European Commission - FED

Study on the vulnerability and resilience factors of tax revenues in developing countries

Final Report

This project is funded by
The European Union

A project implemented by
AETS

EUROPEAN COMMISSION

Study on the vulnerability and resilience factors of tax revenues in developing countries

Contract N°2012/306594/2
FWC COM 2011 - Lot 1 – Studies and Technical Assistance in all Sectors

Final Report

November 2013

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Executive Summary

Beyond the general impact of shocks on economic growth there are specific effects of shocks on revenue systems that shape the capacity of governments to react to adverse external events and sustain development expenditure. These effects vary not only with the kinds of shock affecting the economies, but also with the characteristics of these economies (welfare levels, dependence on natural resources, etc.), the political and administrative capacity of states to react to changing situations, and the structure of the tax systems. Shocks do not only affect the level of tax collection, but also the stability and predictability of revenue. The latter is critical with regard to the adaptation to exogenous changes as well as the financial ability of states to recover from adverse external events.

This study presents an approach to empirically assess the impact of several kinds of shocks on revenue systems in a broad set of countries, and in developing countries in particular. The study thus contributes to an evidence-based policy of the European Commission aimed at strengthening the capacity of developing countries to absorb external shocks and thereby stabilising development expenditures. In particular, it provides evidence on the vulnerability to external shocks of tax revenues in developing countries and presents policy options to strengthen the resilience of tax systems.

Academic research on the relationship of tax revenue and exogenous shocks in developing countries has focused on some factors which supposedly drive revenue vulnerability, but has neglected other factors that might play a crucial role as well. The two most relevant debates in this context – on developing countries' tax effort and performance on the one hand, and on growth volatility and exposure to shocks on the other hand – have not been brought together in a systematic manner. Research has been further hampered by a critical lack of reliable data, in particular from low- and lower-middle-income countries.

Still, the existing literature allows to identify a set of assumptions or broad approximations that guide the empirical research of the present study.

- First, we assume that economic factors, above all the importance of agriculture and industry in the economy, the openness of the economy and the level of economic development are relevant not only for the tax ratio, but also for the sensitivity of revenues facing exogenous shocks.
- Second, we expect different kinds of shocks to have different impacts on developing countries. The impact of shocks could be non-linear, with large shocks having a particularly strong impact. Further, we expect the composition of the tax structure to play a role in this relationship.
- Third, we believe that it is possible to detect groups with specific patterns of tax revenue behaviour facing exogenous shocks. Among those groups already identified in the literature are country income groups, resource-rich countries and countries with democratic (or autocratic) regimes.
- Fourth, vulnerability refers to the sensitivity of revenue, but also to the ability of tax systems to quickly recover from shocks. Apart from the initial sensitivity of revenue and the tax mix, it can be assumed that governance-related factors, i.e. the capacity to formulate and implement corresponding fiscal policies, are key elements of recovery.

Against this background, the present study proceeds in an incremental fashion which unfolds the complexity of the topic before focusing on the most relevant aspects. The initial stage of the analysis derives measures of fiscal capacity and revenue instability for each country in the sample. We then introduce various kinds of shocks – exchange rate pressure, terms of trade, droughts, intensity of natural catastrophes and real GDP decline – to our model, and identify how each of them affects revenue sensitivity. The following stage of our empirical investigation identifies the effects of shocks on tax revenue in various groups of low- and lower-middle-income countries. Finally, to identify possible channels through which external shocks act on government revenue, we run regressions with various types of revenue as dependent variables – non-tax revenue, trade taxes, sales taxes and income taxes.

Tax performance and volatility

The range of structural variables which determine fiscal capacity is derived from the literature and includes measures of trade openness, welfare levels and the sectoral composition of the economy. However, unlike most studies, we use the share of agricultural, mining, manufacturing, and fuel exports to GDP along with imports to GDP rather than a combined measure of trade openness. Looking

at the full sample we observe positive effects of mineral and fuels exports on tax revenue, whereas agriculture and manufacturing are negatively associated with tax revenue. Yet, different stories emerge once the sample is divided in two groups: high- and upper-middle-income countries and low- and lower-middle-income countries. The positive relationship between mineral exports and tax performance seems to be driven above all by higher-income countries. The share of agriculture is negatively associated with tax performance in both groups, but the effect is much bigger in magnitude in the higher-income group. The near-zero effect of imports to GDP in the regression with the full sample is explained by the opposite ways this variable acts on tax performance in countries at different income levels: its effect is negative in higher-income countries, while positive, large, and statistically significant in lower-income countries.

The negative relationship between manufacturing exports and tax revenue, which is even more pronounced for lower-income countries, appears to be counter-intuitive. From the literature we would expect manufacturing to be positively related to tax performance. One explanation could be that manufacturing in poorer countries achieves global competitiveness primarily through low labour costs and margins. The results are also consistent with the global fragmentation of production: manufacturing exports of poor countries are often based on adding a small amount of value added to imported intermediate inputs. Hence, the sector makes no significant contribution to domestic tax revenue.

In a general sense, high volatility of tax revenue can be regarded as an indication for less revenue stability, lower predictability and, ultimately, lower revenue on average. Our data analysis confirms this relationship. The relation is more pronounced for high- and upper-middle-income countries, non-resource-rich countries and democratic countries. With regard to their counterparts (lower-income, resource-rich and non-democratic countries), the former groups appear to be more homogenous and thus exhibit a closer resemblance to the pattern one would assume, i.e. higher total tax volatility being associated with lower total revenues on average.

Shocks and revenue sensitivity

In general terms it can be said that the effects of shocks on revenue are more pronounced and statistically stronger in poorer countries compared to the richer group.

- Exchange rate (ER) pressure contributes negatively to tax revenue in all specifications. The effect is comparably large and significant for both income groups.
- Adverse shocks to terms of trade also reduce tax revenue, and the result is statistically significant for the whole sample as well as for the group of low- and lower-middle-income countries. In this case, richer countries seem to suffer less from shocks.
- The effect of poor rainfall on tax revenue is less clear. All in all, the results seem to confirm that rainfall shocks in SSA primarily hit the informal and subsistence sectors, which do not pay taxes. Hence, they should not affect tax revenue unless there are significant spillovers from the informal to the formal economy.
- The intensity of natural catastrophes also affects tax revenue negatively. The result is primarily driven by the group of poorer countries, where the effect is statistically significant.
- Finally, GDP decline as a proxy for a general output shock does not seem to decrease revenue (as a percentage of GDP). All coefficients are statistically insignificant and very close to zero. These results indicate that on average tax systems are neutral, i.e. the elasticity of revenue with respect to output is close to 1 – independently of the country income group.

Most studies on shocks in developing countries start from a definition that contains a magnitude criterion – a shock being a major event with a large impact on the economy. The (usually implicit) underlying assumption is that the effects of shocks are non-linear – either assuming impacts to grow exponentially or relying on a “tipping point” - approach where external events are irrelevant below a certain threshold, but cause major impacts once this threshold is passed. If large shocks dummies are included in the regressions alone their effect is often significant in the low- and lower-middle-income group, but for most shocks there is little evidence that their effects are non-linear in the sense specified above: Large shock dummies are usually insignificant if included together with the linear specification of the shock. The only exceptions are large ER-shocks in lower-income countries. In this case, the non-linear effect is pronounced and weakly significant, while in high-income countries it is practically non-existent. Hence, we do not find convincing evidence for an approach that focuses exclusively on large shocks when analysing revenue systems.

Country groups

We explore differences between groups of countries with regard to the sensitivity of their tax revenue to external shocks. We first use pre-defined groups based on the respective endowment with natural resources (resource-rich vs. non-rich) and the character of the political regime (democracies vs. non-democracies).

- With regard to natural resource endowment, results indicate that ER pressure has a negative effect in both resource-rich (RR) and non resource-rich (non-RR) countries, but in the former group the effect is much bigger and statistically significant. In turn, the coefficient of terms-of-trade shocks is negative and statistically significant in both groups of countries, but the effect is more pronounced in non-RR countries. Finally, the negative effect of natural disasters intensity seems to be driven entirely by non-RR countries. The reason could be that the extractive industries – the main sources of tax revenue in RR countries – are usually less affected by natural catastrophes than other types of economic activity.
- With regard to political regime type, democratic countries fare better than non-democracies in their revenue sensitivity to all three shocks we consider. The coefficients on shocks are smaller in magnitude and much less significant. For non-democratic countries, the effects of the three kinds of shocks are negative and statistically significant. It should be noted, however, that causality is particularly difficult to establish in this context.

We also check whether certain policy variables interact with external shocks in their effect on tax revenue. Results are generally similar for the three shocks we explore. The findings on ER pressure and terms-of-trade shocks both suggest that the importance of tight fiscal policy during good or normal times is high, while public debt does not seem to be important. Real exchange rate overvaluation and inflation (in case of RR countries and democracies) contribute to higher tax sensitivity. Interestingly, reserves reduce revenue sensitivity in case of terms-of-trade shocks, but not in the case of ER pressure. Results for natural disaster intensity are also similar to those for ER pressure.

Finally, we subject our sample to data-driven methods of grouping countries into homogeneous groups. In general terms, the results support the initial logic of dividing countries according to income, resource endowments, and political regime type. The distributions of *a posteriori* probabilities and the similarity of regression results to the results in predefined groups are the main arguments.

Types of taxes

To identify possible channels through which external shocks act on government revenue, we run regressions with four types of government revenue: non-tax revenue, trade taxes, sales taxes and income taxes. The findings suggest that different shocks act on government revenue through different channels. Even though most of the coefficients do not reach statistical significance, probably due to the limited number of observations, the results support the following conclusions.

- For the whole sample of lower-income countries, ER pressure has a significant negative effect on trade and income tax. In contrast, its effect is negative yet not significant on indirect taxes (goods and services tax), and practically zero on non-tax revenue. The effect is particularly strong and significant in non-democratic as well as in non-resource-rich countries. Apparently, these groups experience more difficulties in counteracting the impact of ER pressure shocks.
- Terms-of-trade shocks have significant negative effects on non-tax revenue. The reason is perhaps that these shocks are likely to reduce profits of public enterprises that act as commodity exporters. The effect is negative and significant for all sub-groups except democracies, but stronger for non-resource-rich compared to resource-rich countries. Terms-of-trade shocks also affect income tax revenue in non-democratic and non-resource-rich countries.
- Natural disaster intensity affects mostly trade and income taxes, although the coefficient is not significant in any specification.

All in all it can be inferred that non-democratic and non-resource-rich countries are particularly vulnerable to shocks affecting income taxes and non-tax revenue. In the case of resource-rich countries, no clear patterns emerge: their revenue structure, though more *volatile* than that of non-resource-rich countries due to a higher dependence on non-tax revenue, could be less *vulnerable* to external shocks. At least, there is no robust evidence pointing to volatility of revenue from natural resources being directly connected to increased vulnerability vis-à-vis shocks analysed in this report. This finding

is somewhat unexpected, as conventional wisdom and the literature on rent incomes from (principally) oil would suggest resource-rich economies to be particularly vulnerable to global price and capital shocks. From the present study we get the impression that it is much more the non-resource-rich countries we should be worried about.

The findings indicate that vulnerability to shocks should not be regarded exclusively as an issue of major adverse events hitting an economy. It may be important for governments, donors and international organisations to prepare for such events and to develop the appropriate financial tools to deal with them. But it is also important to keep in mind that minor events also have significant effects on revenue and that long-term structural reforms (in particular regarding income tax and non-tax revenue) are a necessary ingredient of any strategy targeting vulnerability of revenue in developing countries. In this context, a broad tax portfolio could contribute to making total revenue less susceptible to individual shocks. Further, the better performance of democracies suggests that reforms pointing to accountability, transparency and rule of law could have an important positive effect on revenue resilience, as governments may have more legitimacy to build broad-based revenue systems, as well as additional short-term manoeuvring space to respond to adverse external events.

Case studies

The report summarises the findings of five case studies - Colombia, Ethiopia, Indonesia, Tanzania and Ukraine. The case studies analyse the driving forces of fiscal dynamics in developing countries employing a vector autoregression (VAR) approach. The basis of the VAR approach is identifying the long-run equilibrium relationship between the variables of interest and then analysing how they respond to perturbations of the equilibrium. As there will be an equilibrium between revenue and spending in the long run (a deficit cannot be permanently increasing) we anticipate that spending revenue (tax and, if appropriate, aid) will be cointegrated and test explicitly for this. We find cointegration in all cases, indicating that there is a relationship between spending and revenue and we analyse the response to shocks (to any of the variables).

The analysis showed that tax revenue in the two LICs (Ethiopia and Tanzania) is not resilient and is slow to recover from a shock. Tax revenue is the fiscal driver, i.e. spending responds to tax revenue but revenue does not respond to the other variables. Observing that tax revenue is not a responsive variable implies that the government is unable to alter tax revenue in the short to medium run to adjust to a fiscal disequilibrium (such as a shortfall in aid or unanticipated increase in spending). Further, a shock to tax has a permanent effect, so a negative shock to tax revenue will reduce spending. Hence, we can conclude that revenue is not resilient in LICs. As it takes time to build a resilient tax system, and economic growth to generate a more diverse tax base, in the short to medium term LICs experiencing shocks will require assistance (aid) to compensate for the effects of lower tax revenue.

The two MICs (Colombia and Ukraine) appear to have resilient tax systems. Tax revenue is a responsive variable, implying that the government has the ability to alter tax revenue to adjust to a fiscal disequilibrium; increases in spending appear to be followed by increases in tax. Furthermore, a shock to tax has only a transitory effect; although a decline in tax will induce reductions in spending, revenue recovers fairly quickly and so does spending. It transpires that spending is the fiscal driver: governments are able to make spending decisions with some confidence that they can raise the required revenues (and that tax recovers from shocks). The results for Indonesia were somewhat different to those for the LICs and MICs, which may reflect the fact that in terms of income and economic structure Indonesia has been intermediate between the pairs of LICs and MICs. At the same time, access to data was more limited in Indonesia compared to the other cases.

Overall, the results suggest there is a point of transition: at low levels of income, tax revenue is stagnant and unresponsive but beyond some level of development tax becomes a policy variable amenable to short term influence. This transition is likely to reflect the emergence of a broad and buoyant tax base in the middle terms and access to international capital markets in the short term. Tax systems in LICs lack resilience because the tax base is narrow and overly reliant on resources and large taxpayers that can be difficult to tax. As economies grow and diversify to become MICs the fundamental tax base (private wage employment and private consumption) expands and revenue becomes resilient. Supporting LICs in making this transition is the perennial development challenge.

