29 emerging market economies (EMEs), and 88 low income countries (LICs).

Special attention is paid to the commodity exporting countries whose fiscal revenue should be largely influenced by the commodity prices and TOT. A country is defined as a commodity exporter if the exports of its primary commodities constitute more than 50

[8] The aggregated method is also preferred in our estimations given that more disaggregated variable of tax revenues are available for a much more reduced sample of countries, affecting the broadness of our country coverage.

[9] Primary fiscal revenue and expenditure are calculated when interest income and interest expenditure are excluded from general government revenue and general government expenditure respectively. Due to the data unavailability for many countries about the effects of one-off factors on fiscal aggregates, we use stastical procedure treating and eliminating outliers as one-off factors.

percent of its total exports, like in Cavalcanti et al. (2014).[10] Among 50 commodity exporter countries, 10 of them are oil producers. For detailed country groupings and the list of commodity exporter countries, see Table A4 and A5 in the appendix.

As shown in Table A2, the raw data for 147 countries is unbalanced and the number of observations for some countries variables is small. To ensure reliable regression results, we delete countries whose observations for fiscal revenue or real GDP are less than or equal to 14. We also delete countries with data outliers, in which an outlier is defined when (i) the GDP deflator inflation is higher than 100 percent; or (ii) the fiscal revenue-GDP ratio is bigger than 100 percent; or (iii) the growth rate of TOT index is greater than 100 percent.

The processed panel data, which is used to estimate models, is summarized by Table 1 below. The descriptive statistics of the underlying variables are presented in Table A3. Ninety-six economies are retained while nearly one third of the total 147 countries are deleted. The deleted countries with poor data quality are formed mainly by LICs, whereas the major advanced and emerging economies are retained. For nominal fiscal revenue, asset prices and financial stress index nearly 80 percent of the observations are retained.

Table 1. Summary of the Processed Panel Data, 1970–2012

	No. of cross sections	Observations per cross section			No. of observations
		minimum	average	maximum	
ln_PFR_{it}	96	15	25.6	43	2457
ln_RGDP_{it}	96	15	25.6	43	2459
ln_Def_{it}	96	15	25.5	43	2449
ln_TOT_{it}	96	14	25.1	43	2405
ln_HP_{it}	17	16	35.4	41	601
ln_SP_{it}	34	10	22.7	42	772
FSI_{it}	38	6	21.3	33	811

Given the processed panel data, Table 2 shows the pairwise correlation coefficients for the levels and first-order differences of all the possible explanatory variables when we estimate the fiscal revenue elasticities. For the first-order differences of these variables, their correlation coefficients are relatively small. Nevertheless, for the levels, the correlations among asset price indices and GDP deflator are large. This is one reason why we only choose the FSI_{it} instead of the house price index and share price index in the coming model estimation, when considering financial market conditions. Another reason is that the FSI_{it} is a more general index of financial markets and by using it more countries will be covered by

[10] The literature has various definitions of commodity exporters. In some cases, these are defined as countries in which fiscal revenues originated from resource exports correspond to 20 percent or more of their total revenues (See IMF 2012 or Araujo et al., 2013).

the econometric model as well. A third reason is related to panel co-integration, which will be explained in the following section.

Table 2. Pairwise Correlation Coefficients: Level and First-order Difference

	ln_RGDP_{it}	ln_Def_{it}	ln_TOT_{it}	ln_HP_{it}	ln_SP_{it}	FSI_{it}
ln_RGDP_{it}	**1.000 (2459)**	0.025(2353)	0.029(2309)	0.408(584)	0.452(737)	0.098(773)
ln_Def_{it}	-0.151 (2449)	**1.000 (2449)**	0.100(2309)	0.493(574)	0.123(727)	0.079(773)
ln_TOT_{it}	-0.055 (2405)	0.046(2405)	**1.000 (2405)**	-0.014(564)	0.162(727)	-0.018(773)
ln_HP_{it}	0.368(601)	0.938(591)	0.124(581)	**1.000 (601)**	0.182(389)	0.040(461)
ln_SP_{it}	0.192(772)	0.769(762)	0.139(762)	0.833(401)	**1.000(772)**	-0.110(456)
FSI_{it}	-0.025(811)	-0.136(811)	-0.034(811)	-0.099(478)	-0.181(481)	**1.000(811)**

Note: the lower-triangle entries are the correlation coefficients for the levels of relevant variables, while the upper-triangle entries are for the first-order differences. The numbers in the parentheses are the corresponding observation numbers of the pairwise samples.

IV. Model Estimation and Results

In this section, we display the results of the panel unit root test and co-integration test. Secondly, the estimations of the short-run and long-run fiscal elasticities across countries are presented. The homogeneity and heterogeneity of long-run fiscal elasticities are examined and discussed it detail. Then we describe the country sub-sample analyses, focusing on advanced economies, emerging economies, and commodity exporter countries.

A. Panel Unit Root and Co-integration Tests

Before estimating Model (4), we make sure that all the variables, including the dependent and explanatory, are at most $I(1)$ processes. And there is indeed a co-integration relationship between the dependent and independent variables.

Table 3 evinces that the nominal primary fiscal expenditure, real GDP, TOT, house price, and share price index (all in logarithm) are $I(1)$ processes for the whole panel. That is because the relevant IPS test cannot reject the null hypothesis (panel unit root). The ADF unit root tests for individual countries tell a similar story: for most of the cross sections the corresponding time series indeed have a unit root. For the logs of the nominal aggregate primary fiscal revenue (PFR_{it}), GDP deflator $(Def_{i,t})$, FSI_{it}, and unemployment rate , the IPS tests reject the panel unit root null hypothesis at the 5 percent significance level, but ADF unit root tests for individual countries cannot reject the individual null for most of the cross sections.

These variables in first-differences are all stationary (Table 4). The IPS tests reject the null hypothesis for all the variables in the panel, and individual ADF unit root tests also reject the

null for most cross sections. Therefore, all the variables used in the estimations are at most $I(1)$ processes; and their first-order differences are all panel stationary.

Table 3. Panel Unit Root Test: Levels

	cross sections	No. of series with unit root	No. of series without unit root	IPS-test statistic	IPS-test P-value
ln_PFR_{it}	96	71	25	-3.17	0.00
ln_PFE_{it}	96	81	15	4.33	1.00
ln_RGDP_{it}	96	89	7	7.79	1.00
ln_Def_{it}	96	65	31	-5.10	0.00
ln_TOT_{it}	96	87	9	2.21	0.99
ln_HP_{it}	17	16	1	-0.20	0.42
ln_SP_{it}	34	33	1	0.15	0.56
FSI_{it}	38	28	10	-6.50	0.00
$Unemp_{it}$	61	49	12	-15.71	0.00

Note: The critical values of the IPS-test statistic for the significance levels of 1%, 5% and 10% are respectively -2.33, -1.64 and -1.28 (left tail of the standard normal distribution). For the ADF unit root test for individual countries, when the null hypothesis (there is a unit root) is rejected at the 5% significance level, then the relevant time series is regarded as having no unit root.

Table 4. Panel Unit Root Test: First-order Differences

	cross sections	No. of series with unit root	No. of series without unit root	IPS-test statistic	IPS-test P-value
Δln_PFR_{it}	96	23	73	-23.46	0.00
Δln_PFE_{it}	96	17	79	-24.83	0.00
Δln_RGDP_{it}	96	21	75	-23.64	0.00
Δln_Def_{it}	96	42	54	-16.19	0.00
Δln_TOT_{it}	96	3	93	-34.25	0.00
Δln_HP_{it}	17	7	10	-6.30	0.00
Δln_SP_{it}	34	10	24	-12.16	0.00
ΔFSI_{it}	38	5	33	-19.30	0.00
$\Delta Unemp_{it}$	61	11	50	-38.89	0.00

Note: The critical values of the IPS-test statistic for the significance levels of 1%, 5% and 10% are respectively -2.33, -1.64 and -1.28 (left tail of the standard normal distribution). For the ADF unit root test for individual countries, when the null hypothesis (there is a unit root) cannot be rejected at the 10% significance level, then the relevant time series is regarded as having a unit root.

Moving to the regression of Equation (4), we estimate several dynamic heterogeneous models using different explanatory variables, given the different number of observations of each variable. For that, we test whether there is a panel co-integration relationship between dependent and explanatory variables for several combinations. Table 5 lists the results of Kao's homogeneous and Pedroni's heterogeneous panel co-integration tests for five combinations.[11] The Kao homogenous panel co-integration test is used for the PMG models,

[11] Real GDP and GDP deflator are always included as explanatory variables, indicating that the fiscal revenue elasticities with respect to output gap and the aggregate price level are the basic ones we are interested, and they can be viewed as two control variables while other cyclical factors' effects on fiscal revenue are being examined.

since it assumes homogeneous co-integrating vectors corresponding to homogeneous long-run fiscal elasticities. The Pedroni heterogeneous co-integration test is used for MG models, since it allows heterogeneous co-integrating vectors.