1. Introduction

Financing for development requires developing countries to step up their domestic revenue mobilisation. Such key international players as the EU, OECD, G20 and IMF are calling on the developing countries to increase their tax collection efforts. Recent publications suggest that many low-income and lower-middle-income countries may be failing to tap their full revenue potential. One issue not sufficiently addressed in this context refers to the volatility of public revenue in developing countries and their vulnerability to exogenous shocks.

It has been conventional wisdom for quite some years now that a narrow tax base combined with an excessive reliance on a few commodity exports exposes countries to the risk of increased revenue volatility and, ultimately, lower tax collection. Beyond this general statement, however, there is still a knowledge gap regarding the relationship of exogenous shocks and public revenue in a broad (and increasingly diversified) range of low- and lower-middle-income countries. Facing heterogeneity of cases combined with limited access to data, academic research has found it difficult to even develop consistent measures of tax capacity and tax performance in developing countries - let alone addressing the question of how revenue systems react to unforeseen external events.

But why is it important to analyse the relationship of shocks and taxes in particular? This study argues that beyond the general impact of shocks on economic growth there are specific effects of shocks on revenue systems that shape the capacity of governments to react to adverse external events and sustain development expenditure. These effects vary not only with the kinds of shock affecting the economies, but also with the characteristics of these economies (welfare levels, dependence on natural resources, etc.), the political and administrative capacity of states to react to changing situations, and the structure of the tax systems. At the same time, it is important to keep in mind that shocks do not only affect the level of tax collection, but also (perhaps even more importantly) the stability and predictability of revenue. It can be argued that the latter is critical with regard to the adaptation to exogenous changes as well as the financial ability of states to recover from adverse external events.

This study presents an approach to empirically assess the impact of several kinds of shocks on revenue systems in a broad set of countries, and in developing countries in particular. The study thus contributes to an evidence-based policy of the European Commission to strengthen the capacity of developing countries to absorb external shocks and therefore stabilise development expenditures. The results of this study are also expected to underpin the policy dialog that the European Union holds with developing countries in the context of its regular budget support operations. In particular, it provides evidence on the vulnerability to external shocks of tax revenues in developing countries and presents policy options to strengthen the resilience of tax systems.

Our empirical strategy will address tax vulnerability and resilience in several stages.

First, we derive estimates of revenue performance (the ratio of revenue to GDP) for a wide range of countries. The basic approach is to estimate 'potential' revenue as predicted by standard tax base (economic structure) variables. This will help to characterize the features of tax capacity across countries and to group countries according to specific characteristics.

Second, we assess how unstable or volatile revenues are for the countries (or groups of countries) in the sample and identify determinants of tax revenue instability. This approach follows the reasoning that high revenue volatility is an indication of lower revenue collection, lower predictability and higher vulnerability to external shocks.

Third, we address susceptibility to shocks in particular. We start by looking at five kinds of shocks (exchange rate pressure, terms of trade, natural disaster intensity, drought and real GDP decline), but subsequently focus the analysis on the former three shocks, as the effects observed here are particularly pronounced and affect different groups of countries differently.

Fourth, we explore different ways of identifying subsets of the sample (or groups of countries) with specific patterns of behaviour facing exogenous shocks. Apart from looking at pre-defined groups (according to income levels, natural resource endowments and political regime type), we analyse information provided by interactions of variables and by data-driven clustering methods.

Fifth, we run regression with four types of revenue as dependent variables: income taxes, trade taxes, taxes on goods and services (sales) and non-tax revenue, limiting this analysis to the group of low- and lower-middle-income countries. This is based on the assumption that with regard to developing countries the effect of shocks on tax types can be quite divergent, implying different strategies when facing adverse external events.

Finally, we explore explanatory factors for tax revenue vulnerability and resilience as well as possible policy options for strengthening resilience in the context of five case studies. Despite policy recommendations to the opposite, fiscal policy, in particular government expenditure, in developing countries is often observed to be pro-cyclical, i.e. spending rises during economic upturns and falls when the economy deteriorates. For policy purposes it is important to know if low resilience retards economic performance because the revenue instability induces pro-cyclical fiscal policy.

2. Literature review

With regard to tax systems, the concepts of vulnerability and resilience refer to different functions, such as revenue generation, distribution, stabilisation of income and legitimacy. Apart from affecting the *amount* of revenue collected, external shocks influence above all the *stability* of revenues and, hence, their *predictability* with regard to budgeting and public service delivery. Further, external shocks may alter the distributive effects of existing tax systems, thus undermining (or strengthening) their legitimacy.

The study develops from the assumption that the vulnerability and resilience of tax systems depend on their (in) ability to cope with exogenous shocks (OECD 2008: 12). In this sense, the concept has two dimensions:

- A magnitude dimension (shock absorption & avoidance), referring to the sensitivity of tax revenues facing exogenous shocks, and
- A time dimension (shock counteraction), referring to the capacity of tax revenues to recover from the impact of exogenous shocks.

These categories will be used to classify the range of policy options open to developing countries as well as to international actors, and to evaluate the appropriateness of measures in terms of coping with adverse effects, based on recent attempts to construct indices of economic resilience in developing countries (for instance, see Briguglio et al. 2008).[1] Such an understanding is in line with other studies on developing countries' economic or fiscal volatility and vulnerability against external shocks. Most contributions to the debate define vulnerability in terms of sensitivity and capacity to recover. In this sense, resilient tax systems are those that are not vulnerable to shocks (low sensitivity) or are able to recover quickly; tax systems that are not resilient are very sensitive to shocks and revenue recovers slowly.

For instance, in a recent paper on managing volatility, the International Monetary Fund observes: "research suggests that external shocks contribute to *large* output losses and *protracted* growth slowdowns in LICs" (IMF 2013, 7 – our emphasis). The IMF paper proceeds: "A number of LICs face fragilities defined by their weak institutions, ongoing or recent conflict, and high poverty levels, which put them in a weak position to cope with the effects of shocks and to mediate their social impact. [...] Such underlying structural and policy vulnerabilities could limit their capacity to absorb future external shocks, including through countervailing policy measures" (ibid., 8).

In the following sections, the study reviews the academic literature on tax effort / tax performance (2.1) and on exogenous shocks and vulnerability (2.2). These two academic debates have only been loosely connected so far. We then explore research approaches to the grouping of countries (2.3). Section 2.4 addresses the issue of recovery from exogenous shocks. Section 2.5 summarises the findings from the literature review.

2.1. Tax Effort

The *tax effort* or *tax performance* [2] debate is based on the assumption that a number of structural features of the economy and tax system shape the capacity or potential of revenue collection. These features determine the level and trend performance of the tax/GDP ratio (the standard measure of tax performance). The extent to which the potential tax revenue or measure of *fiscal capacity*, as pre-

[1] A related, but conceptually less elaborated approach is the Economic Vulnerability Index (EVI) assembled by the United Nations Department of Economic and Social Affairs (UN-DESA) in order to identify Least Developed Countries (LDCs). The index distinguishes exposure to shocks (measured in terms of structural economic, demographic and geographical features) and impact by shocks (measured as instability of exports and agricultural production as well as number of victims from natural disasters). See http://www.un.org/en/development/desa/policy/cdp/ldc/ldc_criteria.shtml#evi (accessed 07.03.2013) for further details.

[2] Both terms are sometimes used synonymously – for instance, see Gupta 2007. IMF (2011) uses "tax performance" synonymously to tax ratio, and "tax effort" to refer to the ratio of actual to potential revenue. This paper employs both terms as suggested by the IMF.

dicted by structural features,[3] deviates from actual tax/GDP is attributed to political will, and affected by policy.

The standard approach in the tax effort literature (Lotz / Morss 1967; Tanzi 1992; Stotsky / WoldeMariam 1997; Fauvelle-Aymar 1999; Gupta et al. 2003; Teera / Hudson 2004; Gupta 2007; Le / Moreno-Dodson / Rojchaichaninthorn 2008; OECD / AfDB / ECA 2010; Profeta / Scabrosetti 2010; Le / Moreno-Dodson / Bayraktar 2012) is to model the tax to GDP ratio as determined by variables chosen to proxy for the tax base and structure of the economy.

In general terms, tax revenue is the tax rates applied to the various tax bases. In advanced economies tax modelling is usually based on detailed data on tax bases, such as individual and corporate incomes, capital gains and expenditures liable to VAT or excises. In developing countries such detailed data are often not available and proxy indicators are used: (i) agriculture and industry value added as a percentage of GDP; (ii) a measure of international trade; (iii) GDP per capita (these three are the variables most often included); (iv) several studies explore the relationship of aid (ODA) to tax collection; and (v) variables for demographic features, such as urbanisation, or indicators of governance and institutions are often included. All in all, some 50 variables are currently in use in the comparative tax effort literature.

- Tax performance is expected to be lower the larger the share of agriculture in GDP and the smaller the share of industry or manufacturing. A large agricultural sector reduces taxable capacity as in low-income countries agriculture is largely a subsistence activity which is difficult to tax directly (Emran / Stiglitz 2005). A large industrial sector is easier to monitor and tax, and a larger share of manufacturing in GDP captures economic development.
- Measures of trade openness are included in most studies. Trade taxes are relatively easy to collect and have historically been a major share of tax revenue in low-income countries (Greenaway / Milner 1991; Ghura 1998; Aizenman / Jinjarak 2009). As agriculture itself is difficult to tax developing countries often levied taxes on commodity (cash crop) exports as a way of taxing the sector, and also tended to impose high tariffs on imports. Thus, many studies include the trade volume measure of openness (the sum of exports and imports as a percentage of GDP) and it is usually significant (with a positive effect). In the context of the present study, however, such a composite measure would make little sense, as imports and exports have different effects on tax revenues facing exogenous shocks.
- GDP per capita is often included as a proxy for the level of economic development to capture increased tax buoyancy (the responsiveness of revenue to income growth) and collection efficiency (Musgrave 1969; Chelliah 1971; Tanzi 1992; Burgess / Stern 1993; Cheibub 1998; Piancastelli 2001; von Haldenwang / Ivanyna 2012). For instance, Baskaran / Bigsten (2012) find that GDP per capita and the share of manufacturing in total exports are the only two significant determinants of the tax/GDP ratio.
- A number of recent studies have included ODA as a determinant of the tax/GDP ratio. For example, Gupta et al. (2003) and Benedek et al. (2012) found that ODA reduces tax effort, especially if it is given in the form of grants (see also Knack 2008, Gambaro / Meyer-Spasche / Rahman 2007). These studies have been challenged by Clist / Morrissey (2011) and Carter (2010). The evidence on whether ODA affects tax effort is inconclusive, with studies using the same data often getting a mix of insignificant, positive and negative significant results according to the specification.
- Some studies also include a measure of urbanisation but this is likely to be related to the manufacturing share in terms of the effect on tax revenue. For instance, Aizenman / Jinjarak (2009) as well as Mahdavi (2008) find that tax collection increases with urbanisation. Across countries it is only if urbanisation is an indicator of formal (taxable) employment that it affects revenue and this is captured by manufacturing share. Over time we observe increasing urbanisation in most countries; in those with manufacturing growth (e.g. East Asia and South

[3] Pessino / Fenochietto (2010, 66) distinguish "tax capacity", defined as "the maximum tax revenue that could be collected in a country given its economic, social, institutional, and demographic characteristics" from "potential tax collection", defined as "the maximum revenue that could be obtained through the law tax system". The reference to a *maximum* level is owned to the stochastic frontier model used by the authors. See also IMF 2011, 59. This is different from other studies, where the average is taken as a benchmark and countries can achieve ratings above 1.0 (or 100), as for instance in Stotsky / WoldeMariam 1997; Le / Moreno-Dodson / Rojchaichaninthorn 2008; OECD / AfDB / ECA 2010.

America) it may be associated with increased tax revenue, but this is not the case in African countries where urban employment is mostly informal and manufacturing share remains low.

In sum, the tax base measures employed in research on developing countries are all no more than approximate and not consistently significant. Gupta et al. (2003) find agriculture and industry value added shares significant in their baseline regression as do Clist / Morrissey (2011), but neither is consistently significant in other specifications, and they are not significant except for agriculture in one regression in Benedek et al. (2012). In several cases, multicollinearity of variables leads to an imprecise estimation of coefficients. This is the case, for instance, of GDP per capita and agriculture (Fauvelle-Aymar 1999; Gupta 2007; von Haldenwang / Ivanyna 2012).

Teera and Hudson (2004), covering 1975-98 for 120 countries (developing and developed), is typical of recent studies of tax performance. Agriculture share in GDP is significant (and negative) for all (and the full sample) except developed countries; manufacturing share is significant and negative for middle income countries, mixed results for developed countries, but insignificant for low income countries (and the full sample). The trade volume measure of openness is positive and significant in all cases except upper middle income countries (sometimes insignificant) and developed countries (negative and significant). Results for GDP per capita are very mixed and aid is insignificant in all cases. Thus, for developing countries the most consistent determinants are agriculture share (negative) and trade volume (positive) but the importance of particular determinants varies across different groups of countries (here classified by income).

There are many potential **governance variables** that have been included in previous studies, but, again, few are consistently significant. The underlying idea is that, in addition to economic and demographic structures, institutional features shape the capacity of governments to collect taxes. In broad terms, it is possible to distinguish between (i) factors influencing the political decision-making process and (ii) factors influencing the capacity of governments to effectively implement policies. All in all, however, Bird's verdict that "it is inherently extremely difficult to specify correctly any model of (usable) taxable capacity" (Bird 1976, 253) seems to hold and we are still far from a standard approach to the institutional structures shaping tax performance.

- A growing body of research explores the relation between political regimes and tax collection, tax policy or tax structure, covering a broad range of theoretical and methodological approaches (Musgrave 1969, 40-65; Levi 1988; Olson 1993; Cheibub 1998; Fauvelle-Aymar 1999; Boix 2003; Ross 2004; Mulligan / Gil / Sala-i-Martin 2004; Kenny / Winer 2006; Acemoglu / Robinson 2006; Besley / Persson 2009; Timmons 2010; Profeta / Puglisi / Scabrosetti 2011; Winer / Kenny / Hettich 2010; Ehrhart 2012). Most scholars argue in favour of a positive correlation between democratic structures and tax collection, but the theoretical underpinnings of their arguments differ widely and the view of democracy favouring higher tax collection is by no means uncontested. For instance, Cheibub (1998) analyses the impact of regime type on tax collection with data for 108 countries between 1970 and 1990. He finds no robust evidence regarding a differential impact of regime type on taxation. In a similar fashion, Ross (2004) for 115 countries with an observation period from 1971 to 97 does not produce any significant association between tax ratio and regime. In contrast, Garcia / von Haldenwang (2011) find a U-shaped relation between political regimes and tax ratio, with full autocracies and full democracies collecting significantly higher shares than political regimes located in-between both margins.
- Fiscal contractualism emphasizes the importance of legitimacy and credibility in bargaining processes and tax compliance (Moore 2008; Fauvelle-Aymar 1999; Timmons 2005; Levi / Sacks 2007; Bates / Lien 1985; Mahdavi 2008). In this context, democracy should lead to higher tax collection, as tax payers can be more confident that taxes are spent for the common good, that the distribution of the tax burden is fair and that the risk of radical policy changes in the future is low. The argument is based on a fiscal contract model of "quasi-voluntary" tax payments in exchange for public services (Levi 1988). Timmons (2010) explores the relationship of representation and taxation by analyzing panel data from 106 countries between 1970 and 99 as well as cross-sectional data from 75 democracies (1990-98). He finds weak evidence indicating that democratic rule and voter turn-out increase tax revenue, but results do not support the fiscal contractualism argument pointing from higher legitimacy to a broader reliance on direct (income) taxation.