Table 5. Panel Co-integration Tests: P-values

Tests	Statistics	(1)	(2)	(3)	(4)	(5)
Pedroni	Panel ν	0.22	0.89	0.29	0.60	1.00
	Panel rho	0.00	0.06	0.90	0.97	1.00
	Panel PP	0.00	0.00	0.32	0.02	0.00
	Panel ADF	0.00	0.00	0.00	0.00	0.00
	Group rho	0.12	1.00	0.99	1.00	1.00
	Group PP	0.00	0.00	0.26	0.00	0.00
	Group ADF	0.00	0.00	0.00	0.00	0.00
Kao	ADF	0.00	0.00	0.00	0.00	0.00
No. of cross sections		96	96	17	34	36

Note: Seven combinations of dependent variable and explanatory variables are respectively: (1) ln_PFR_{it}, ln_RGDP_{it}, ln_Def_{it}; (2) ln_PFR_{it}, ln_RGDP_{it}, ln_Def_{it}, ln_TOT_{it}; (3) ln_PFR_{it}, ln_RGDP_{it}, ln_Def_{it}, ln_TOT_{it}, ln_HP_{it}; (4) ln_PFR_{it}, ln_RGDP_{it}, ln_Def_{it} ln_TOT_{it}, ln_SP_{it}; (5) ln_PFR_{it}, ln_RGDP_{it}, ln_Def_{it}, ln_TOT_{it}, FSI_{it}. For the four within-dimension cases of Pedroni test, we use the weighted statistics. The null hypothesis is there is no panel co-integration relationship.

For all the five cases analyzed the Kao statistics in Table 5 reject the null hypothesis that there is no panel co-integration relationship. So under the assumption of co-integration homogeneity, it can be regarded that all the six cases have panel co-integration relationships. Hence, the PMG approach can be applied to all of them. However, if the co-integration homogeneity does not hold strictly, the tests are no longer consistent. Therefore, we rely further on the Pedroni heterogeneous panel co-integration test, which is more general (see also Caceres et al., 2013).

There are seven statistics of the Pedroni panel co-integration test: four based on within-dimension approach and three based on between-dimension approach. According to Pedroni (1997), among these seven statistics Panel ADF and Group ADF statistics are more reliable. Using these tests, we find that there is a co-integration relationship among $\ln\left(PFR_{it}\right)$, $\ln\left(RGDP_{it}\right)$, and $\ln\left(Def_{it}\right)$—Model (1) in Table 5. That is because both Panel ADF and Group ADF statistics reject the null, besides fiveof the seven Pedroni statistics also rejecting the null hypothesis of no co-integration at the 5 percent significance level.

Now we add another variable $\ln\left(TOT_{it}\right)$, getting Model (2) in Table 5. At the 10 percent significance level only two Pedroni statistics of seven fails to reject the null hypothesis of no co-integration, and both Panel ADF and Group ADF statistics reject the null. So, we conclude that there is a stable long-run relationship among $\ln\left(PFR_{it}\right)$, $\ln\left(RGDP_{it}\right)$, $\ln\left(Def_{it}\right)$, and $\ln\left(TOT_{it}\right)$.

Model (3) in Table 5 adds the variable of house price into our benchmark Model (2), Model (4) adds the share prices, and Model (5) adds the FSI_{it}. Due to the data unavailability of asset prices for most developing and low income economies, the number of cross sections decreases sharply when asset prices are taken under consideration. Comparing Models (3), (4) and (5), we can find that Models (4) and (5) perform better than Model (3) under the panel co-integration test: four Pedroni statistics (including both Panel ADF and Group ADF) reject the null hypothesis. Model (5) covers more countries than Model (4). Combining this coverage of Model (5) with the reasons explained in Section III.C, we consider only FSI_{it} and estimate Model (5), abstracting from the variables of house price or share price.

To summarize, based on these cointegration tests, we estimate Models (1), (2) and (5) of Table 5 to obtain fiscal revenue elasticities with respect to various cyclical factors. Model (1) only considers real GDP and GDP deflator and is a basic model. Model (2) is our baseline regression, which covers as many countries as possible and simultaneously covers as many explanatory variables as possible. Model (5) takes all the explanatory variables of interest into account, including financial variables, but covers only 36 countries, most of which advanced economies.

B. Elasticity Estimation Results

We report both the MG and PMG model estimation results of fiscal revenue elasticities across countries for Models (1), (2) and (5) of Table 5. The Hausman test judges which approach suits the data better. The corresponding results are shown in Table 6, 7, 8 respectively. Again, for the MG approach, we estimate the dynamic model for each individual country separately, and report the average short-run and long-run elasticities. For the PMG approach, the dynamic heterogeneous panel model is estimated by maximum likelihood method with the long-run fiscal elasticities homogeneous across countries.

Real GDP and GDP Deflator

Our first analysis investigates the fiscal revenue elasticities with respect to the output gap and the deflator gap when real GDP and GDP deflator are included as the only explanatory variables. According to Table 6, the Hausman test statistic for such specification (Model (1) of Table 5) is 1.32, and the corresponding $P-value$ is 0.52. Therefore, we cannot reject the null hypothesis H_0 and, thus, the PMG estimator is the preferred estimator (most efficient). The mean values of the short-run elasticities with respect to real GDP and GDP deflator across countries are respectively 1.44 and 0.94 for the PMG approach, both of which are statistically significantly different from zero at the 1 percent significance level.

The average short-run elasticity with respect to real GDP is also statistically different from one. Our average estimation is 1.44, which is different from the unit fiscal revenue elasticity with respect to output gap assumed for aggregated method (Fedelino et al., 2009; and

Bornhorst, et al., 2011) or for the disaggregated method (Girouard and André, 2005; and European Commission, 2005).[12] This result highlights the automatic stabilizing role of the fiscal revenue in the enlarged sample of 96 countries beyond the OECD countries (Belinga, 2014). For the possible bracket-creep effect of inflation on nominal fiscal revenue, the average short-run elasticity with respect to GDP deflator estimated here, 0.94, is not significantly different from one. So on average, we find that the nominal fiscal primary revenue moves in tandem to the GDP deflator in the short run across the 96 countries in the sample. The long-run fiscal revenue elasticities with respect to the real GDP are on average significantly larger than one for the PMG (preferred) estimator. As it will be shown later on, this result holds only for LICs, suggesting that the tax base has increased more than proportionally to the real GDP. Such result may be related to the increase on revenue mobilization through tax reforms promoting progressive taxation and improvements on revenue collection in the LICs (Gupta and Tareq, 2008; IMF, 2011). Moreover, the (average) error correction parameter (ECP) for the PMG approach is -0.32, which is a significantly different from zero. It indicates the adjustment to the long-run trend is gradual, with only about one third of that adjustment occurring within one year.

Table 6. Fiscal Revenue Elasticities (Mean): Real GDP and GDP Deflator, Full Sample

	MG		PMG (preferred)		Hausman test
VARIABLES	LR	SR	LR	SR	P-value
ECP		-0.587***		-0.323***	
		(0.032)		(0.027)	
$D.ln\_RGDP_{it}$		1.438***		1.438***	
		(0.115)		(0.105)	
$D.ln\_Def_{it}$		0.886***		0.941***	
		(0.077)		(0.061)	
$L.ln\_RGDP_{it}$	0.908*		1.151***		0.74
	(0.527)		(0.020)		
$L.ln\_Def_{it}$	0.949***		0.998***		0.87
	(0.220)		(0.013)		
Constant		-4.470***		-2.242***	
		(0.487)		(0.193)	
Joint Hausman test	Statistic=1.32		P-value=0.52		
Observations			2351		
No. of countries			96		

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Thus, from Table 6 we conclude that: (i) the short-run fiscal revenue elasticities with respect to the output gap are heterogeneous cross countries, and their mean value is 1.44, significantly larger than one; and (ii) it makes sense to assume the homogeneity of the long-

[12] Specifically these papers estimate fiscal revenue elasticities larger than one for corporate and personal income taxes, equal to one for indirect taxes, and smaller than one for social security contributions.

run elasticities, which are 1.15 and 1.00 with respect to real GDP and GDP deflator respectively.