- Several studies emphasize the relevance of state (administrative) capacity (Cheibub 1998; Gerry / Mickiewicz 2008; Thies 2010; D'Arcy 2009). For instance, Aizenman / Jinjarak (2006, 2009) include indicators of institutional quality but results are not robust across specifications. Other authors focus on corruption in particular: Pessino / Fenochietto (2010); Le / Moreno-Dodson / Rojchaichaninthorn (2008) and Gupta (2007) observe that corruption affects tax collection negatively, corroborating earlier findings by Ghura (1998) and Tanzi / Davoodi (2000).
- Combining different governance perspectives, Baskaran / Bigsten (2012) use data for 31 sub-Saharan African countries over 1990–2005 and find a negative association between tax/GDP and corruption, but (only in some specifications) a positive association with democracy. As these indicators of the quality of governance could be determinants of tax performance they employ an instrumentation strategy so the results are interpreted as indicative that improved tax capacity promotes more democratic and less corrupt regimes. Fauvelle-Aymar (1999) and Gupta (2007) test for political variables such as government stability, political stability, law & order, democracy and volatility of inflation (as a proxy for government credibility), but fail to produce conclusive results regarding their impact on fiscal capacity and tax performance. Another study of this kind is authored by Bird / Martinez-Vazquez / Torgler (2004), who explore the impact of a broad set of governance, tax morale, inequality, and decentralization indicators on tax and total revenue effort.

Observed tax performance over time is going to be affected by **policy reforms**, notably in tax rates (such as tariff reductions or introducing VAT), and administrative measures (especially if designed to increase collection efficiency). Clist / Morrissey (2011) argue that this is one of the reasons why it is difficult to identify an effect of ODA on tax effort, as conditionality affects policy. With the exception of trade liberalisation that reduced trade taxes (removing export taxes and reducing tariffs) and tended to be associated with lower tax revenue initially, most reforms may not have had significant effects on total revenue. In reviewing the tax reform literature, Prichard / Brun / Morrissey (2012, 8) conclude that the depth of reforms has been limited: (i) Levels of tax collection have increased only marginally in recent decades (Bird 2008; Keen 2012; IMF 2011), although this is against a background of declines in trade tax revenue and income tax rates. (ii) Gains have tended to be temporary in countries that experienced rapid improvements in performance. (iii) Despite broadly similar reform efforts across countries, differences in effectiveness of the implementation of tax rules seem persistent (Gupta 2007), in part perhaps because tax administrations change only slowly.

It makes sense to assume that the features discussed so far with reference to tax performance (i.e., the level of tax collection) are also relevant for the vulnerability of tax revenues facing external shocks, but the discussion summarised above teaches us to be cautious regarding the choice of variables included in the main specification.

2.2. Exogenous shocks and vulnerability

External shocks are the outcome of factors beyond the control of those bearing the consequences. Although they are not necessarily unforeseeable as such, they are often unpredicted in their concrete manifestation. Further, while some shocks are temporary events, with external conditions quickly returning to the *status quo ante*, other shocks may indicate a permanent change of conditions. The IMF defines an exogenous shock "as a sudden event beyond the control of the authorities that has a *significant negative* impact on the economy" (IMF 2003, 4 – our emphasis). This definition is pragmatic in the sense that it limits the range of events to be taken into account, but it entails some additional questions. Above all, significance levels are difficult to determine *ex ante*, leading to arbitrary decisions regarding what constitutes a shock as opposed to a minor external event.[4]

Against this background, the present study is based on a general definition of exogenous shocks without references to threshold values, significance levels or directions of impact. However, it is important to note that the impact of exogenous factors on tax revenues could be non-linear. For instance, complex revenue systems may be able to cope with minor changes in the terms of trade or commodity

[4] The Vulnerability Exercise for Low-Income-Countries developed by the IMF assumes a shock to be severe, "if the annual percentage change of the relevant variable falls below the 10th percentile in the left-tail of the country-specific distribution". In the case of natural disasters, the top 25 per cent of events in terms of people affected and economic damage are considered. See IMF 2013, 31.

prices. Once these changes reach a certain "tipping point", the system shifts from one state to another and experiences major disruptions. The notion of tipping points is a key feature of current debates on climate change (for instance, Gladwell 2000). Schumacher / Strobl (2008) find that the relationship between wealth and economic losses due to natural disasters is linked to disaster risk, presenting non-linear patterns both for high-risk and for medium- and low-risk countries. Hence, this study will control for non-linear effects by introducing criteria of significance in subsequent stages of analysis.

The commodity boom of the last decade as well as the recent global financial and economic crisis have spurred academic debate on the impact of exogenous shocks in developing countries. Researchers are often particularly interested in commodity or energy price shocks. However, the debate focuses almost exclusively on economic growth and distribution of rents and income as dependent variables.[5] In contrast, empirical studies covering the impact of shocks on public revenue in developing countries are scarce and mostly related to managing windfall profits from extractive industries (for instance, Venables 2011; van der Ploeg / Venables 2011; Ross 2012; Same 2009). While older approaches stress the importance of policy responses to external shocks, recent contributions focus on structural factors such as financial and trade openness, market rigidities and institutions (see IMF 2003; Loayza / Raddatz 2007).

A somewhat broader debate on the fiscal consequences of macroeconomic volatility refers to Latin America (for instance, see Fanelli / Jiménez / Kacef 2011; Villafuerte / Lopez-Murphy / Ossowski 2010; CEPAL 2013). This is partly due to that region's historical record of fiscal distress, a history that has recently experienced a remarkable reversal in several countries of the region. The predominant direction of inquiry, however, points to the role revenue systems can play in managing shock absorption and recovery. In this context, the notion of fiscal space and the capacity of states to mobilise additional revenues are highlighted. Following this discussion, it is fair to assume that those factors that affect the tax performance of countries also have a significant effect on the sensitivity of tax revenue facing exogenous shocks.

Revenue instability in developing countries is likely to have adverse effects on fiscal and even macroeconomic performance (Lensink / Morrissey 2000; IMF 2003; Ehrhart / Guerineau 2013). Above all, it is likely to affect spending: specifically, if unanticipated shortfalls in tax revenue cannot be compensated from other sources (such as aid or borrowing), expenditure may be reduced and this can have adverse impacts on the economy. A number of studies identify an effect of revenue instability on expenditure instability (Bleaney / Gemmell / Greenaway 1995; Fielding 1997; Ebeke / Ehrhart 2012). In a broader context, investment is essential for growth, but uncertainty about the performance of the economy or the availability of finance for investment discourages investment (Lensink / Morrissey 2006). Revenue instability generates uncertainty in a number of ways. The most direct effect is that a shortfall in revenue is likely to reduce public investment. At the same time, large-scale investment projects are more difficult to plan and realise in a context of revenue volatility, as they usually require several budget years of funding. In low-income countries, where investment in infrastructure is necessary and tends to crowd-in private and foreign investment, this is likely to have a subsequent adverse effect on private investment (see Ebeke / Ehrhart 2012 with evidence from SSA).

It may often be the case that external events generate the uncertainty. Economies dependent on one or a few commodities for export revenues are particularly susceptible to terms of trade shocks, and the poorest countries tend to be more susceptible to natural disasters such as droughts or floods. The range of impacts is summarised by the IMF as follows:

> *Both terms-of-trade shocks and natural disasters can also have a significant impact on macroeconomic (fiscal and external) balances and debt. Government revenues can be directly affected by terms of trade shocks if the relevant export products are a significant source of tax revenue (...). Natural disasters can also affect the government's ability to collect revenue. In addition, government expenditures, particularly social expenditures, frequently expand following a shock. While it is possible for governments to take offsetting measures to adjust to reduced revenues or higher expenditures, these have to be carefully designed so as not to exacerbate income losses for those hardest hit by the shock, or to constrain capital spending*

[5] For recent contributions, see for instance IMF 2013; Anand / Prasad 2012; Bourguignon 2012; van den Bremer / van der Ploeg 2012; IMF 2012c; Dagher / Gottschalk / Portillo 2012; Cherif / Hasanov 2012; Jha / Rhee 2012; Cantore / Antimiani / Rui Anciaes 2012; Bredenkamp / Bersch 2012; van der Ploeg / Poelhekke 2009; Collier / Goderis 2009; Berg et al. 2011.

> *when reconstruction is needed, or to divert resources from investments that have longer term pay offs in raising economic performance. In most cases, the fiscal deficit is likely to rise, with additional financing needed. A country's flexibility in responding to a shock will depend in part on its initial fiscal position, how the deficit is financed, and the sustainability of its debt (IMF 2003, 12).*

Few studies have specifically analysed tax revenue instability in developing countries, either in terms of determinants or consequences (Ehrhart / Guerineau 2013). The few that have addressed tax instability in sub-Saharan Africa (SSA) focus on the consequences rather than determinants. Bleaney / Gemmell / Greenaway (1995) examined possible causes of revenue instability for SSA economies both in terms of the underlying structure of their tax systems and the wider structure of their economies. Trade tax dependence largely explains differences in tax revenue instability between developed countries (with low instability and trade tax dependence) and developing countries (high instability and trade tax dependence). However, trade tax dependence does not explain differences in tax instability between developing countries, nor do differences in tax structure. For developing countries, tax instability is found to be greater in poorer, more open and more inflation-prone economies with greater output variability. In line with this, SSA has higher tax instability than other groups of developing countries, about twice as high as for Asia and 50% higher than for Latin America, for the mid 1970s to mid 1980s (Bleaney / Gemmell / Greenaway 1995, 887). Bulíř / Hamann (2003, 85-86) measure revenue instability (the variance of the detrended series) for a sample of 72 countries over 1975-1997 (but do not provide regional averages).

It is also useful to consider the components of **tax structure**, as different taxes may be affected in different ways by determinants and policy reforms. Aizenman / Jinjarak (2006, 2009) distinguish 'easy to collect' taxes (especially trade taxes) from 'hard to collect' taxes such as VAT and income taxes, which are either politically or administratively more difficult to collect. Examining tax performance over 1980-99, they find that urbanisation has a positive effect on VAT revenue whilst agriculture share has a positive effect on tariffs (otherwise both are insignificant); trade volume tends to be negatively associated with tariffs but positively associated with VAT revenue, especially in politically durable regimes. This is difficult to interpret intuitively and suggests problems in aggregating imports with exports in the trade volume measure, but highlights that the importance of particular determinants varies across different types of taxes. The authors note that the trade liberalization policies implemented in many developing countries from the mid-1980s reduced tax/GDP ratios because they involved reductions in tariffs or export taxes (that were easy to collect) whilst it took a number of years to replace the revenue with harder to collect VAT (see also Baunsgaard / Keen 2005).

Several studies have explored issues of tax performance and volatility with regard to the composition of the tax system. Specific emphasis has been placed on the mix of direct (corporate and private income) vs. indirect (consumption) taxes, the changing relevance of trade taxes and the weight of revenue from extractive industries. Ebeke / Ehrhart (2012) show that tax revenue instability (measured as the standard deviation of the log difference) remains high in SSA countries (they do not compare with other developing countries) but has declined from a peak in the late 1980s as the tax composition changed. Corporate and trade taxes tend to be the most unstable, so the gradual decline in overall tax instability is attributed to increased shares of relatively more stable indirect taxes. Tax instability tends to increase with instability of GDP, less consistently with dependence on natural resource rents, and in some specifications is lower in countries with higher trade openness (the trade volume measure) and per capita GDP (Ebeke / Ehrhart 2012, Table 5). Although limited, this is further evidence that instability is associated with exposure to exogenous shocks and related to the composition.

Negative external shocks deteriorate the tax basis via several channels. The most commonly employed measure for external shocks is the volatility of terms of trade (Rodrik 1998; Rodrik 2001). With regards to the business cycle in more open developing economies, world price shocks play an important role (Kose / Riezman 2001; Kose 2002). According to Raddatz (2007, 157), changes in commodity prices are the most important external source of GDP fluctuations in low-income countries. Further, there is evidence that GDP instability is a good proxy for exposure to shocks (Bleaney et al 1995; Ebeke and Ehrhart 2012; Lledó and Poplawski-Ribeiro 2013).

Another type of shock occurs as an outcome of natural disasters that affect entire societies, countries or regions (Grin / Rotmans / Schot 2010; Giddens 2009). Natural disasters lead to situations of "concentrated resource scarcity" (Nel / Righarts 2008). Much of this debate focuses on geophysical events

commonly ascribed to global climate change: floods, droughts and fires, etc. In this context, several studies have explored the economic or social impacts of weather changes and rainfall (Deschenes / Greenstone 2007; Deschenes / Greenstone 2011; Fisher et al. 2012), even though few papers have addressed these issues with regard to low-income countries, due to data challenges (for instance, see Burke et al. 2011). However, natural incidents other than rainfall or even not caused at all by climate change, for instance earthquakes, volcano eruptions and accidental oil spills, may also have disastrous impacts on the economies and fiscal revenues of developing countries (Keefer / Neumayer / Plümper 2011). According to the IMF, "between 1997 and 2001, the average damage per natural disaster was over 5 percent of GDP in low-income countries", and "97 percent of disaster-related deaths were in developing countries" between 1990 and 98 (IMF 2003, 4-6).