Baseline Model Including Terms of Trade

Model (2) of Table 5 is our most comprehensive specification, including the real GDP, GDP deflator and TOT; and covering all the 96 countries under consideration. Table 7 displays its MG and PMG estimation results, whereas the estimated short-run fiscal revenue elasticities for advanced and emerging economies are listed in Table A6 in the Appendix. The Hausman test cannot reject the null of long-run homogeneity (statistic of 1.08 and P value of 0.78). Hence, we choose again the PMG estimator for this specification.

Some results regarding the fiscal revenue elasticities with respect to real GDP and GDP deflator are consistent with those of the previous subsection. The (average) short-run elasticity with respect to real GDP is significantly larger than one.

Table 7. Fiscal Revenue Elasticities (Mean): Baseline Model, Full Sample

	MG		PMG (preferred)		Hausman test
VARIABLES	LR	SR	LR	SR	P-value
ECP		-0.657***		-0.319***	
		(0.038)		(0.029)	
$D.ln\_RGDP_{it}$		1.541***		1.413***	
		(0.129)		(0.103)	
$D.ln\_Def_{it}$		0.775***		0.882***	
		(0.108)		(0.086)	
$D.ln\_TOT_{it}$		-0. 008		-0.101	
		(0.076)		(0.087)	
$L.ln\_RGDP_{it}$	5.368*		1.143***		0.35
	(3.019)		(0.021)		
$L.ln\_Def_{it}$	-1.301		1.010***		0.33
	(1.609)		(0.014)		
$L.ln\_TOT_{it}$	7.362		-0.069***		0.48
	(6.989)		(0.024)		
Constant		-5.026***		-2.112***	
		(0.637)		(0.192)	
Joint Hausman test	Statistic=1.08		P-value=0.78		
Observations			2307		
No. of countries			96		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

An important finding of Table 7 is that the long-run fiscal revenue elasticity with respect to the TOT is statistically significantly different from zero and negative. This significant negative coefficient suggests that when the TOT increases (i.e., the price of exports increases more than the price of imports), the primary fiscal revenues go down. That may be related to

tax incentives for exports as well as a large presence of import taxes in the countries of our sample. If indeed the tax structure provides incentives towards exports, an increase in the export-orientation of a country may make that long-run elasticity negative. The mean value of the short-run fiscal revenue elasticity with respect to the TOT, in turn, is not statistically significantly different from zero. However, for countries whose tax on imports and exports are relevant, such as commodity exporters, this short-run elasticity is highly significant as will be shown in the analysis for country groupings later on. This is already clear from Table A6, in which the short-run elasticity with respect to the TOT is found to be significant for some countries.

Financial Stress Index

Now we examine an additional specification including the financial stress index FSI_{it} as explanatory variable in line with Model (5) of Table 5. Because of the data unavailability for FSI_{it} in LICs, the sample size of such specification becomes much smaller than the previous ones. To ensure the reliability of the regression results, we delete countries whose time series for FSI_{it} are shorter than or equal to 10 years. This way, 32 AEs and EMEs are retained.

We also control for financial crisis episodes separately. If the financial conditions indeed have a significant impact on fiscal revenue, its effect in the episodes of financial crisis could be quite different from that in normal periods. Besides using the short-run revenue elasticity to FSI_{it} in order to measure the response of PFR_{it} to the normal deterioration of financial stress,[13] we add a dummy variable in the regression to capture the possible extra effect of financial markets in crisis periods. Then the dynamic heterogeneous panel data model is modified as follows:

$$\Delta \ln PFR_{it} = \phi_i \left(\ln PFR_{i,t-1} - c_i - \theta_i' X_{i,t-1} \right) + \delta_{i0}' \Delta X_{it} + \delta_{i0}^5 \times dummy_{it} \times \Delta FSI_{it} + \varepsilon_{it}, \qquad (12)$$

where:

$$\boldsymbol{X}_{it} = (\ln RGDP_{it}, \ln Def_{it}, \ln TOT_{it}, FSI_{it})', \text{ and } Dummy_{it} = \begin{cases} 1, if\ FSI_{it} \geq 3 \\ 0, if\ FSI_{it} < 3 \end{cases}.$$

The threshold value of $FSI_{it} \geq 3$ is chosen to define a financial crisis given that it indicates a three-standard-error deviation from average financial conditions across sub-indices. This could be generated, for example, by large declines in asset prices or an abrupt increase in risk

[13] Such financial stress could be caused by the higher volatility in financial markets or lower returns of financial assets.

and uncertainty of financial markets. In fact, the aggregate short-run fiscal revenue elasticity with respect to FSI_{it} is then given by:

$$\delta_{i0}^{4} + \delta_{i0}^{5} \times Dummy_{it}.$$

Table 8 reports the MG and PMG estimation results for the Equation (12) above. The Hausman test cannot reject the null of long-run homogeneity, since the statistic is 0.47 with the P-value equal to 0.98. Hence, we choose the PMG estimator for this specification. Table A6 in the Appendix provides, in addition, the country-specific short-run elasticities, including those with respect to FSI and the financial crisis dummy variable. For the 32 countries covered, the average elasticity with respect to real GDP becomes smaller, either in the short- or long-run. Regarding the elasticity with respect to the GDP deflator, we find that the bracket-creep effect still exists in the long run.

Table 8. Fiscal Revenue Elasticities (Mean): Equation (12), Full Sample

	MG		PMG (preferred)		Hausman test
VARIABLES	LR	SR	LR	SR	P-value
ECP		-0.794***		-0.375***	
		(0.102)		(0.054)	
$D.ln\_RGDP_{it}$		0.727***		0.829***	
		(0.190)		(0.134)	
$D.ln\_Def_{it}$		1.057***		0.976***	
		(0.317)		(0.143)	
$D.ln\_TOT_{it}$		-0.087		-0.164	
		(0.189)		(0.121)	
$D.FSI_{it}$		-0.003		0.002	
		(0.003)		(0.001)	
$Dummy \cdot D.FSI_{it}$		-0.004		-0.004	
		(0.005)		(0.003)	
$L.ln\_RGDP_{it}$	0.986**		0.831***		0.86
	(0.434)		(0.034)		
$L.ln\_Def_{it}$	1.203**		1.107***		0.92
	(0.488)		(0.021)		
$L.ln\_TOT_{it}$	0.315		0.117***		0.62
	(0.196)		(0.031)		
$L.FSI_{it}$	-0.005		-0.005***		0.97
	(0.004)		(0.002)		
Constant		-9.164*		-2.009***	
		(4.969)		(0.296)	
Joint Hausman test	Statistic=0.47		P-value=0.98		
Observations			728		
No. of countries			32		

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The long-run elasticity with respect to the TOT is now significantly positive. As it will be shown later on, this is related to the sample composition in Table 8 towards for AEs and EMEs which are more financially integrated and, therefore, with more data for the FSI_{it} index. For this sample, a larger terms-of-trade suggests that economic activity is accelerated, generating more revenues for the government. The short-run elasticity on average is, in turn, not significant.

In the long run FSI_{it} has a significantly negative effect on fiscal revenue, even when the real GDP, the GDP deflator, and TOT are controlled for. Along with the deterioration of conditions in financial markets (higher risks or lower assets returns), the aggregate nominal primary fiscal revenue seems to be persistently affected negatively. This reinforces recent calls for the inclusion of financial variables in the analyses of structural balances (Price and Dang, 2011; Borio et al., 2013; and Poghosyan et al., 2015). It might also indicate a change in the country's risk perception as well as a reduction in private investment due to uncertainty (Bloom, 2009), having a persistent effect in the country's revenue base. In the short run, both FSI and the dummy variable of financial crisis, on average, have no significant effect on fiscal revenue.[14]

C. Sub-sample Analyses

This subsection divides the full sample into several sub samples. Different groups of countries may have different elasticity properties, especially owing to distinguished sources of fiscal revenues and tax systems.

Our first sub-sample analysis utilizes our baseline model in two ways. First, we divide the countries in three groups according to their income level—AEs, EMEs, and LICs. Second, the analysis splits the countries into groups depending on whether they are commodity exporters (CEC), within which a sub-group of oil producing countries is included or not.

The estimation results of these two division criteria are shown in Tables 9 and 10, respectively. For each subgroup, we use again the Hausman test to decide whether the PMG approach should be employed or not. Only the mean values of the heterogeneous elasticities are reported in the tables. For all subsamples, the PMG approach is preferred.

Income level country groups

[14] Table A7 indicates that financial crises have a significant short-run influence on fiscal revenue for a few countries. The effect is usually negative, except for UK. The difference of short-run influences of financial stress and financial crisis among different economies may reflect the differences in the economic and financial structure, the stage of financial development and the tax system of these economies.

For real GDP, on average, LIC's fiscal elasticities seem to be larger than those of advanced economies both, in the short- and in the long-run. This indicates that for those countries, economic growth has more influential impact on the aggregate fiscal revenue. The bracket-creep effect of inflation exists in the long run for AEs, but not for EMEs and LICs. The effect of TOT on fiscal revenue is negative for AEs and LICs in the long-run, but positive for EMEs, albeit small. This may be related to the fact that AEs and LICs tend to be net importers and may rely on more import taxes and tariffs, whereas for EMEs (net exporters) the boost in domestic activity generated by the terms-of-trade leads to a higher revenue collection. The short-run effect of TOT is not significant for any of the three groups.

Table 9. Fiscal Revenue Elasticities (Mean): Baseline Model, Sub-samples, Case 1

	AEs **(PMG)**		***EMEs*** **(PMG)**		***LICs*** **(PMG)**	
	SR	LR	SR	LR	SR	LR
Real GDP	1.02***	0.86***	1.21***	1.16***	1.70***	1.53***
GDP deflator	0.91***	1.16***	0.98***	0.98***	0.74***	0.94***
TOT	--	-0.16***	--	0.07*	--	-0.30***
ECP	-0.24***		-0.37***		-0.37***	
Observations	880		446		981	
No. of countries	28		21		47	

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

We also perform the sub-sample analysis for Equation (12). For the two groups (20 AEs and 12 EMEs), the results given by Table 10 are consistent with our previous findings. On average, the elasticities of real GDP are larger for EMEs than for AEs both in the short- and in the long-run, but particularly for the latter. The bracket-creep effect of inflation is significant in the long-run for AEs. The long-run effect of the TOT on fiscal revenue remains negative for AEs, but positive for EMEs.

Financial stress has a significantly positive, but very small long-run effect on fiscal revenues for AEs which, therefore, are not relevant for structural balances calculations. In EMEs, the long-run effects of financial stress are significantly negative. In the short run, AEs also have a positive and small elasticity of financial stress on revenues, but a negative extra effect in crisis periods, albeit this latter result is not robust to different crisis identification as we will show later on.[15] For EMEs, financial stress in both, normal and crisis periods, has no significant short-run influence on average. Table A8 in the appendix provides the country-specific results of sub-sample estimations of Equation (12).

[15] Such significant effects may be related to financial taxation among other characteristics of financial markets in those countries (see Matheson, 2011).

Table 10. Fiscal Revenue Elasticities (Mean): Equation (12), Sub-samples, Case 1

	***AEs* (PMG)**		***EMEs* (PMG)**	
	SR	LR	SR	LR
Real GDP	0.75***	0.35***	0.83***	0.90***
GDP deflator	1.05***	1.48***	1.10***	1.07***
TOT	-0.30*	-0.44***	--	0.09**
FSI	0.003***	0.005***	--	-0.013***
Dummy·FSI	-0.003*		--	
ECP	-0.30***		-0.50***	
Observations	549		179	
No. of countries	20		12	

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Commodity exporters

Table 11 presents the analysis for the second type of country grouping depending on whether they are commodity exporters or not. As expected, the results suggest that for oil exporters, the TOT has a significant positive effect on fiscal revenue both in short- and long-run. Again, an improvement in TOT in commodity exports boosts economic activity and increases fiscal savings in those countries (Adler and Magud, 2015; and Celasun et al., 2015). This effect has the inverted sign for the non-exporting countries. For these latter, terms-of-trade has a significantly negative effect on fiscal revenue in the long-run.

Table 11. Fiscal Revenue Elasticities (Mean): Baseline Model, Sub-samples, Case 2

	***CEC* (PMG)**		*Oil CEC* (PMG)		*Non-oil CEC* (PMG)		***Non-CEC* (PMG)**	
	SR	LR	SR	LR	SR	LR	SR	LR
Real GDP	2.00***	1.57***	1.72***	0.66***	2.05***	1.57***	1.19***	1.11***
GDP deflator	0.84***	0.94***	1.07***	1.09***	0.80***	0.93***	0.90***	1.01***
TOT	--	-0.28***	0.37*	0.32***	--	-0.28***	--	-0.10***
ECP	-0.41***		-0.50***		-0.46***		-0.31***	
Observations	577		106		471		1730	
No. of countries	27		5		22		69	

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

The different effects of TOT on fiscal revenues between Oil-CEC countries and Non-oil CEC countries reflect the different economic structure and thus different revenue structure for these two country groups. It also reveals the need to take TOT into account when adjusting fiscal revenue, even when real GDP and GDP deflator have been controlled for.

D. Robustness Checks

This section presents the robustness checks regarding the analysis using TOT and financial crisis. The roles of real GDP and GDP deflator on nominal fiscal revenue are straightforward. But the influence of TOT and financial stress conditions on fiscal revenue for a particular country may depend on this country's economic structure and the importance of international trade and financial markets for this economy. Therefore, this section implements some robustness checks to test whether our previous results concerning TOT and financial stress and crisis are sensitive to different specifications of the model or parameters.

Terms of Trade

For TOT, our sub-sample analysis indicates that for oil-exporting countries, terms-of-trade has a significantly positive effect on fiscal revenue (Table 11). In this section we test if this result holds for largely opened economies in which taxation on international trade constitute a significant part of their fiscal revenues.

An increase of export price or a decline of import price can result in an improvement of TOT, but they may have quite different and even opposite influences on one country's international trade, aggregate economy and fiscal revenue. For oil-exporting countries, the fluctuation of TOT is more likely to be a result of the fluctuation of oil (export) price; but for other opened economies, the fluctuation of imported goods' prices may govern the variability of TOT.

Hence, we examine a group of countries for which the taxes on international trade and transactions $\left(FRT_{it}\right)$ constitute a big proportion of their total fiscal revenues $\left(PFR_{it}\right)$. We call these countries as "Trader (T) countries". The proportion of the taxes on international trade and transactions to total fiscal revenues is denoted by T. When T is equal to or greater than 25 percent, 30 percent, or 35 percent, this country is called a T20 country, T25 country, or T30 country, accordingly. Table 12 gives the "T countries" in our sample, together with oil exporting countries. Most of the T countries are not oil exporters.

Table A8 in the Appendix shows the PMG estimation results of our baseline model for "T countries". It evinces that for these three groups of T countries the TOT has a significantly robust negative effect on fiscal revenue in the long run. This result is opposite to that for the group of oil exporters, revealing how the TOT affect negatively fiscal revenue in some of largely opened countries whose taxation may be more skewed towards import tariffs.

Table 12. Oil exporter countries (Oil CEC) and Trader "T" countries

Oil CEC	T20 countries	T25 countries	T30 countries
Algeria	Algeria	Algeria	Algeria
Ecuador	Benin	Benin	Benin
Indonesia	Comoros	Comoros	--
Kazakhstan	Dominica	Dominica	Dominica
R. of Congo	Ethiopia	--	--
Sudan	Ghana	--	--
Venezuela	Grenada	--	--
	Jamaica	Jamaica	--
	Lebanon	Lebanon	--
	Madagascar	Madagascar	Madagascar
	Maldives	Maldives	Maldives
	Niger	Niger	--
	St. Vincent	St. Vincent	St. Vincent
	Sudan	--	--
	Togo	Togo	Togo

Note: The definition of Oil CEC is given in Table A4 in the appendix. A country is defined as a "T country" if its taxes on international trade and transactions constitute more than or equal to x percent of its total fiscal revenue (in the sense of sample mean): when x=20, 25, or 30, it is a T20 country, T25 country or T30 country, respectively.

Financial Stress

We also check whether our previous results about the influences of financial stress condition and financial crisis on fiscal revenue are sensitive to our definition of financial crisis. Robustness checks are implemented in two ways. One is that a financial crisis period is defined when financial stress index is greater than or equal to 2.5 or 3.5:

$$Dummy2_{it} = \begin{cases} 1, if\ FSI_{it} \geq 2.5 \\ 0, if\ FSI_{it} < 2.5 \end{cases}$$

$$Dummy3_{it} = \begin{cases} 1, if\ FSI_{it} \geq 3.5 \\ 0, if\ FSI_{it} < 3.5 \end{cases}$$

The other check is the use of Laeven and Valencia (2008), covering the period of 1970–2007, to identify financial crisis periods. These authors define financial crisis as systemic banking crisis, currency crisis or debt crisis.

Table A9 in the Appendix displays the financial crisis episodes identified by this database for the 32 countries covered by Equation (12). Since our dataset for model estimations covers the period 1970–2012, we extend the identification Laeven and Valencia (2008) for the period 2008–2012 by using the financial stress index in the same way as before. Thus in the new financial-crisis dummy variable, $Dummy4_{it}$, a financial crisis year is identified when the financial stress index is again greater than or equal to 3 for the period 2008–2012.