2.3. Sub-sets of countries

Many studies exploring the impact of different variables on tax effort or tax performance assume that there are sub-sets in the sample characterised by specific properties. The literature provides us with some initial clues regarding the identification and tax performance behaviour of specific country groups, but there are only few cases where categorisations are driven by, and provide feedback to, theory:

- Country income groups (following the World Bank classification) are frequently used to control for differentiated effects in poorer and richer countries. For instance, Le / Moreno-Dodson / Bayraktar (2012) observe that the world-wide increase in tax revenue between 1998 and 2009 is particularly pronounced in low-income countries. This could be due to the commodity-based structure of many poorer economies, given that global commodity prices have been on the rise over the last decade. Gupta (2007) also creates income-group-specific indexes for tax effort.
- Revenue from extractive industries can be expected to strongly influence tax revenue, even though the impact is not easy to model, as rents from fuels and minerals are sometimes obtained through taxes and sometimes through non-tax sources of income, such as profits from public enterprises (Burgess / Stern 1993; Collier 2010). Some studies use dummies for oil producers or exporters, or focus specifically on this group of countries, without, however, producing robust evidence concerning the positive or negative effect of rents from non-renewables on tax collection (for instance, Bornhorst / Gupta / Thornton 2008; Herb 2005; Knack 2008; McGuirk 2013). The IMF has identified revenue from extractive industries as a major area of concern for more than 40 developing countries (IMF 2012b; IMF 2012a).
- The volatility of tax revenue itself is a relevant factor of a country's sensitivity to exogenous shocks. Volatile tax systems are usually characterised by small tax bases, low levels of diversification and a high dependence on commodity taxation. A question rarely tackled in academic research, however, refers to the identification of different patterns of sensitivity while controlling for general levels of volatility. Following Raddatz (2007), shocks only explain a small part of output variance of low-income countries. Hence, grouping countries according to their revenue volatility could provide important insights into how shocks affect revenue systems.
- As mentioned above, governance levels affect tax performance (i) by influencing the political debate and the formulation of common-interest-oriented tax policies and (ii) by shaping the capacity of states to enact tax legislation and manage tax systems (von Haldenwang / Ivanyna 2010). In particular, countries are grouped according to political regime type.
- Regional patterns may affect tax performance in various ways, including competition for investments, shared beliefs or cultural values, colonial histories, contagion from neighbours and patterns of world market integration. Several authors find those patterns, even though the issue is not explored from a conceptual perspective (see von Haldenwang / Ivanyna 2010; Davoodi / Grigorian 2007; Profeta / Puglisi / Scabrosetti 2011; Le / Moreno-Dodson / Bayraktar 2012). Others look at regional tax performance with more detail, but focus on individual regions (such as for instance Bird / Martinez-Vazquez / Torgler 2004 on Latin America).
- Revenue from ODA: There is an ongoing debate on whether ODA funds (grants and loans) discourage domestic revenue mobilisation. Recently, Benedek et al. (2012) find support for the argument of a crowding-out effect of ODA grants on taxes, originally advanced by Gupta

et al. (2003). The effect appears to be particularly strong in low-income countries. There are, however, some relevant criticisms regarding this approach, for instance with regard to sample composition, observation periods, omitted variables and endogeneity (Clist / Morrissey 2011; Carter 2010). Taking these aspects into account, the theoretical argument loses strength and in empirical terms, the effect turns insignificant or even changes sign.

2.4. Recovery

If countries facing exogenous shocks differ with regard to the stability of tax revenue, they are likely to differ as well with regard to their ability to recover from the impact of shocks. Recovery in this context means that a country returns to pre-shock conditions of tax revenue, both in terms of tax performance (levels of tax collection) and revenue stability. Even more than sensitivity to shocks, this is an important aspect of vulnerability. It reflects the capacity of countries to respond to revenue instability – either through market mechanisms (economic structure) or through purposeful political action (governance). Countries highly dependent on a few commodities (a typical condition of many developing countries) might have to live with greater exposure to external shocks. Still, there are obviously different ways of coping with this situation, and high revenue volatility may not mean the same in Country X as in Country Y. We assume that a tax system's capacity to recover from the impact of exogenous shocks hinges on structural factors, but also on policy measures undertaken by the government, sometimes assisted by external actors and ODA flows (Collier / Dehn 2001; IMF 2003, 4).

Responding to (domestic) revenue instability is difficult in developing countries, especially in low-income countries, because of constraints to implementing fiscal adjustments (Lledó / Poplawski-Ribeiro 2013): weak forecasting capacity (exacerbated by poor data); ambitious revenue targets combined with political incentives for excess spending (given revenue) or insufficient tax effort; vulnerability in scale and frequency to external shocks as manifested in macroeconomic instability; inadequate budget institutions and procedures; volatile and unpredictable aid flows; and unstable political systems. Governments of developing countries rely essentially on taxes and aid (grants and concessional loans) for recurrent revenue; aid is most important for the poorest countries. These largely determine total revenue to finance government expenditure; borrowing can in general be treated as a residual (in principle financing a temporary or unanticipated deficit). In some countries resource rents are large; although often considered as non-tax revenues for convenience we consider these as taxes (and include them as such if they are in the data). Governments are likely to form targets or expectations of tax and aid revenues in budget planning and the accuracy of these forecasts influences budget performance. This has been addressed in the literature on the cyclicality of fiscal policy.

Fiscal policy, in particular government expenditure, in developing countries is often observed to be pro-cyclical, i.e. spending rises during economic upturns and falls when the economy deteriorates (so spending is counter to and hence exacerbates the business cycle). This has been explained most commonly by social inequality (Woo 2009); corruption, institutions and political structures (Lane 2003; Talvi / Végh 2005; Alesina / Tabellini / Campante 2008); or constrained access to international credit markets (Gavin / Perotti 1997). However, there is no consensus explanation as empirical studies employ different explanations (Alesina / Tabellini / Campante 2008; Thornton 2008; Woo 2009). Although this literature is not directly relevant, it highlights the potential gain in understanding what determines tax instability as if instability can be reduced, or more generally resilience increased, adverse effects on fiscal policy can be mitigated.

It is not clear a priori that a strong correlation between tax and expenditure instability is to be expected, although developing countries with high tax revenue instability tend also to have high expenditure instability. If most of the variation in tax revenue is recognised by governments as temporary, expenditure will not adjust in the short-run. Governments will be aware of any political and economic costs associated with replacing lost revenues with alternative sources of funds, as compared to the costs associated with expenditure cuts. Bleaney et al. (1995) investigated the links between total revenue and expenditure instability in more detail for a sample comprising Botswana, Ghana, Kenya, Malawi, Swaziland, and Zambia. The evidence pointed consistently to a close link between revenue and expenditure instability, suggesting that governments have very limited capacity to maintain expenditures when tax revenues fluctuate. However, even if revenues and expenditures are both highly volatile they do not move together in a uniform manner, and the direction of causality is generally

ambiguous. In some cases foreign borrowing (including aid) is used more to finance expenditure increases than to counteract revenue shortfalls.

The limited ability of countries to reduce tax instability, or to adjust the mix of alternative revenue sources to mitigate the effect of tax instability on expenditure, implies that tax recovery will be low in countries with high instability, i.e. shortfalls in tax revenue from trend are difficult to make up. One underlying mechanism could be that under conditions of procyclical fiscal policy a shock to tax revenue exacerbates the economic cycle, which leads to further changes in tax revenue in the direction of the shock. Above all, however, it is difficult for many developing countries to adjust tax revenue due to limited state capacity and political lock-ins. For these countries, tax should not be considered a policy variable amenable to short run adjustments in order to restore equilibrium.

Using data covering 2004-10 Lledó / Poplawski-Ribeiro (2013) find that fiscal gaps, measured as the difference between fiscal projections and fiscal outcomes (as reported by the IMF) for budget balances, revenue and spending, are less likely to be reduced the larger the gap and, in most cases, the larger the macroeconomic forecast errors (which may capture shocks). There is some evidence that fiscal adjustment (reducing gaps) is less likely in SSA countries with weaker institutional quality (measured as rule of law from WGI) and budgetary capacity (using the measure constructed by Dabla-Norris et al. 2010, for 2006-08). For SSA the planned fiscal variable is significant (positive) and rule of law is significant (negative) for the size of the balance and, very weakly, revenue. When budgetary quality is interacted with rule of law, the quality of budget implementation is significant (negative) for balances and more weakly for revenues. The authors contend that "most of the effects of (budget and governance) institutions in the overall balance implementation gaps come from their effects on the revenue implementation" (Lledó / Poplawski-Ribeiro 2013, 9).

The political economy approach argues that institutional and political incentives determine the cyclical nature of fiscal policy. Indeed, Talvi / Végh (2005) contend that large fluctuations in revenues (due to shocks or the business cycle) distort political incentives and can cause pro-cyclical fiscal policies. Economic shocks and cycles can have a large effect on the tax base and tax revenues in developing countries; as revenues increase during an upturn there is political pressure to increase spending (pro-cyclical expenditure) policies, so that when a shock or downturn reduces revenues there is a more pronounced reduction in spending (exacerbated if access to borrowing is constrained). In a similar vein, Alesina / Tabellini / Campante (2008) argue that a sceptical public in developing countries believe that corrupt government appropriates revenues and therefore push for increased expenditures during good times to limit rent-seeking, hence generating political pressure for pro-cyclical public spending. They find that fiscal policy is more pro-cyclical in countries with higher corruption, especially in corrupt democracies (as the accountability to voters reinforces the political pressure). However, Thornton (2008) finds that lower corruption is associated with greater pro-cyclicality in the sample of 37 African countries, perhaps because higher corruption leads to lower revenues and hence lower baseline government expenditure, implying less scope for fiscal pro-cyclicality.

Overall, the existing evidence is quite weak in terms of identifying determinants, especially for revenue gaps. As it appears, the greater is tax instability the more prolonged will recovery be. Improvements in fiscal capacity can help shorten recovery time, whereas tax diversification is likely to be most effective in reducing instability. Tax system resilience is associated with increased reliance on direct (income) and indirect (sales) taxes, and especially less reliance on trade taxes and resource rents.

2.5. Summary and guiding assumptions

The preceding sections have shown that our knowledge regarding the relationship of tax revenue and exogenous shocks in developing countries is limited to a handful of rather basic insights, such as for instance high revenue volatility originating from taxing commodity exports. Academic research has focused on some factors which supposedly drive revenue vulnerability, but has neglected other factors that might play a crucial role as well. The two most relevant debates in this context – on developing countries' tax effort and performance on the one hand, and on growth volatility and exposure to shocks on the other hand -- have not been brought together in a systematic manner. Research has been further hampered by a critical lack of reliable data, in particular from low- and lower-middle-income countries.

Still, the short literature review sketched out above helps to identify a set of assumptions or broad approximations to academic inquiry indicating the general direction of empirical research. The strategic approach chosen here is to start with a parsimonious model and introduce additional complexity in subsequent stages of the analysis.

The first assumption is based on the tax effort / tax performance literature, which explores cross-country variations in the tax ratio by looking at core measures of economic structure, above all the importance of agriculture and industry in the economy, the openness of the economy (external trade) and the level of economic development. We consider these factors to be relevant not only for the level of tax revenue in per cent of GDP (the tax ratio), but also for the sensitivity of revenues facing exogenous shocks. Hence, our analysis starts with a basic model that relates to the tax effort / tax performance debate.

A second assumption refers to the impact of shocks on tax revenue. Even though our basic model already accounts for a number of structural economic factors, we would still expect different kinds of shocks to have different impacts on our sample. In addition, from the many studies that define shocks as events with a certain significance of impact we infer that the impact of shocks could be non-linear. Further, we expect the tax mix (reliance on direct, indirect and trade taxes, revenues from non-renewables) to play an important role in this relationship.

A third assumption relates to the identification of sample sub-sets or groups of countries with shared properties. The discussion summarised in the preceding sections leads us to believe that beyond our main specification it is possible to detect groups with specific patterns of tax revenue behaviour facing exogenous shocks. Some groups have already been identified in the literature, for instance country income groups (based on the World Bank classification) or resource-rich countries.

Finally, vulnerability to exogenous shocks refers to the sensitivity of revenue, but also to the ability of tax systems to quickly recover from the impacts suffered from shock. The existing literature indicates that several factors may influence recovery. Apart from the initial sensitivity of revenue and the composition of the tax structure, it can be assumed that governance-related factors, i.e. the capacity to formulate and implement corresponding fiscal policies, are key elements of recovery.

3. Research design

Our identification strategy is the following: The initial stage of the analysis will derive measures of fiscal capacity and revenue instability for each country in the sample to characterize tax resilience features of the sample. These measures will then be regressed on a set of factors specified below. All countries from our sample will be used in the regressions. We will then introduce various kinds of shocks to our model, and identify how each of them affects tax ratio and revenue instability. The following stage of our empirical investigation will identify the effects of shocks on tax revenue in various groups of countries. The data we use (variables and operationalisation, descriptive statistics, additional information on pre-defined categories) can be found in Appendix 5.

3.1. Tax performance (level and composition)

We follow the standard approach reviewed in section 2.1 (Tanzi 1992; Gupta et al. 2003; Teera / Hudson 2004) but with some adjustments in variables used. While sector shares of agriculture and industry and the trade volume measure of openness are suitable for cross-country analysis with period averages, especially for reasonably long periods, we have seen that results are not robust. These measures are less suitable for panel studies with annual data or short (4 or 5 year) period averaged data because shares of agriculture and industry in GDP will tend to change only slowly over time (typically following a clear trend) and shares themselves are poor measures of sector performance (as an indicator of the tax base). The trade volume measure of openness is also of questionable relevance as it combines imports and exports; both are taxed but the applicable tax rates vary and have been changed in different ways. We consider it more helpful to distinguish the import/GDP ratio, as an indicator of the tax base for tariffs, from the export/GDP ratio that can be interpreted more as an indicator of the performance of major sectors in the economy (as many countries eliminated direct export taxes in the 1980s). It is also useful to allow for the composition of exports (which reflects the structure of the economy) so we aim to distinguish agriculture (soft commodities), minerals and fuels ('hard' commodities) and manufactured exports (measured as shares of GDP). Thus, our basic specification is:

$$Rev = f(agri\_exp, min\_exp, fuel\_exp, manuf\_exp, manuf\_exp, imports + gdp\_pc) + e \quad (1)$$

Tax revenue (*Rev*) is measured as a ratio of GDP. Agricultural exports (*agri_exp*), mineral exports (*min_exp*), fuel exports (*fuel_exp*), manufactured exports (*manuf_exp*) and imports (*imports*) are also measured relative to GDP. Treating each type of export separately allows for differential performance of separate parts of the economy, which may be related to external shocks and the tax structure (as discussed below). For example, climatic shocks are most likely to affect agri_exp, product-specific world price or demand shocks may affect primarily agri_exp, min_exp or fuel_exp , and manuf_exp should be the most resilient to shocks (except for global demand shocks). GDP per capita (*gdp_pc*) is included as a measure of the level of development that is expected to reflect improvements in administrative capacity and tax collection efficiency.

Although there is a relationship between aid and tax revenue it is complex and related more to policies associated with aid conditionality rather than to the amount of aid. For this reason, we do not include aid as a determinant. Similarly, we do not include indicators of government quality or political regime in our base specification (we will use such variables later in the analysis). It is not feasible to allow for country-specific reforms in a broad cross-country study of tax performance as there is so much variability in timing and types of reforms. To the extent that reforms had limited effects on revenue this is unlikely to weaken our analysis. Significant country-specific effects on tax performance will be captured in fixed effects estimations.