For the previous estimations of Equation (12), shown in Tables 8 or 10, the number of financial crisis episodes identified for the 32 countries in that model was 79. For $Dummy2_{it}$, $Dummy3_{it}$, and $Dummy4_{it}$, the numbers of financial crisis episodes identified for the 32 countries are respectively 97, 56, and 56. Because the country grouping analysis using the FSI_{it} indicates that financial stress (and financial crisis) has different effects on fiscal revenue for AEs and EMEs, we assume different long-run homogeneity of fiscal revenue elasticities for these two groups of countries. So in our robustness checks, we re-estimate Equation (12) for these two country groupings.

The PMG estimation results, corresponding to $Dummy2_{it}$, $Dummy3_{it}$, and $Dummy4_{it}$ are shown in Table A10, A11, and A12, respectively. Comparing these tables with Table 11, we conclude that our results are robust to the financial crisis episodes identification methods. Financial stress has a positive long-run effect on fiscal revenue for AEs, but a negative long-run effect for EMEs. In the short run, financial stress has a positive effect in normal time on average for AEs, and for EMEs financial crisis episodes have no significant short-run influence, on average. The only non-robust result is that crisis episodes have a negative extra effect in the short-run for AEs.

V. STRUCTURAL FISCAL BALANCES

This section displays the calculation of structural fiscal balances for several representative countries using the estimated fiscal elasticities. With the estimated revenue elasticities, we calculate the trend level of fiscal revenue for each country, given the trend-cycle decomposition method for explanatory cyclical factors. The trend level of government expenditure can be obtained according to Equation (7). The structural fiscal balances are then computed as the difference of trend fiscal revenue and trend fiscal expenditure.

There exist several methods to do the trend-cycle decomposition in the literature.[16] For simplicity, here we use the HP filter (with the usual HP parameter set to be 100 for annual data)[17] to do this decomposition for three cyclical factors under consideration: real GDP,

[16] Liu (2014) gives a detailed literature review of the trend-cycle decomposition of aggregate variables, and provides a new framework to estimate structural fiscal balances, which combines DSGE modelling and state-space econometric models and is different from the one employed in this paper.

[17] Tereanu et al. (2014) argue that successful implementation of structural fiscal targets requires the ability to measure output gaps accurately in real time, and potential GDP and the output gap are subject to significant revisions especially during crisis periods. They claim about a third of a growth surprise reflects on average a permanent change in potential growth and such an indicative rule of thumb could help improve the estimation of cyclically adjusted primary balances.

GDP deflator, and the term of trade index (all in logarithm). We assume zero as the constant trend level value for the financial stress index, which implies neutral financial market conditions on average across the banking sector, the securities markets and the exchange markets.

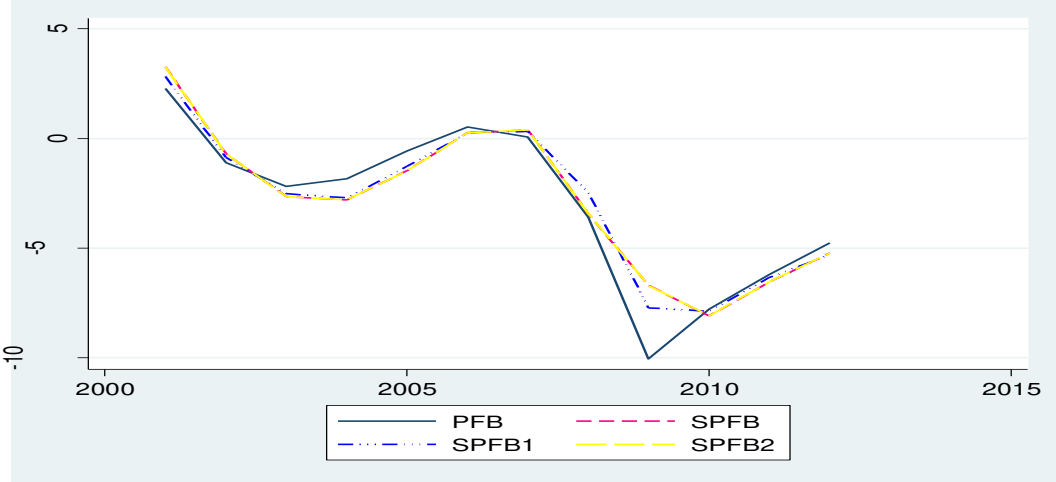

Figure 2. US Structural Primary Fiscal Balances (in percent of potential nominal GDP)
Note: PFB means primary fiscal balances (in percent of nominal GDP), and SPFB refers to structural primary fiscal balances (in percent of potential nominal GDP) adjusted using the elasticities estimated from model (5) (PMG approach) for two sub samples. SPFB1 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle and GDP deflator cycle only; and SPFB2 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle, GDP deflator cycle and TOT cycle only.

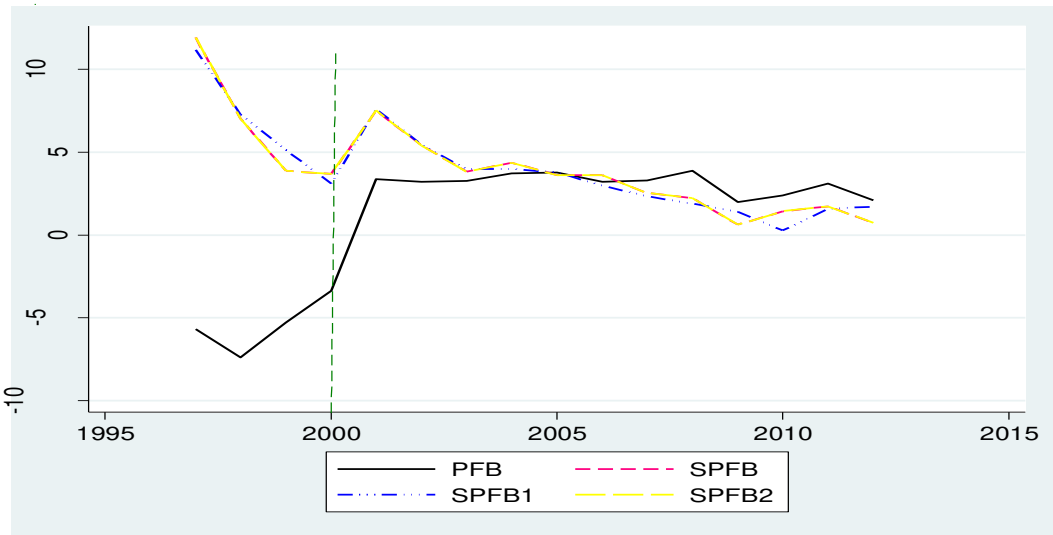

Figure 3. Brazil Structural Primary Fiscal Balances (in percent of potential nominal GDP)
Note: PFB means primary fiscal balances (in percent of nominal GDP), and SPFB refers to structural primary fiscal balances (in percent of potential nominal GDP) adjusted using the elasticities estimated from model (5) (PMG approach) for two sub samples. SPFB1 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle and GDP deflator cycle only; and SPFB2 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle, GDP deflator cycle and TOT cycle only.

Figures 2 and 3 depict the primary fiscal balances (PFB_{it}) (in percent of nominal GDP) and structural primary fiscal balances ($SPFB_{it}$)—in percent of potential nominal GDP defined as the product of trend real GDP and trend GDP deflator—for the US and Brazil. In addition, Figures B1 and B2 in Appendix B display PFB_{it} and $SPFB_{it}$ for Italy and China. In those figures we use the fiscal revenue elasticities estimated using the specification of Equation (12) for AEs and EMEs groups (Table A8). There, we also plot the primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to the real GDP cycle and the GDP deflator cycle only; or according to the real GDP cycle, the GDP deflator cycle and the TOT cycle.

For the US (and Italy), the evolving path of $SPFB_{it}$ does not deviate much from that of PFB_{it}. But for Brazil (and China), the $SPFB_{it}$ deviates substantially from PFB_{it}. For Brazil, before the year 2000, the PFB_{it} is always negative (indicating a fiscal deficit), but the $SPFB_{it}$ is always positive, suggesting a structural primary surplus.