Accounting for data limitations, we will distinguish four categories of revenues: income taxes (inc) on personal and corporate incomes; general taxes (gs) on domestic consumption, sales taxes, excises and VAT; trade taxes (trd), especially tariffs; and non-tax revenue (non_tax).

Table 1 presents a stylized representation of the determinants that are likely to affect each measure of tax revenue. As all variables capture economic activity and tax bases, all are expected to increase tax revenue. As direct taxes and VAT are harder to collect they should increase with GDP per capita.

Although incomes in agriculture are difficult to tax, good performance should increase general sales taxes and, if there are export taxes, trade tax revenue. The mineral and fuel sector typically has weak linkages with the economy. Hence, effects on revenue may be muted, although strong performance of mineral and fuel exports should generate higher non-tax revenue. Manufacturing exports indicate private sector performance and is mostly likely to affect total revenue and income taxes. Imports are only likely to affect the performance of trade taxes and through them total tax revenue.

Table 1: Base Specification of Tax Revenue Determinants

Variables	Total revenue	Income tax	General sales tax	Trade tax	Non-tax revenue
GDP per capita	+	++	++	0	+
Agricultural exports	+	+	++	+	0
Mineral exports	+	+	0	+	++
Fuel exports	+	+	0	+	++
Manufacturing Exports	+	+	0	0	0
Imports	+	0	0	++	0

Notes: The aim is to indicate the expected effect of the variables on tax revenues, where ++ is positive and significant; + is weakly positive; 0 is insignificant; none are expected to have a negative effect.

3.2. Measuring tax volatility

On the principle that trend growth (or decline for a specific tax) in tax revenue should not be part of the instability measure, preferred measures compute the instability of a de-trended series. We propose a measure of volatility based on deviations around an observed trend. The index is based on the coefficient of variation but it uses a de-trended data series. It is a simple descriptive measure of the total amount of instability. Instability measured as average or standard deviations around a linear or exponential trend is an easily interpreted summary statistic of percentage variation over the period; higher values are clearly more unstable. The measures are appropriate for ranking countries according to the extent of instability, and especially for evaluating the extent and causes of long-run instability. First, we specify the trend equation:

$$lny_t = \alpha + \beta_1 t + \beta_2 t^2 + e_t \qquad (2)$$

where y is the variable whose level of instability we want to find, t is time, and e_t is the residual at time t. To obtain the index we use the formula:

$$\frac{100}{\bar{y}}\sqrt{\frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{n-3}} \qquad (I)$$

where $\bar{y}$: arithmetic mean of y

y_t : observed value of y in year t

$\hat{y}_t$: estimated value of y, from (2), in year t.

The square root term in (I) yields the standard deviation of residuals from a quadratic time trend, as the mean of the residuals is necessarily zero. This is divided by the arithmetic mean of y to normalise the index, enabling cross-country comparisons to be made. The variable t^2 is included in the time trend to pick up possible non-linearities: a significant value for c may imply a break in the trend, so the index could be interpreted as an average of two instabilities (from two trends). Note that if the overall performance of (2) is poor, the derived measure of (I) is unreliable. The index is to be interpreted as the typical deviation of the variable from a quadratic time trend over the period. As such it records average volatility over this period.

3.3. Introducing shocks

Initially, we analyze five shocks. First, we use the exchange rate (ER) pressure index as a proxy for export demand and foreign capital flows shocks. The ER pressure index has been widely used in international finance literature (see Berg / Patillo 1999; Candelon / Dumitrescu / Hurlin 2010; Kaminsky / Lizondo / Reinhart 1998; Sachs / Tornel / Velasco 1996). It is generally defined as a weighted average of percentage changes of policy variables in response to current account or financial account shocks. We use the following definition:

$$PI_{it} = w_{E,i}\frac{\Delta E_{it}}{E_{i,t-1}} - w_{RES,i}\frac{\Delta RES_{it}}{RES_{i,t-1}} \quad (3)$$

where i identifies the country, t is the year, E is the exchange rate in local currency units per USD, RES – size of reserves, $w_{E,i}$ and $w_{RES,i}$ are country-specific weights: $w_{E,i} = \frac{\sigma_{RES,i}}{\sigma_{RES,i}+\sigma_{E,i}}, w_{RES,i} = \frac{\sigma_{E,i}}{\sigma_{RES,i}+\sigma_{E,i}}$. Here $\sigma_{RES,i}$ is the standard deviation of $\frac{\Delta RES_{it}}{RES_{i,t-1}}$ in country i in 1980-2012, $\sigma_{E,i}$ is the same for $\frac{\Delta E_{it}}{E_{i,t-1}}$. The logic behind the index is that in response to an adverse balance-of-payment shock a country could employ different strategies: the government could devaluate the currency, but it could also use its international reserves to defend the exchange rate. Both policy variables should be considered in measuring the magnitude of external shocks. The weights in (3) are country-specific and chosen so that the more volatile series gets smaller weight. To reduce the impact of outliers, the ER pressure index is transformed as follows:

$$PI_{transf} = sign(PI) * \log(1 + |PI|) \quad (4)$$

The other shocks that we use are (i) terms-of-trade index - scaled as the unit-price of imports divided by unit price of exports; (ii) drought – equal to negative value of rainfall deviation from its country-specific historical mean; (iii) intensity of natural catastrophes; and (iv) real GDP decline (opposite of real GDP growth) – a proxy for a general output shock. [6]

All five shocks enter our regression as continuous variables, but we also check for possible non-linear effects when the magnitude of shocks is particularly large. For each shock X, we define a dummy variable "X, large", which is equal to 1 if a shock is greater than the 90th percentile of the income group distribution.[7] For instance, if the regression includes only, say, HICs and HMICs, we use the distribution of the shock in this group. For each shock we run regressions with (i) only X, (ii) only "X, large", and (iii) X and "X, large".

The summary statistics for each shock are reported in Table 2, and the correlations between episodes of large shocks are given in Table 3. All shocks are ordered the way that higher values mean worse outcomes. For instance, the 90th percentile of ER pressure is 2.86, which roughly corresponds to a weighted average of currency devaluation and decline in reserves of 16.5 per cent.

Table 2: External shocks, summary statistics, 1980-2010

	Mean	St. Dev	p10	median	p90	Observations
ER pressure	-0.159	2.283	-2.985	-0.192	2.862	4362
Terms of Trade (log)	-0.057	0.293	-0.445	0	0.209	3488
Drought	-0.041	0.999	-1.323	-0.029	1.170	875[8]
Natural catastrophe	0.005	0.022	0	0	0.006	5182
Real GDP Decline	-3.182	5.641	-8.071	-3.660	1.948	4729

Note: p10 – 10th percentile, p90 – 90th percentile

[6] See Table 24 for the definitions (Appendix 5).

[7] We also explore other approaches to defining the extreme values of shocks. First we take values that are greater than 90th percentile in the country-specific distributions of the shock, which is the definition used by the IMF in its vulnerability exercise (see IMF 2013). Second, we take values that are greater than 90th percentile in the world-wide distribution of the shock. The results of these regressions are not qualitatively different from the approach reported here.

[8] Only African countries.

Table 3 shows that the episodes of extreme shocks are largely uncorrelated. As expected, the general output shock (real GDP decline) is positively correlated with all shocks, but even these correlations are very close to zero. For clarity, and because the shocks are largely uncorrelated, we analyze each shock in a separate regression.

Table 3: Correlations of extreme shock values, 1980-2010[9]

	ER pressure	ToT	Natural catastrophe	Real GDP Decline
ER pressure	1			
Terms of Trade (log)	0.064	1		
Natural catastrophe	0.011	0.033	1	
Real GDP Decline	0.120	0.047	0.006	1

Table 4 presents a stylized representation of shocks that are likely to transmit instability through the determinants of tax performance.

Table 4: Shocks and Tax Instability Determinants

Variables	Total revenue	Income Tax	General Sales Tax	Trade Tax	Non tax revenue
GDP per capita	GDP_*decline*	GDP_*decline*	GDP_*decline*		GDP_*decline*
Agricultural exports	Drought, ND	Drought	Drought, ND	Drought, ToT	
Mineral exports	ToT, *ER_pressure*	ToT, *ER_pressure*	ToT, *ER_pressure*	ToT, *ER_pressure*	ND, ToT, *ER_pressure*
Fuel exports	GDP_*decline*	GDP_*decline*, ND	ND		GDP
Manufacturing Exports	ToT, *ER_pressure*		ToT, *ER_pressure*	ToT, *ER_pressure*	

Notes: The aim is to indicate the shocks most likely to affect instability of revenues and the determining variable through which the shock is transmitted, where GDP_decline designates a GDP decline shock, Drought *is a rainfall shock; ND is a natural disaster; ToT is terms of trade shock and ER_pressure is a general external shock*

As measures of GDP instability (GDP_decline) capture economy-wide or aggregate shocks and any specific shocks of sufficient magnitude to affect the economy, this is a transmission through income affecting all taxes and total tax revenue. The agriculture sector is especially susceptible to natural shocks, climate / rainfall (drought) or natural disaster (ND); these reduce output and are transmitted to revenue through performance (agricultural exports). Climate / rainfall shocks are most specific to agriculture and could affect taxes on exports (trade taxes) or general economic activity (income tax and general sales tax); natural disasters would have broader effects on economic activity so the effect may not be specific to trade taxes. Terms of trade shocks (ToT) that affect export commodity demand or prices are transmitted through agricultural exports (agri_exp), fuel exports (fuel_exp) and mineral exports (min_exp) especially to trade taxes or non tax revenue. However, ToT shocks may also affect imports (such as oil or food price increases) and can thus affect a variety of taxes. External rate shocks (*ER_pressure*), are allowed to have multiple effects, primarily associated with mineral production and exports. The manufacturing sector is expected to be more robust but performance (manufacturing exports is the proxy) would be affected by aggregate shocks and natural disasters, and may transmit to tax revenue.

[9] Drought is excluded from this table to avoid an overly small sample. In the smaller sample results remain very similar. Specifically the drought shock is weakly negatively correlated with ER pressure (-0.029) and weakly positively correlated with the other shocks

3.4. Identifying effects of external shocks on tax revenue

In order to identify the sign and the magnitude of the effect that a shock has on tax revenue, we first fit the following linear regression:

$$rev_{\{i,t\}} = \alpha + \beta w_{\{i,t\}} + \Gamma X_{\{i,t\}} + \epsilon_{\{i,t\}} \quad (5)$$

where *i* is the country index, and *t* is the year index; *rev* is total revenue (as percentage to GDP); *w* is external shock - GDP_decline, Drought, ND, ToT, or *ER_pressure*. X is the vector of our controls – Agriculture exports, mineral exports , fuel exports ,manufactured exports and imports. ε is a random error. Our interest is β.

The OLS estimator of β may not be consistent - it can be contaminated by the relationship between historical averages of *rev* and *w*. For example, suppose w is rainfall. What we want to estimate is in country *i* how would a random shock on rainfall affect tax revenue at year *t*. However, the economy of country *i* - its long standing traditions and institutions - may be affected by historical rainfall patterns. Warm tropical countries with high rainfall traditionally based their economy on agriculture, which required little investment in innovations and quality of institutions. When these countries were colonized, institutions introduced by the new rulers were not likely to be growth-inducing either, since colonizers did rarely consider these countries for permanent settlement. As a result, these countries would historically tend to have lower levels of development, and, hence, a lower tax ratio (although this itself may depend on the nature of the colonial experience, as shown by Mkandawire 2010). Hence, by just running OLS on (5) we will likely find rainfall negatively affecting tax revenue. In fact, that would be exactly the opposite to what would be the expected sign of β if we were to identify a random shock - at least, in SSA good rainfall is a sign of good harvest, and hence a good output.

To control for historical relationship between *rev* and *w* we will use fixed effects panel estimation. With regard to the climate shocks a similar approach was used in Deschenes and Greenstone (2007), Deschenes and Greenstone (2011), Fisher et al. (forthcoming), and Burke et al. (2011). We will run the following regression:

$$\ddot{rev}_{\{i,t\}} = \alpha + \beta\, \ddot{w}_{\{i,t\}} + \Gamma\, \ddot{X}_{\{i,t\}} + \ddot{\epsilon}_{\{i,t\}} \quad (6)$$

Here for any variable *a*, $\ddot{a}$ denotes its time-demeaned value:

$$\ddot{a}_{\{i,t\}} = a_{\{i,t\}} - \sum_t a_{\{i,t\}} = a_{\{i,t\}} - \bar{a} \quad (7)$$

Fixed effects panel estimations effectively means that now we are checking the relationship between random deviations of an external factor from its historical mean and deviations of tax revenue from its historical mean - exactly what we mean by identifying the effect of a random shock.

Note that with some shocks FE would still be insufficient to identify the causal effect. For instance, a shock to international capital flows may arise due to both exogenous push factors (e.g. shock to global risk aversion, US interest rate, regional contagion, etc.) and endogenous pull factors (e.g. implementation of capital controls, misalignment of real exchange rate, etc.). Nevertheless, the FE method would still provide for a more robust estimation of associations in the data.

3.5. Grouping countries

Our goal is to cluster countries into groups according to various factors so that countries in one group are similar in the reaction of their tax revenue to a shock. This way we will be able to identify country characteristics that are associated with their resilience to various kinds of shocks. We will employ three methods presented below – (i) *a priori* grouping, (ii) interactions, and (iii) FMM. Each method has its advantages and disadvantages. By employing various methods we broaden the analysis and cross-check results.

For the **a priori grouping** approach, we will run regressions for various groups of countries according to Section 2 of this report.

By focusing on the **interactions** of shocks and factors, the second approach allows to identify the relationship between shocks and certain country's properties within an OLS framework. For this purpose we will employ regressions with interactions. Specifically, suppose p is the "country's property" variable. It can be a dummy or discrete variable (for instance, one if a country belongs to the group of low-income countries), and it can also be a continuous variable, for instance revenue from extractive industries. We will run the following regression (with fixed effects):

$$trev = \alpha + \beta\, w_{\{i,t\}} + \chi\, w_{\{i,t\}} * p_{\{i,t\}} + \Gamma\, X_{\{i,t\}} + \epsilon_{\{i,t\}} \quad (8)$$

The effect of an external shock on tax revenue in country *i* is:

$$\frac{\partial rev_{\{i,t\}}}{\partial w_{\{i,t\}}} = \beta + \chi p_{\{i,t\}} \quad (9)$$

Eventually the effect in a particular country depends on the average effect for all countries corrected for the country specific property (how it interacts with the shock). In the example of a terms-of-trade shock, we would expect χ>0 if p{i,t} measures dependence of a country on non-renewables exports.[10]

Third, to complement the analysis and to explore new directions of grouping we will perform data-driven clustering of countries. One way to do this is to use Finite Mixture Models (FMM). The assumption behind this approach is that there is a finite number of latent classes in the data, where the relationship between dependent and independent variables – e.g. tax revenue instability and a shock in our case - is different. To give an example, for an oil price shock, the possible latent classes of countries would be oil exporters and oil importers.