We obtain several interesting findings for the four countries analyzed. First of all, the adjustment of the fiscal balances to the real GDP cycle and the GDP deflator cycle accounts for most of the necessary correction. This implies that the real GDP and the GDP deflator are the most important factors that would affect nominal fiscal balances for them. Secondly, adjusting fiscal balances according to the cyclical fluctuation of TOT is necessary for some countries, especially for the US and Brazil. Third, financial stress conditions and financial crises seem to play a little role in the structural adjustment of fiscal balances in those countries, even though their elasticities are statistically significant. This is because the revenue elasticities (both in the short- and long-run) with respect to FSI_{it} and financial crisis are very small, normally less than 1 percent in absolute value for these countries.[18]

VI. CONCLUDING REMARKS

How large are fiscal revenues elasticities around the world? This paper investigates empirically revenue elasticities for 96 countries spanning from 1970 to 2012. Revenue elasticities are estimated using a dynamic heterogeneous panel data model with respect to gaps in the real GDP, GDP deflator, TOT, and financial stress conditions.

[18] It is necessary to emphasize that the country-specific elasticities estimated in this paper are for reference only given that for many countries the time series of data are short. If quarterly data, rather than annual, are available, this increases the number of degrees of freedom and improves the estimations.

Homogeneity and heterogeneity of fiscal revenue elasticities are examined in detail. Sub-sample analyses are implemented to see the distinct roles of real GDP, GDP deflator, TOT, and financial stress and financial crisis for different groups of economies. Sensitivity analyses are further implemented in order to verify the influences of TOT and financial stress and crisis on fiscal revenue. Finally, we calculate structural fiscal balances for Brazil, China, Italy, and the US as examples of how to apply our - elasticity-trend approach.

Our main result evinces that for the 96 economies analyzed, on average, the TOT elasticity is significant, indicating the importance of using this variable in the calculation of structural fiscal balances. For the total sample that elasticity is negative, but for EMEs and oil exporters, the elasticity is highly significant and positive, as expected.

Another important finding is that the short-run elasticity with respect to real GDP is significantly larger than one for our sample. This finding confirms the important automatic stabilizing role that fiscal policy plays around the world. This was particularly the case for LICs, as our subsample analysis demonstrates, indicating a rise in revenue mobilization in those economies over time through tax reforms and improvements in revenue collection (Gupta and Tareq, 2008; and IMF, 2011).

Finally, we also obtain that the bracket-creep effect of inflation on nominal aggregate fiscal revenue exists on average for AEs in the long-run. Moreover, for a reduced sample of 32 countries, we find that financial stress (here captured by the financial stress index, FSI) has a negative long-run effect on fiscal revenue in EMEs, but in the short run both FSI and the dummy variable of financial crisis on average have no significant effect on fiscal revenues.

With those elasticities, we calculate the structural fiscal balances for Brazil, China, Italy and the US to illustrate our methodology. Such exercise highlights that for these countries, real GDP cycle and GDP deflator cycle explain most part of the fluctuation of nominal fiscal balances. However, adjusting fiscal balances according to the cyclical fluctuation of TOT is relevant for Brazil, a large emerging and commodity exporting country.

Our research also points out to the importance of using terms of trade and long-run (besides short-run) elasticities when computing structural balances. Ignoring that short-term tax elasticities may differ from long-term tax elasticities may contribute to inaccurate (cyclically-adjusted) fiscal indicators on which policy actions or recommendations may be based (Wolswijk, 2007).

Further research on fiscal elasticities and structural fiscal balances based on the cross-country perspective of this paper can be carried on at least in three dimensions. First, with more available data, one-off effects could be better corrected and the same estimations can be perfomed for different types of tax revenues. This would allow us to apply different elasticities for different tax bases. Secondly, one could estimate long-run elasticities

assuming a Pooled Mean Group approach in which only a subset of them are homogeneous across countries (Pesaran et al., 1997). Third, a comprehensive theoretical macroeconomic model could be developed, in order to better understand the mechanism of the cyclical factors affecting the aggregate fiscal revenue, expenditures, and their interactions. We leave these extensions for further research.

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APPENDICES

Appendix A: Supplementary Tables

Table A1. List of variables and data source

Variable	Description	Source
PFR_{it}	Primary fiscal revenue	IMF WEO database and author's computation
PFE_{it}	Primary fiscal expenditure	IMF WEO database and author's computation
$RGDP_{it}$	Real GDP	IMF WEO database
Def_{it}	GDP deflator	IMF WEO database
TOT_{it}	Terms of trade	IMF WEO database
HP_{it}	Index of house price	OETSADB database
SP_{it}	Index of share price	IFTSTSUB database
FSI_{it}	Financial stress index	Balakrishnan *et al.* (2009) and IMF update
U_{it}	Unemployment rate	IMF WEO Database
FRT_{it}	Taxes on international trade and transactions	IMF WEO Database
FCE	Financial crisis episodes	Laeven and Valencia (2008)

Table A2. Summary of the Raw Panel Data

	No. of cross sections	Observations per cross section			No. of observations
		minimum	average	Maximum	
ln_PFR_{it}	147	8	22.6	43	3328
ln_PFE_{it}	147	6	21.1	43	3095
ln_RGDP_{it}	147	1	38.0	43	5585
ln_Def_{it}	147	11	38.1	43	5607
ln_TOT_{it}	142	9	36.1	43	5133
ln_HP_{it}	18	25	40.1	41	721
ln_SP_{it}	39	8	25.1	42	977
FSI_{it}	44	5	20.3	33	895
U_{it}	88	6	29.4	43	2585

Table A3. Descriptive Statistics for the Processed Panel Data, 1970–2012

Statistic	Country Grouping	PFR/GDP percent of GDP	PFE/GDP percent of GDP	RGDP growth percent	GDP Deflator Inflation percent	TOT growth percent	Housing price inflation percent	Share Prices Inf. percent	FSI ndex numbe	Unemp. Rate percent	FRT/GDP percent of GDP
Mean	All	29.99	30.05	3.61	6.97	0.65	6.82	12.29	-0.02	7.97	3.29
	AE	39.26	39.14	2.65	5.16	0.05	6.82	9.28	0.05	6.50	0.91
	EME	25.32	25.65	4.59	8.52	0.78	NA	18.21	-0.23	8.28	1.98
Standard Deviation	All	12.21	12.04	4.06	7.89	11.12	8.66	31.84	2.28	5.69	3.98
	AE	9.70	10.22	2.83	6.48	4.42	8.66	23.97	2.43	3.90	1.03
	EME	8.83	9.35	4.13	8.19	8.21	NA	41.70	1.83	4.44	1.66
Minimum	All	4.48	8.42	-41.89	-24.57	-50.87	-18.31	-92.67	-5.87	0.31	0.00
	AE	13.19	11.98	-14.10	-6.01	-21.83	-18.31	-92.67	-5.87	0.31	0.00
	EME	10.72	10.97	-17.70	-5.99	-27.88	NA	-60.09	-3.64	0.66	0.15
Maximum	All	67.79	80.13	33.63	77.30	90.41	70.10	321.05	14.99	37.25	37.75
	AE	60.37	66.43	14.78	77.30	28.20	70.10	111.15	14.99	25.00	4.99
	EME	53.83	48.22	15.20	75.27	63.05	NA	321.05	7.15	22.45	9.63

Table A4. IMF FAD-specific Country Groupings

Advanced Economies (AEs) (30)				Emerging Market Economies (EMEs) (29)			
country	**code**	**country**	**code**	**country**	**code**	**country**	**code**
U.S	111	Greece	174	Turkey	186	Thailand	578
U.K	112	Iceland	176	South Africa	199	Kenya	664
Austria	122	Ireland	178	Argentina	213	Morocco	686
Belgium	124	Portugal	182	Brazil	223	Nigeria	694
Denmark	128	Spain	184	Chile	228	Kazakhstan	916
France	132	Australia	193	Colombia	233	Bulgaria	918
Germany	134	New Zealand	196	Mexico	273	Russia	922
Italy	136	Israel	436	Peru	293	China	924
Netherlands	138	Hong Kong	532	Jordan	439	Ukraine	926
Norway	142	Korea	542	Saudi Arabia	456	Latvia	941
Sweden	144	Singapore	576	India	534	Hungary	944
Switzerland	146	Czech	935	Indonesia	536	Lithuania	946
Canada	156	Slovak	936	Malaysia	548	Poland	964
Japan	158	Estonia	939	Pakistan	564	Romania	968
Finland	172	Slovenia	961	Philippines	566		

Note: There are 147 countries in the sample, and the remaining countries are defines as *Other Developing Economies* (ODE).