A key advantage of the FMM procedure is that it identifies not only coefficients of regressions within each class, but also a probability that each observation belongs to a particular class. Classes are latent, i.e. not identified a priori by the researcher. Indeed, despite many examples of possible classes presented in the previous section, ascribing countries to these classes may not always be easy.

Mathematically, FMM fits the data as if it were a mixture (weighted sum) of several different distributions. Maximum likelihood is:

$$\max_{\pi,\beta} \ln L = \sum_{t=1}^{N} \left(\ln \left(\sum\nolimits_{j=1}^{K} \pi_j f(y|\beta_j) \right) \right) \quad (10)$$

where N is the number of observations; K - number of latent classes (this has to be predefined by a researcher); 0<πj<1 - a prior probability of an observation to belong to a class j ($\sum_{j=1}^{K} \pi_j = 1$); f - probability density function, which is characterized by parameters βj - different for each class j. β j and πj are parameters to estimate.

FMM nests OLS in the sense that it would replicate OLS results if *K*=1 and *f* is a normal probability density function. Hence if there were indeed only one class in the data (as is assumed and estimated under OLS) FMM estimates would not be different from OLS estimates. The cost of running FMM comparing to OLS is that it requires the estimation of a larger number of parameters: if *M* is the number of parameters for OLS, then the number of parameters to estimate under FMM is *K**(M+1).

Each method has both advantages and disadvantages relative to each other. Using interactions between shocks and factors is more economical in terms of the number of parameters to estimate for a given number of observations. In addition, interactions allow the estimation of continuous effects, when factors are continuous.[11]

[10] In this example, χ>0 would mean that countries with higher dependence on non-renewables exports are more vulnerable to ToT shocks than countries which depend on other types of exports.

[11] For example, if a factor is the share of agriculture in GDP the resilience to a shock would continuously depend on this factor. FMM or a priori grouping would instead split all countries in, say, two groups – high and low agriculture share (with an arbitrary threshold).

At the same time, interactions as well as *a priori* grouping of countries requires *a priori* knowledge about correct specifications and divisions of countries. By contrast, FMM allows finding latent constellations - including those where factors interact with each other or act non-linearly - that make certain countries respond to shocks differently. Considering advantages and disadvantages of each method described, using of all three of them should produce robust and comprehensive results.

3.6. Capturing recovery

To capture transmission channels and to analyse the impact and time patterns of shocks to the determinants of tax revenues in more detail we conduct additional econometric tests (time series / vector autoregressions) at the level of individual country cases. These are included in the five case studies. The basis of our VAR approach is identifying the long-run equilibrium relationship between the variables of interest and then analysing how they respond to perturbations of the equilibrium.

4. Results

4.1. Tax performance

Our initial results on the determinants of tax performance (as introduced in Section 2.1) are presented in Table 5. The dependent variable in all regressions is general government total revenue without grants as a share of GDP, including tax revenue, social contributions and other revenue (from property income, interest payments, sales of goods and services, etc.). We chose this broader category in order to account for the often considerable non-tax revenue accruing from natural resource endowments. We apply three estimation methods: pooled OLS, fixed effects (FE), and fixed effects with country-specific quadratic time trend (FEIS). FEIS is an extension of FE, which allows to control for time-constant variables, as well as for country-specific time trends common to all variables. In all specifications we include year dummies; standard errors are robust to arbitrary heteroscedasticity and serial correlation within country. Columns 1-3 show the results with all countries included, whereas in column 4 we exclude countries with the largest export/import figures.[12]

Table 5: Base specification: Determinants of revenue performance

	Full Sample			
	OLS	FE	FEIS	FE
	All	All	All	No outliers
Agricultural Exports (% GDP)	0.197**	-0.0104	0.00217	-0.0465
	(0.0903)	(0.0567)	(0.0342)	(0.0564)
Mineral Exports (% GDP)	0.0461	0.239**	0.140**	0.252**
	(0.0908)	(0.0935)	(0.0638)	(0.0989)
Manufacturing Exports (% GDP)	-0.103*	-0.0694	-0.0372	-0.129*
	(0.0600)	(0.0467)	(0.0355)	(0.0675)
Imports (% GDP)	0.0322	0.0194	-0.0139	0.0745**
	(0.0531)	(0.0377)	(0.0235)	(0.0352)
Fuel Exports (% GDP)	0.193***	0.235***	0.148***	0.284***
	(0.0564)	(0.0822)	(0.0511)	(0.0671)
Agriculture, Value Added (% GDP)	-0.0964	-0.115	-0.102***	-0.113
	(0.0859)	(0.0832)	(0.0294)	(0.0831)
GDP per capita (in logs)	3.905***	-0.483	-0.159	-0.891
	(0.787)	(1.630)	(1.328)	(1.520)
Constant	-3.139	35.40**	-0.347	37.27***
	(9.038)	(13.72)	(0.241)	(12.74)
R-squared	0.599	0.111	0.063	0.126
Observations	2664	2664	2663	2497
Number of countries	152		148	

*Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. OLS – ordinary least squares (pooled); FE – fixed effects; FEIS – fixed effects with individual slopes (linear and quadratic). No outliers: excluding countries with Manuf. Exp/GDP>45% or Imports/GDP>100% or Fuel Exp/GDP>60%.*

The following variables are used as revenue determinants in all our specifications: share of agricultural, mining, manufacturing, and fuel exports to GDP, imports to GDP, share of agriculture in GDP, and logarithm of real GDP per capita. The results vary considerably according to the methods used, especially comparing OLS with FE / FEIS. Still, mineral and fuel exports to GDP are associated with higher revenue throughout all specifications, and fuel exports are statistically significant in all of them. Manufacturing exports to GDP and share of agriculture in GDP demonstrate negative contribution to

[12] See the exact definition in the note to Table 5. We have also excluded countries with a population of less than 300,000 to control for specific patterns of small states (not shown in the table), without observing major changes to our results.

revenue performance throughout all specifications, although the results are not always significant.[13] The contribution of imports to GDP is very small, rarely significant and changes signs. The effect of agricultural exports to GDP is also unclear.

The exclusion of outliers does not seem to matter much for our results. The significance of some coefficients improves (e.g. imports to GDP, fuel exports to GDP), but neither their magnitudes nor the signs change substantially. This suggests that the low statistical significance of the coefficients and small magnitude for some of them may stem from overall heterogeneity of countries that we pool together in our regressions.

The fact that there is significant heterogeneity between the countries is demonstrated in Table 6, where we run the same regressions, but divide countries in two groups: high and upper middle income countries and low and lower middle income countries. From Table 6 we can see that the two groups are quite different. The positive relationship between mining to GDP and tax performance seems to be driven above all by high income countries, whereas the negative relationship between manufacturing exports to GDP and tax revenue is much more pronounced among low income countries. The share of agriculture in GDP is negatively associated with tax performance in both groups, but the effect is much bigger in magnitude in the high-income group. The near-zero effect of imports to GDP in our pooled regressions is explained by the opposite ways this variable acts on tax performance in countries with different income: its contribution is negative in high income countries, whereas in low income countries its contribution is positive, large, and statistically significant.

Table 6: Determinants of revenue performance by income groups

	High- and upper-middle income		Low- and lower-middle income	
	FE	FEIS	FE	FEIS
Agricultural Exports (% GDP)	0.0856	0.00397	-0.00700	-0.00126
	(0.0996)	(0.0580)	(0.0665)	(0.0466)
Mineral Exports (% GDP)	0.466***	0.274***	-0.0367	-0.00828
	(0.0975)	(0.0932)	(0.102)	(0.0862)
Manufacturing Exports (% GDP)	0.0176	0.00245	-0.124***	-0.0805***
	(0.0765)	(0.0549)	(0.0451)	(0.0282)
Imports (% GDP)	-0.122**	-0.0742***	0.170***	0.0545*
	(0.0588)	(0.0281)	(0.0344)	(0.0292)
Fuel Exports (% GDP)	0.318***	0.200***	0.295***	0.183***
	(0.108)	(0.0685)	(0.0829)	(0.0566)
Agriculture, Value Added (% GDP)	-0.627	-0.0252	-0.0849	-0.107***
	(0.433)	(0.143)	(0.0726)	(0.0327)
GDP per capita (in logs)	-3.627	-1.141	0.135	-0.124
	(3.213)	(2.878)	(2.125)	(1.432)
Constant	74.61**	-0.663**	19.20	0.0805
	(30.52)	(0.307)	(15.53)	(0.382)
R-squared	0.114	0.087	0.223	0.099
Observations	1393	1393	1242	1241
Number of countries	85		97	

*Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 FE – fixed effects; FEIS – fixed effects with individual slopes (linear and quadratic)*

The negative coefficient on manufacturing exports in the revenue equation, consistently significant for poorer (low and lower middle income) countries, is counter-intuitive at first glance. Higher shares of manufacturing in the economy are expected to indicate a relatively larger formal sector and, as this is

[13] Note that we use very conservative standard errors in our analysis as we cluster standard errors by country - i.e. control for any heteroscedasticity and serial correlation within a country. Given that we have up to 30 time periods for each country this does in fact lead to quite large standard errors.

easier to tax than the informal sector, is expected to be associated with higher tax revenue. It is also the case that formal firms, in contrast to informal microenterprises, are more likely to export. The coefficient remains negative and statistically significant if we use tax revenue instead of general revenue without grants or run the regression without GDP per capita. The coefficient ceases to be significant only if the imports/GDP variable is omitted from the regression (not shown in the tables). This suggests that, controlling for country openness to trade, poorer countries with more manufacturing exports (rather than mining, fuel, agriculture, services) collect less revenue. A plausible interpretation is that for manufacturing in poorer countries to be globally (export) competitive they need to restrain labour costs and margins; wages and profits are low so the sector makes no significant contribution to the tax base. The results are also consistent with global fragmentation of production: manufacturing exports of poor countries are based on adding a small amount of value added to imported intermediate inputs, hence do not contribute to domestic tax revenue (although any tariffs on the imports do contribute).

In the following sections, we chose FE without exclusion of outliers as our benchmark specification. Compared to FE, FEIS generally produces smaller coefficient estimates, which are also less statistically significant. The reason is that the inclusion of country-specific time trends wipes out more variation then simply allowing for country-specific intercepts (as is the case for FE). Wiping out this variation may not always be reasonable. For instance, an increase in a country's fuel exports to GDP may very well cause an increase in its tax ratio. This is the relationship that we want to capture. Yet, if we track that country from the onset of fuel production and export, FEIS may not be able to capture this relationship, as both increases in tax ratio and fuel exports would be accounted for by the time trend.

We also abstain from using OLS. Unlike FE, OLS leaves important variables uncontrolled – many of which are time-constant or change only slowly with time. For instance, within a relatively stable institutional environment of a particular country, an increase in mining exports to GDP is likely to cause an increase in tax ratio, and this is the effect we want to estimate. Yet, institutional environments – and hence tax regimes in the mining industry - between the countries vary a lot: some countries manage to extract a large share of rents from the mining companies, whereas in other countries most of the potential tax revenue is diverted to private pockets. As a result, OLS would estimate no empirical relationship between mining exports and tax ratio, whereas FE would (see above, Table 5).

4.2. Revenue volatility

Another question we want to address in this section of the chapter refers to whether revenue performance is associated with high revenue volatility. Are volatility rates different in specific groups compared to others? While the growth and volatility of tax revenues is governed by a number of determinants such as the structure and composition of the tax portfolio, this section adds the aspect of stylized features based on country grouping and its relevance for the interrelationship of average total tax revenue and the attributed volatility. Guided by the a priori grouping introduced in Section 3.5, we contrast average total tax revenue and total tax volatility as calculated by Index I (Section 3.2).

In a general sense, high volatility of tax revenue can be regarded as an indication for less revenue stability, lower predictability and, ultimately, lower revenue on average. Our data analysis confirms this relationship. Figure 1, Figure ***2*** and Figure ***3*** emphasize the negative relation of total tax revenue volatility (as measured by Index I – x-axis) and average total tax revenue (y-axis). The relation is more pronounced for high- and upper-middle income countries, non-resource-rich countries and democratic countries. With regard to their grouping counterparts, on average, the aforementioned country groups appear to be more homogenous and thus exhibit a closer resemblance to the pattern one would assume, i.e. higher total tax volatility being associated with lower total revenues on average.[14]

Table 7 to Table ***9*** complement the graphical illustration by providing the descriptive statistics for total tax revenue volatility and average total tax revenue for the respective groupings and divided by subsamples. Low-and lower-middle-income countries, resource-rich countries and non-democratic countries have on average lower total tax revenues and at the same time more volatile tax revenues which holds over the entire sample as well as for the sub-periods (1980s, 1990s and 2000s).

[14] We also check for total revenue without grants (variable "rev", see Appendix 2, Table 24) which includes non-tax revenue without grants (not shown in the table). The relationship between revenue and volatility is less pronounced in this case, indicating that non-tax revenue is even more volatile than tax revenue, especially for lower-income and resource-rich countries.

Figure 1: Average total tax revenue vs. total tax revenue volatility by country income group

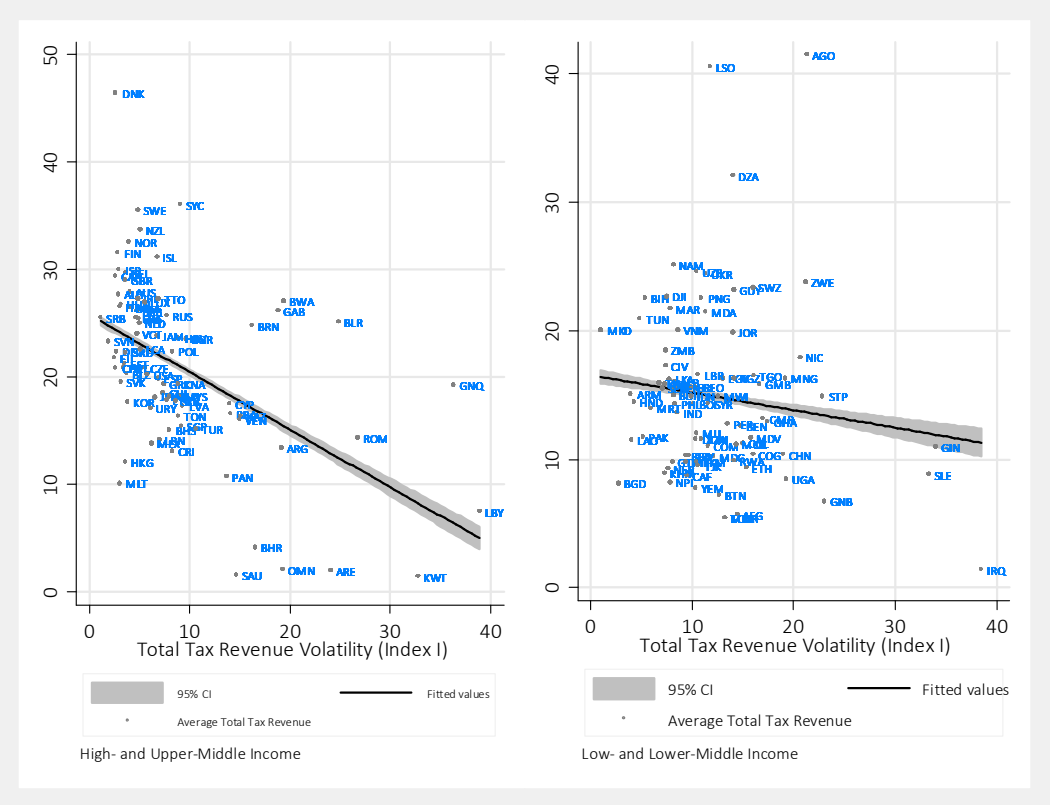


Figure 2: Average total tax revenue vs. total tax revenue volatility by resource endowment

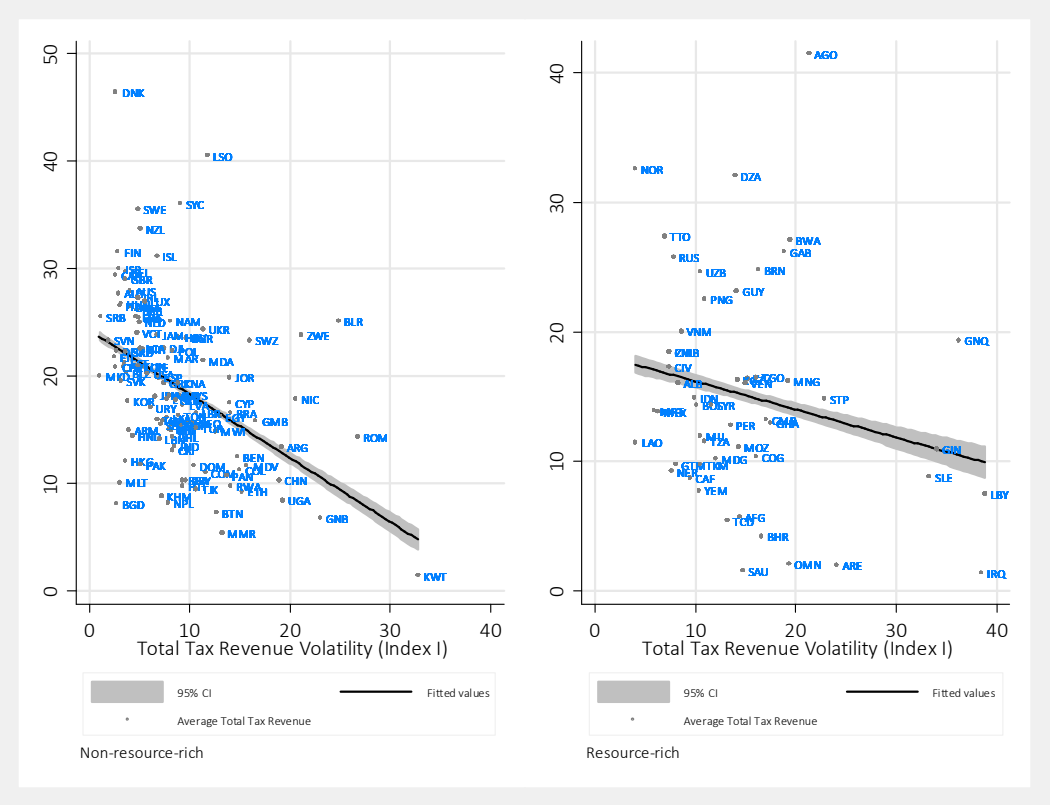


Figure 3: Average total tax revenue vs. total tax revenue volatility by regime type

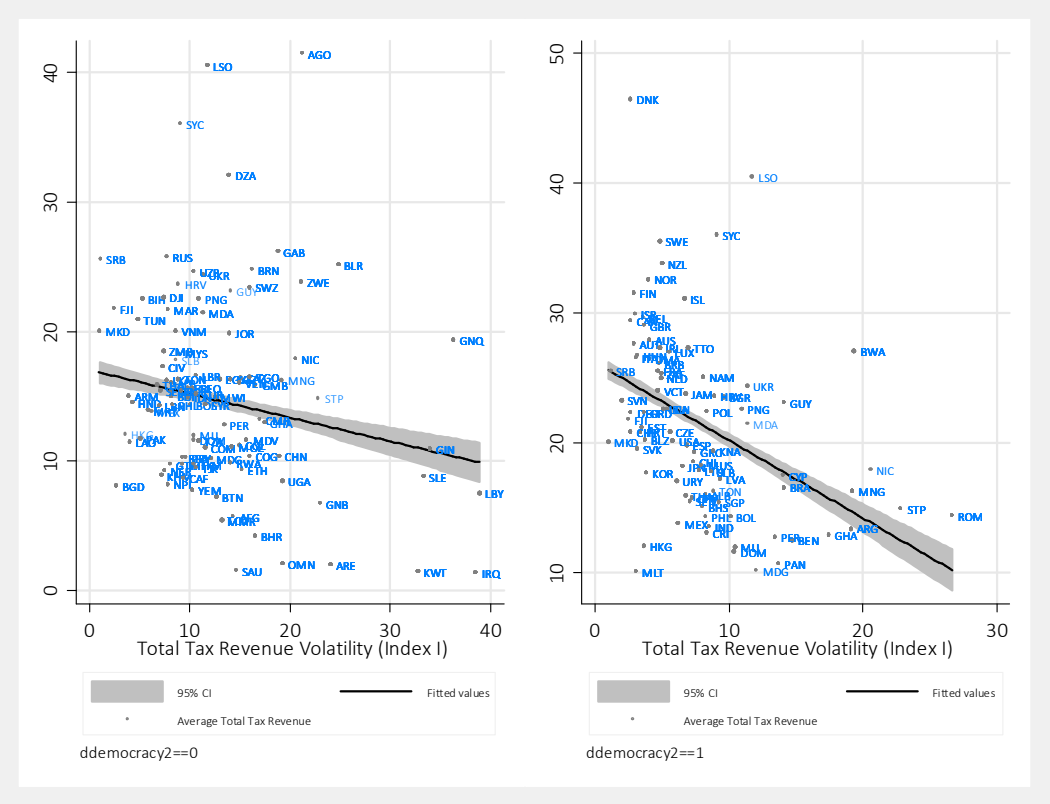


Table 7: Descriptive statistics for average total tax revenue by income group

Variable / Sample		High- and upper-middle-income	Low- and lower-middle-Income
Sample: 1980-2010			
Average Total Tax Revenue	Mean	21.016	14.884
	Standard Deviation	8.066	6.772
	No. of Observations	2511	2635
Total Tax Revenue Volatility (Index I)	Mean	8.972	12.192
	Standard Deviation	7.705	6.378
	No. of Observations	2511	2635
Sample: 1980-1989			
Average Total Tax Revenue	Mean	21.840	14.095
	Standard Deviation	8.595	6.412
	No. of Observations	540	570
Sample: 1990-1999			
Average Total Tax Revenue	Mean	20.702	14.464
	Standard Deviation	8.436	6.445
	No. of Observations	780	740
Sample: 2000-2010			
Average Total Tax Revenue	Mean	21.828	15.581
	Standard Deviation	8.443	7.315
	No. of Observations	880	935

Table 8: Descriptive statistics for average total tax revenue by resource richness

Variable / Sample		Non-resource-rich	Resource-rich
Sample: 1980-2010			
Average Total Tax Revenue	Mean	19.129	15.128
	Standard Deviation	7.566	8.355
	No. of Observations	3534	1612
Total Tax Revenue Volatility (Index I)	Mean	8.683	14.868
	Standard Deviation	5.679	8.383
	No. of Observations	3534	1612
Sample: 1980-1989			
Average Total Tax Revenue	Mean	18.240	16.844
	Standard Deviation	8.429	8.567
	No. of Observations	810	300
Sample: 1990-1999			
Average Total Tax Revenue	Mean	19.304	14.004
	Standard Deviation	8.065	7.087
	No. of Observations	1050	470
Sample: 2000-2010			
Average Total Tax Revenue	Mean	19.949	15.700
	Standard Deviation	7.926	8.900
	No. of Observations	1243	572

Table 9: Descriptive statistics for average total tax revenue by regime type

Variable / Sample		Non-democratic	Democratic
Sample: 1980-2010			
Average Total Tax Revenue	Mean	14.590	21.759
	Standard Deviation	7.492	6.847
	No. of Observations	1079	913
Total Tax Revenue Volatility (Index I)	Mean	13.319	7.432
	Standard Deviation	7.723	5.009
	No. of Observations	1079	913
Sample: 1980-1989			
Average Total Tax Revenue	Mean	-	-
	Standard Deviation	-	-
	No. of Observations	-	-
Sample: 1990-1999			
Average Total Tax Revenue	Mean	13.924	21.933
	Standard Deviation	6.985	7.280
	No. of Observations	162	142
Sample: 2000-2010			
Average Total Tax Revenue	Mean	15.108	22.652
	Standard Deviation	8.295	6.702
	No. of Observations	884	766

4.3. Exogenous shocks and tax revenue sensitivity

At this stage of the analysis we introduce shock variables to our regressions. As mentioned in section 3.3, we start with five kinds of shocks: (i) exchange rate pressure, (ii) terms of trade; (iii) drought; (iv) intensity of natural catastrophes; and (v) real GDP decline (opposite of real GDP growth) as a proxy for a general output shock. Based on the discussion of estimation methods in the previous section, FE is the only estimation method we use in analyzing shocks. Results are reported for all countries pooled together, and separately for richer (high-income and higher-middle-income) and poorer (low-income and lower-middle-income) countries. Year dummies are included in each regression, and the standard errors are robust to heteroscedasticity and serial correlation within each country. All regressions are run according to the equations (5) and (6) in the methodology section.

With access only to annual data, we look for contemporaneous effects – assuming that the effect of shocks on revenue will materialise itself in the same calendar year. However, as a robustness check (not shown in the tables) we also use one-year forward government revenue as the dependent variable. None of the shocks is found to significantly affect the revenue in the next period, once the current government revenue is controlled for. We find, however, that government revenue has a sizeable autoregressive component, i.e. current revenue depends on last year's revenue, so external shocks may have an indirect lasting effect on government finance as they affect current revenue. The only country group where the autoregressive component of the government revenue does not seem to be present are democracies.

The results in this section can be summarized as follows: different shocks have different effects on revenue, and the effects are usually more pronounced and more significant in poorer countries compared to the richer group. If large shocks dummies are included in the regressions alone, then their effect is often significant, but for most shocks there is little evidence that their effects are non-linear: Large shock dummies are usually insignificant if included together with the linear specification of the shock, the only exception being large ER-shocks in the group of poorer countries.

Regarding specific shocks, the following findings can be reported:

- Exchange rate (ER) pressure contributes negatively to tax revenue in all specifications, including both income groups (see Table 10). If all countries are used in the estimation, an increase in the index by 10 per cent would reduce tax revenue roughly by 1.3 percentage points (column 1). The effect is comparably large and significant for both income groups (column 7 vs. column 4). There is also some evidence that the episodes of extreme ER pressure exacerbate the effect (column 3); the non-linear effect is pronounced and weakly significant in lower-income countries, while in high-income countries it is practically non-existent (column 9 vs. column 6).

- Adverse shocks to terms of trade also reduce tax revenue. The result is statistically significant for the whole sample as well as for both income groups (see Table 11). In this case, however, richer countries seem to suffer less from shocks, as point estimates are considerably lower. Compared to our base specification (see Table 6), the mineral exports coefficient loses significance in all groups. There is no evidence of adverse non-linear effects at the right tail of the distribution. In fact, there is some evidence to the contrary, as the large shock coefficient is positive though not significant for the full sample (column 3) and higher-income countries appear to be less affected by the upper 10 per cent of events as compared to minor shocks. In this income group the non-linear effect is pronounced and significant (column 6). In lower-income countries large shocks have a significant negative effect on revenue, but the point estimate is lower than for ToT shocks in general and testing for non-linear effects does not produce significant results (column 9).

- The effect of poor rainfall on tax revenue is less clear (see Table 12).[15] The sign of the coefficient is always negative for the continuous variable, but it is statistically insignificant in all estimations (columns 1, 4 and 7). The coefficient for the linear specification based on large shocks is positive yet insignificant (column 2), obviously driven by the lower-income group where the result is positive and significant (column 8). Looking at the magnitudes of coefficients, high- and upper-middle-income countries seem to suffer more from this shock, but this is based only on six countries.

[15] Please note that we check the effect of this shock only for African countries, due to data constraints.

Somewhat unexpectedly, large shocks have a significant positive effect on revenue in low- and lower-middle-income countries (columns 8 and 9).[16] All in all, however, the results in Table 12 are not surprising, as rainfall shocks in SSA would primarily hit the informal and subsistence sectors, which do not pay taxes. Hence, it should not affect tax revenue unless there are significant spill-overs from the informal to the formal economy.

– The intensity of natural catastrophes also affects tax revenue negatively, except in the high- and upper-middle-income group, where the effect is essentially zero (see Table 13). The result is primarily driven by the group of poorer countries, where the effect is statistically significant. Again, no adverse non-linear effects can be observed. This finding would be in line with expectations, as richer countries should be in a better position to respond to natural disasters relying on tax measures and other public policies.

– Finally, we checked for GDP decline as a proxy for a general output shock (not shown in the tables). The fall of output does not seem to decrease revenue (as a percentage of GDP). All coefficients are statistically insignificant and very close to zero. These results indicate that on average tax systems are neutral, i.e. the elasticity of revenue with respect to output is close to 1 – independently of the country income group.

In the following stages of our empirical analysis we therefore only report on shocks related to exchange rate pressure, terms of trade and natural catastrophe intensity, as these shocks do have statistically and economically large effects on government revenue.