Table A5. Commodity Exporter Countries (CEC): 50 Countries

country	**code**	**country**	**code**	**country**	**code**	**country**	**code**
Algeria [1]	612	Ecuador [1]	248	Mauritania	682	Senegal	722
Argentina	213	Egypt	469	Moldova	921	Sierra Leone	724
Armenia	911	Gambia, The	648	Mozambique	688	Sudan [1]	732
Australia	193	Ghana	652	New Zealand	196	Tajikistan	923
Benin	638	Guatemala	258	Nicaragua	278	Tanzania	738
Bolivia	218	Guyana	336	Niger	692	Togo	742
Burundi	618	Honduras	268	Norway	142	Uganda	746
Cameroon [1]	622	Indonesia [1]	536	Panama	283	Uruguay	298
Central African Republic	626	Kazakhstan [1]	916	Papua New Guinea	853	Venezuela [1]	299
Chile	228	Kenya	664	Peru	293	Zambia	754
Colombia	233	Kyrgyz Republic	917	Russia [1]	922	Zimbabwe	698
Congo, R. of [1]	634	Malawi	676	Rwanda	714		
Côte d'Ivoire	662	Mali	678	Saudi Arabia [1]	456		

Note: A country is defined as a commodity exporter if the exports of its primary commodities constitute more than 50 percent of its total exports (in the sense of sample mean), like in Cavalcanti et al. (2014). [1] indicates that this country is an oil producer, also according to IMF FAD-specific country groupings.

Table A6. Short-run Fiscal Revenue Elasticities: Model (2), PMG

	Country	EC parameter	Real GDP	GDP deflator	TOT
AE(28)	Australia	--	1.293***	--	--
	Austria	--	0.611***	1.333***	--
	Belgium	-0.178***	0.465***	1.259***	--
	Canada	--	0.895***	1.172***	-0.274*
	Czech Republic	-0.681**	1.244***	0.880***	--
	Denmark	-0.549***	1.113***	0.502***	--
	Estonia	--	0.486***	0.868***	1.699***
	Finland	-0.240***	0.635***	0.985***	--
	France	-0.252**	0.924***	1.028***	-0.155*
	Germany	--	0.767***	1.222***	--
	Greece	--	0.639**	1.095***	--
	Iceland	-0.377***	1.241***	0.870***	--
	Italy	--	0.701***	0.988***	0.182*
	Hong Kong SAR	-0.484***	1.750***	0.981*	--
	Japan	-0.223**	1.034***	1.009***	-0.146***
	Korea	-0.380**	0.857***	--	--
	Netherlands	--	0.726***	1.977***	-2.158**
	New Zealand	--	1.075***	1.482***	--
	Norway	-0.145**	1.308***	0.985***	0.220***
	Portugal	--	1.039***	0.719***	--
	Singapore	--	3.269***	2.070***	-4.130***
	Slovak	-0.336**	0.893***	--	--
	Slovenia	-0.562**	1.047***	1.093***	--
	Spain	--	1.064***	1.191***	--
	Sweden	--	1.038***	1.123***	--
	Switzerland	-0.164*	0.924***	--	--
	United Kingdom	-0.339***	0.737***	1.319***	-0.368***
	United States	-0.109*	1.649***	1.183***	-0.204**
EE(21)	Argentina	--	1.395***	1.187***	--
	Brazil	-1.070***	--	1.052***	--
	Chile	-0.465***	2.481***	0.799***	--
	China	-0.0706**	0.746*	--	--
	Colombia	--	1.338***	0.954***	-0.165**
	Hungary	-0.676***	--	1.290***	-1.903**
	India	-0.304**	1.063**	1.444***	-0.939**
	Indonesia	-0.372***	--	0.959***	--
	Jordan	--	0.677*	0.947***	--
	Kenya	-0.392***	2.405***	--	--
	Latvia	-0.422***	1.029***	1.042***	--
	Lithuania	-0.802***	0.962***	0.897***	--
	Malaysia	--	0.954**	--	--
	Mexico	-0.287**	0.679*	0.800***	--
	Morocco	-0.295*	--	--	--
	Pakistan	--	--	--	--
	Philippines	--	2.119***	2.172***	--
	Poland	-0.511**	1.235**	1.630***	-0.704***
	Russia	-0.585**	1.884***	0.833***	--
	Thailand	-0.477***	1.998***	2.136***	--
	Ukraine	-0.118	1.199***	0.891***	--

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Table A7. Short-run Fiscal Revenue Elasticities: Equation (12), PMG

Country	EC parameter	Real GDP	GDP deflator	TOT	Financial stress	Financial crisis dummy
Australia	--	1.223***	--	--	0.006*	-0.008*
Austria	-0.379***	--	0.865***	--	--	--
Belgium	-0.205**	--	0.881***	--	--	--
Canada	--	0.851***	1.281***	-0.312**	--	--
Denmark	-0.312***	0.975***	0.543***	0.322*	--	--
Finland	-0.274***	0.825***	0.770***	--	--	--
France	-0.136*	0.582***	1.123***	-0.373***	--	--
Germany	-0.295*	0.594**	1.435***	--	--	--
Greece	--	--	2.964**	--	--	--
Italy	-0.328***	--	0.814***	--	0.004*	--
Japan	-0.129**	1.084***	0.763**	--	--	--
Korea	-0.736***	--	--	--	0.012***	--
Netherlands	--	0.661***	1.777***	-2.112**	--	--
Norway	-0.121*	1.404***	1.048***	0.213**	--	--
Portugal	-1.205***	--	--	--	--	--
Spain	-0.297***	1.516***	0.981***	--	--	--
Sweden	--	1.099***	1.315***	--	-0.005**	--
Switzerland	-0.195***	1.257***	--	0.360***	--	-0.015***
United Kingdom	--	1.121***	1.182***	--	--	0.008**
United States	-0.121*	1.265***	1.266***	-0.482***	--	-0.009***
Argentina	--	0.953***	1.464***	--	--	--
Brazil	-1.085***	0.882***	1.542***	--	0.012**	--
Chile	-0.564***	3.583***	3.337***	-0.646***	--	--
China	-0.060**	0.986*	1.582***	--	-0.009*	--
Colombia	-1.037***	1.414***	0.763**	--	--	--
Hungary	-0.678***	--	--	-2.553**	--	--
Malaysia	-0.593***	--	--	--	0.018***	--
Mexico	-0.355***	1.471***	--	1.221**	0.017**	-0.024*
Morocco	--	--	--	--	0.018**	--
Pakistan	-0.498**	--	--	0.584*	--	--
Philippines	-0.485**	1.095*	1.184*	--	--	--
Poland	-0.621***	1.347***	0.918***	-0.392**	--	--

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Table A8. Long-run and Short-run Fiscal Revenue Elasticities: Equation (12), Sub-samples

Country	EC parameter	Real GDP	GDP deflator	TOT	Financial stress	Financial crisis dummy
Long-run for AE		0.354***	1.484***	-0.439***	0.005***	
Short-run for AE						
Australia	-0.062*	1.292***	--	--	--	--
Austria	-0.369***	--	0.517**	-0.181*	0.004***	--
Belgium	-0.168**	0.360**	0.785***	-0.301*	--	--
Canada	--	0.786***	1.315***	-0.270**	--	--
Denmark	-0.126***	0.991***	0.781***	--	--	--
Finland	-0.163**	0.853***	1.049***	--	--	--
France	-0.077**	0.607***	1.066***	-0.422***	--	--
Germany	-0.909***	0.712***	--	--	0.005**	--
Greece	-1.154***	0.878***	1.792**	-0.293*	--	--
Italy	--	0.536**	1.211***	--	0.006**	-0.010*
Japan	-0.067*	1.098***	--	-0.149*	--	--
Korea	-0.550***	--	--	--	0.017***	--
Netherlands	-0.519***	0.723***	1.843***	-2.243***	--	--
Norway	--	1.478***	1.148***	0.155*	--	--
Portugal	-1.473***	--	4.083***	-2.404***	--	-0.024*
Spain	--	1.387***	1.053***	--	--	--
Sweden	--	1.142***	0.830***	--	-0.006**	--
Switzerland	-0.143***	1.192***	--	0.286**	--	-0.016***
United Kingdom	--	1.303***	1.158***	--	--	0.008**
United States	-0.087*	1.263***	1.101***	-0.605***	0.003**	-0.010***
Long-run for EE		0.901***	1.070***	0.093**	-0.013***	
Short-runfor EE						
Argentina	--	0.982***	1.363***	--	--	--
Brazil	-1.009***	0.940***	1.716***	-0.200*	0.009*	--
Chile	-0.594***	3.441***	3.275***	-0.668***	--	--
China	-0.065**	0.943*	1.578***	--	-0.009*	--
Colombia	-0.715**	1.181**	0.996**	--	-0.012*	--
Hungary	-0.538**	--	1.024	-2.711**	--	--
Malaysia	-0.598***	--	--	--	0.014***	--
Mexico	-0.342***	1.403***	--	1.281**	0.014*	--
Morocco	--	--	--	--	0.018**	--
Pakistan	-0.556**	--	--	0.493*	--	--
Philippines	-0.566***	--	1.636**	--	--	--
Poland	-0.733***	1.179***	1.205***	-0.412***	--	--

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Table A9. Fiscal Revenue Elasticities for "Trader T countries": Baseline Model, PMG

	T20 countries		**T25 countries**		**T30 countries**	
	SR	LR	SR	LR	SR	LR
Real GDP	1.79***	1.27***	2.22***	1.27***	2.15***	1.24***
GDP deflator	0.79***	0.92***	0.81***	0.92***	0.84***	0.93***
TOT	--	-0.19***	--	-0.20***	--	-0.21***
ECP	-0.45***		-0.45***		-0.46***	
Observations	305		236		191	
No. of countries	13		10		8	

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant. A country is defined as a "T country" if its taxes on international trade and transactions constitute more than or equal to x percent of its total fiscal revenue (in the sense of sample mean): when x=20, 25, or 30, it is a T20 country, T25 country or T30 country respectively.

Table A10. Financial Crisis Episodes for Model (5): IMF Database, 1970-2007

Country	**Financial crisis years** (starting date)
Australia	
Austria	
Belgium	
Canada	
Denmark	
Finland	1991,1993
France	
Germany	
Greece	1983
Italy	1981
Japan	1997
Korea	1997,1998
Netherlands	
Norway	1991
Portugal	1983
Spain	1977,1983
Sweden	1991,1993
Switzerland	
United Kingdom	2007
United States	1988, 2007
Argentina	1975,1980,1981,1982,1987,1989,1995,2001,2002
Brazil	1976,1982,1983,1987,1990,1992,1994,1999
Chile	1972,1976,1981,1982,1983
China	1998
Colombia	1982, 1985, 1998
Hungary	1991
Malaysia	1997, 1998
Mexico	1977, 1981, 1982, 1994, 1995
Morocco	1980, 1981, 1983
Pakistan	1972
Philippines	1983, 1997, 1998
Poland	1981, 1992

Source: Laeven and Valencia (2008). "Systemic Banking Crises: A New Database", IMF Working Paper.
Note: "Financial crisis" here refers to systemic banking crisis, currency crisis or debt crisis.

Table A11. Fiscal Revenue Elasticities (Mean): Equation (12), Robustness Check 1

	***AEs* (PMG)**		***EMEs* (PMG)**	
	SR	LR	SR	LR
Real GDP	0.76***	0.35***	0.88***	0.90***
GDP deflator	1.06***	1.49***	1.04***	1.07***
TOT	-0.29*	-0.44***	--	0.09**
FSI	0.003***	0.005***	--	-0.013***
Dummy2·FSI	-0.002		--	
ECP		-0.30***		-0.50***
Observations		549		179
No. of countries		20		12

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Table A12. Fiscal Revenue Elasticities (Mean): Equation (12), Robustness Check 2

	***AEs* (PMG)**		***EMEs* (PMG)**	
	SR	LR	SR	LR
Real GDP	0.77***	0.35***	0.80***	0.91***
GDP deflator	1.09***	1.49***	1.14***	1.06***
TOT	-0.32**	-0.45***	--	0.09***
FSI	0.003***	0.004***	--	-0.018***
Dummy3·FSI	-0.004**		--	
ECP		-0.30***		-0.47***
Observations		549		179
No. of countries		20		12

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Table A13. Fiscal Revenue Elasticities (Mean): Equation (12), Robustness Check 3

	***AEs* (PMG)**		***EMEs* (PMG)**	
	SR	LR	SR	LR
Real GDP	0.76***	0.36***	0.67*	0.28**
GDP deflator	1.06***	1.47***	1.42***	1.73***
TOT	-0.31*	-0.47***	--	-0.12**
FSI	0.003***	0.004***	0.007**	-0.008*
Dummy4·FSI	--		--	
ECP		-0.30***		-0.37***
Observations		549		179
No. of countries		20		12

Note: ***, **, and * indicate significance at the level of 1%, 5%, and 10% respectively. -- denotes that the relevant coefficient is not significant.

Appendix B: Supplementary Figures

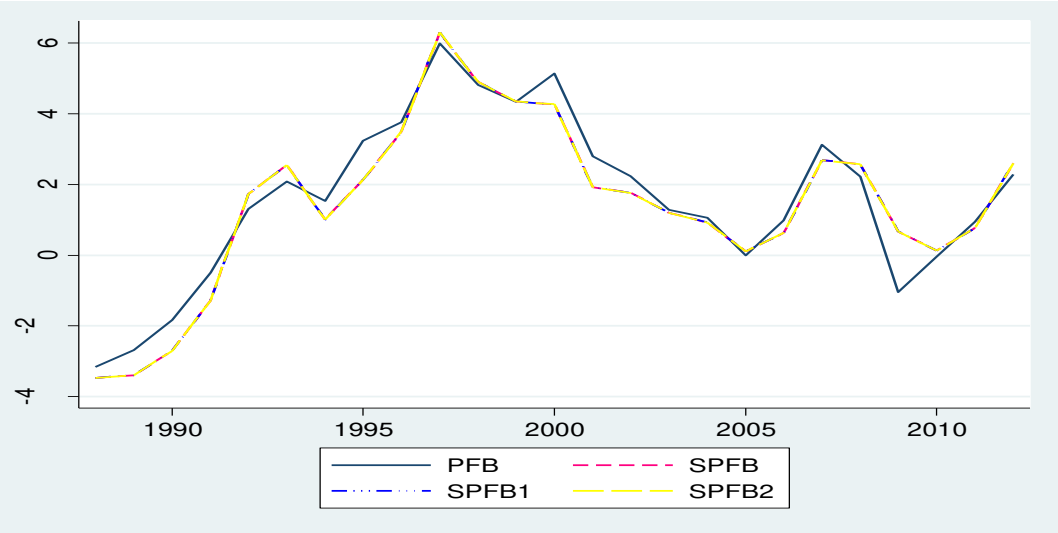

Figure B.1. Italy Structural Primary Fiscal Balances (in percent of potential nominal GDP)
Note: PFB means primary fiscal balances (in percent of nominal GDP), and SPFB refers to structural primary fiscal balances (in percent of potential nominal GDP) adjusted using the elasticities estimated from model (5) (PMG approach) for two sub samples. SPFB1 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle and GDP deflator cycle only; and SPFB2 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle, GDP deflator cycle and terms of trade cycle only.

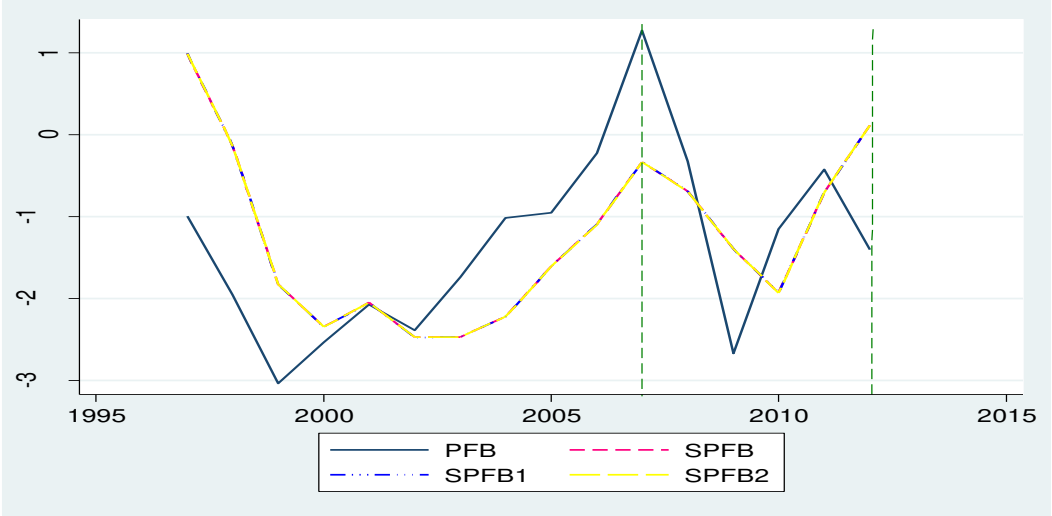

Figure B.2. China Structural Primary Fiscal Balances (in percent of potential nominal GDP)
Note: PFB means primary fiscal balances (in percent of nominal GDP), and SPFB refers to structural primary fiscal balances (in percent of potential nominal GDP) adjusted using the elasticities estimated from model (5) (PMG approach) for two sub samples. SPFB1 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle and GDP deflator cycle only; and SPFB2 is primary fiscal balances (in percent of potential nominal GDP) partially adjusted according to real GDP cycle, GDP deflator cycle and terms of trade cycle only.