[16] A possible interpretation could be that large drought shocks induce an increase in commercial food imports for urban areas. These imports would generate revenue contemporaneously if food is subject to tariffs (which it often is) and because imported food is more likely to attract indirect taxes than domestically grown staples (food is not usually zero-rated for VAT). This is plausible, at least for SSA countries, as large droughts disrupt supplies to urban areas.

Table 10: Effect of shocks on revenue: exchange rate pressure, fixed effects estimation

	Full Sample			High- and upper-middle-income			Low and lower-middle-income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Exchange Rate Pressure	-0.130***		-0.0879*	-0.165***		-0.141**	-0.149**		-0.0770
	(0.0489)		(0.0485)	(0.0619)		(0.0691)	(0.0708)		(0.0676)
Large Shock		-1.041**	-0.708		-0.953	-0.442		-1.466**	-1.168*
		(0.496)	(0.522)		(0.746)	(0.825)		(0.599)	(0.592)
Agricultural Exports (% GDP)	-0.0278	-0.0254	-0.0264	0.0554	0.0495	0.0551	-0.0301	-0.0199	-0.0240
	(0.0536)	(0.0543)	(0.0539)	(0.101)	(0.102)	(0.101)	(0.0634)	(0.0644)	(0.0632)
Mineral Exports (% GDP)	0.207**	0.212***	0.209**	0.399***	0.403***	0.400***	-0.0583	-0.0483	-0.0508
	(0.0816)	(0.0812)	(0.0811)	(0.0828)	(0.0825)	(0.0826)	(0.106)	(0.108)	(0.107)
Manufacturing Exports (% GDP)	-0.0778*	-0.0760*	-0.0762*	-0.00518	-0.00751	-0.00546	-0.109**	-0.103**	-0.103**
	(0.0447)	(0.0452)	(0.0451)	(0.0742)	(0.0748)	(0.0742)	(0.0421)	(0.0420)	(0.0416)
Imports (% GDP)	0.0355	0.0328	0.0336	-0.0923*	-0.0913*	-0.0929*	0.190***	0.184***	0.186***
	(0.0354)	(0.0351)	(0.0352)	(0.0551)	(0.0548)	(0.0548)	(0.0324)	(0.0321)	(0.0320)
Fuel Exports (% GDP)	0.169**	0.175**	0.172**	0.237**	0.240**	0.238**	0.277***	0.289***	0.285***
	(0.0724)	(0.0725)	(0.0724)	(0.0912)	(0.0914)	(0.0912)	(0.0826)	(0.0843)	(0.0831)
Agriculture, Value Added (% GDP)	-0.105	-0.107	-0.106	-0.570	-0.558	-0.566	-0.0750	-0.0798	-0.0784
	(0.0816)	(0.0804)	(0.0810)	(0.406)	(0.408)	(0.409)	(0.0719)	(0.0707)	(0.0715)
GDP per capita (in logs)	-1.011	-0.944	-0.984	-4.289	-4.068	-4.236	-0.135	0.00269	-0.0618
	(1.563)	(1.561)	(1.563)	(2.805)	(2.820)	(2.803)	(2.243)	(2.234)	(2.243)
Constant	39.64***	39.20***	39.47***	80.69***	78.67***	80.23***	20.43	19.64	20.01
	(13.19)	(13.17)	(13.20)	(26.38)	(26.51)	(26.40)	(16.39)	(16.33)	(16.40)
R-squared	0.100	0.100	0.101	0.098	0.096	0.098	0.229	0.232	0.233
Observations	2524	2524	2524	1332	1332	1332	1168	1168	1168
Number of countries	147	147	147	83	83	83	93	93	93

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Large Shock - equal 1 if exchange rate pressure is above 90th percentile of the income group distribution.*

Table 11: Effect of shocks on revenue: terms of trade, fixed effects estimation

	Full Sample			High- and upper-middle-income			Low and lower-middle-income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Terms of Trade	-4.740***		-5.390***	-2.843*		-4.272**	-4.894***		-4.924***
	(1.302)		(1.423)	(1.649)		(1.756)	(1.279)		(1.506)
Large Shock		-1.358*	0.786		0.143	1.829**		-1.751**	0.0338
		(0.696)	(0.589)		(0.965)	(0.845)		(0.728)	(0.694)
Agricultural Exports (% GDP)	-0.0523	-0.0536	-0.0516	-0.0110	-0.0102	-0.00737	-0.0494	-0.0368	-0.0494
	(0.0537)	(0.0547)	(0.0535)	(0.106)	(0.106)	(0.108)	(0.0657)	(0.0679)	(0.0657)
Mineral Exports (% GDP)	-0.0381	0.0140	-0.0417	0.149	0.217	0.122	-0.134	-0.0877	-0.134
	(0.0861)	(0.0947)	(0.0868)	(0.159)	(0.146)	(0.161)	(0.0864)	(0.0983)	(0.0865)
Manufacturing Exports (% GDP)	-0.0871**	-0.0896***	-0.0847**	-0.0369	-0.0394	-0.0305	-0.121**	-0.127**	-0.121**
	(0.0338)	(0.0327)	(0.0339)	(0.0469)	(0.0488)	(0.0476)	(0.0463)	(0.0490)	(0.0467)
Imports (% GDP)	0.0595	0.0503	0.0619	-0.0283	-0.0455	-0.0242	0.165***	0.166***	0.165***
	(0.0408)	(0.0440)	(0.0406)	(0.0422)	(0.0438)	(0.0430)	(0.0299)	(0.0314)	(0.0299)
Fuel Exports (% GDP)	0.172	0.243*	0.170	0.177	0.220	0.172	0.275**	0.346***	0.275**
	(0.134)	(0.135)	(0.134)	(0.164)	(0.162)	(0.163)	(0.112)	(0.105)	(0.112)
Agriculture, Value Added (% GDP)	-0.0438	-0.0550	-0.0409	-0.192	-0.189	-0.192	-0.0502	-0.0612	-0.0501
	(0.0563)	(0.0618)	(0.0553)	(0.297)	(0.312)	(0.297)	(0.0562)	(0.0620)	(0.0556)
GDP per capita (in logs)	-1.731	-1.554	-1.778	-1.500	-2.025	-1.989	-1.895	-1.304	-1.893
	(1.433)	(1.561)	(1.427)	(2.255)	(2.448)	(2.290)	(2.075)	(2.223)	(2.078)
Constant	41.83***	40.95***	41.89***	49.59**	54.94**	53.54**	33.40**	29.52*	33.37**
	(11.86)	(12.89)	(11.76)	(22.48)	(24.28)	(22.72)	(14.97)	(15.95)	(15.00)
R-squared	0.213	0.177	0.215	0.250	0.232	0.260	0.258	0.230	0.258
Observations	1994	1994	1994	893	893	893	1093	1093	1093
Number of countries	149	149	149	83	83	83	92	92	92

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Large Shock - equal 1 if terms of trade is above 90th percentile of the income group distribution.*

Table 12: Effect of shocks on revenue: drought, fixed effects estimation

	Full Sample			High- and upper-middle-income			Low and lower-middle-income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Drought	-0.137		-0.282	-0.436		-0.142	-0.0912		-0.366
	(0.202)		(0.290)	(0.493)		(0.414)	(0.234)		(0.360)
Large Shock		0.497	1.031		-2.395	-2.116		1.261**	1.943*
		(0.748)	(1.071)		(2.080)	(2.343)		(0.608)	(1.124)
Agricultural Exports (% GDP)	0.164	0.175	0.178	-0.501	-0.548	-0.598	0.111	0.124	0.128
	(0.200)	(0.204)	(0.207)	(0.742)	(0.730)	(0.769)	(0.208)	(0.212)	(0.216)
Mineral Exports (% GDP)	0.00690	-0.000688	0.000956	0.304	0.339	0.336	-0.0770	-0.0960	-0.0871
	(0.130)	(0.129)	(0.129)	(0.364)	(0.297)	(0.344)	(0.154)	(0.148)	(0.148)
Manufacturing Exports (% GDP)	0.0928	0.0869	0.0872	0.472**	0.513*	0.507*	0.0245	0.00706	0.0141
	(0.1000)	(0.105)	(0.102)	(0.173)	(0.224)	(0.225)	(0.0998)	(0.109)	(0.109)
Imports (% GDP)	-0.000309	-0.00519	-0.00268	-0.0126	-0.0136	-0.00487	-0.00599	-0.0144	-0.0132
	(0.1000)	(0.0993)	(0.0998)	(0.221)	(0.198)	(0.206)	(0.107)	(0.106)	(0.107)
Fuel Exports (% GDP)	0.184	0.192	0.190	0.929	0.749	0.761	0.139	0.152	0.145
	(0.214)	(0.212)	(0.212)	(0.769)	(0.706)	(0.767)	(0.285)	(0.280)	(0.279)
Agriculture, Value Added (% GDP)	-0.223**	-0.224**	-0.230**	-1.439	-1.457	-1.421	-0.200*	-0.206*	-0.215*
	(0.101)	(0.101)	(0.105)	(1.188)	(0.977)	(1.089)	(0.113)	(0.115)	(0.120)
GDP per capita (in logs)	-10.54*	-10.66*	-10.68*	-24.43	-22.60	-22.31	-6.560	-6.526	-6.682
	(5.867)	(6.010)	(5.974)	(20.21)	(19.98)	(20.87)	(6.542)	(6.783)	(6.685)
Constant	93.36**	94.29**	94.45**	227.6	212.8	210.1	66.22	66.43	67.53
	(39.86)	(40.69)	(40.61)	(177.0)	(174.2)	(181.8)	(42.30)	(43.70)	(43.34)
R-squared	0.259	0.259	0.262	0.693	0.707	0.708	0.279	0.284	0.287
Observations	348	348	348	48	48	48	298	298	298
Number of countries	35	35	35	6	6	6	32	32	32

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Large Shock - equal 1 if drought is above 90th percentile of the income group distribution.*

Table 13: Effect of shocks on revenue: intensity of natural disasters, fixed effects estimation

	Full Sample			High- and upper-middle-income			Low and lower-middle-income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intensity of Natural Disaster	-5.015		-5.553	1.594		-1.026	-8.580**		-9.310**
	(4.238)		(4.474)	(9.345)		(8.868)	(3.590)		(3.783)
Large Shock		-0.144	0.0575		0.192	0.229		-0.252	0.0819
		(0.344)	(0.389)		(0.706)	(0.788)		(0.273)	(0.302)
Agricultural Exports (% GDP)	-0.00669	-0.00847	-0.00665	0.0886	0.0881	0.0882	0.000486	-0.00595	0.000782
	(0.0578)	(0.0575)	(0.0578)	(0.103)	(0.103)	(0.103)	(0.0662)	(0.0666)	(0.0662)
Mineral Exports (% GDP)	0.0461	0.0475	0.0461	0.341**	0.341**	0.341**	-0.0418	-0.0389	-0.0415
	(0.0909)	(0.0905)	(0.0909)	(0.159)	(0.159)	(0.159)	(0.102)	(0.101)	(0.102)
Manufacturing Exports (% GDP)	-0.0850*	-0.0850*	-0.0851*	-0.00446	-0.00443	-0.00437	-0.126***	-0.125***	-0.126***
	(0.0487)	(0.0486)	(0.0487)	(0.0789)	(0.0789)	(0.0790)	(0.0451)	(0.0453)	(0.0451)
Imports (% GDP)	0.0206	0.0202	0.0206	-0.130**	-0.130**	-0.130**	0.173***	0.171***	0.173***
	(0.0400)	(0.0399)	(0.0400)	(0.0598)	(0.0598)	(0.0599)	(0.0338)	(0.0343)	(0.0339)
Fuel Exports (% GDP)	0.279***	0.279***	0.279***	0.344***	0.344***	0.344***	0.294***	0.294***	0.294***
	(0.0939)	(0.0938)	(0.0940)	(0.120)	(0.120)	(0.120)	(0.0831)	(0.0830)	(0.0833)
Agriculture, Value Added (% GDP)	-0.121	-0.121	-0.121	-0.579	-0.579	-0.579	-0.0861	-0.0858	-0.0859
	(0.0849)	(0.0850)	(0.0848)	(0.441)	(0.440)	(0.441)	(0.0727)	(0.0729)	(0.0727)
GDP per capita (in logs)	-0.296	-0.300	-0.293	-3.038	-3.031	-3.031	0.124	0.108	0.132
	(1.640)	(1.641)	(1.639)	(3.282)	(3.279)	(3.280)	(2.107)	(2.125)	(2.113)
Constant	34.46**	34.52**	34.43**	70.24**	70.17**	70.17**	19.21	19.44	19.13
	(13.80)	(13.82)	(13.80)	(31.16)	(31.12)	(31.13)	(15.39)	(15.55)	(15.45)
R-squared	0.116	0.116	0.116	0.114	0.114	0.114	0.225	0.223	0.225
Observations	2603	2603	2603	1350	1350	1350	1242	1242	1242
Number of countries	148	148	148	81	81	81	97	97	97

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Large Shock - equal 1 if the intensity of the natural disaster is above 90th percentile of the income group distribution.*

4.4. Country groups

Results in the previous two sections clearly demonstrate that pooling all countries into one single sample in order to estimate the sensitivity of tax revenue to external shocks is not a good idea. At the very least, richer and poorer countries seem to respond to shocks very differently; the tax determinants in these groups are different. We check whether this is true statistically by performing Chow tests on the two groups.[17] The results are reported in Table 14. Looking at the joint distribution of coefficients on shocks and tax determinants (the structural variables from our base specification), the F-statistics of the test are very high, which means that the odds of the coefficients being different in the two groups are high. At the same time, coefficients on shocks alone do not seem to be statistically different (p-values are on the order of 0.5). This is mainly due to large standard errors of the estimators, as the point estimates in the two groups are clearly different, and the difference is economically significant. For instance, a 10 per cent worsening of the terms-of-trade index would reduce tax revenue in lower-income countries by about 1.4 percentage points more than in higher-income countries.

Table 14: High- and upper-middle-income vs. low- and lower-middle-income, Chow tests

	Exchange Rate Pressure	Terms of Trade (in logs)	Intensity of Natural Disasters
Only shocks			
t-statistic	-0.02	-1.2	-1.15
p-value	0.99	0.23	0.25
Shocks and structural variables			
F-statistic	4.07	9.03	4.83
p-value	0.0001	0.0000	0.0000

In this section we explore differences between groups of countries with regard to the sensitivity of their tax revenue to external shocks. We first use pre-defined groups based on the respective endowment with natural resources (resource-rich vs. non-rich) and the character of the political regime (democracies vs. non-democracies). Then we check whether certain policy variables interact with external shocks in their effect on tax revenue. Finally, we subject our sample to data-driven methods of grouping countries into homogeneous groups.

In the following subsections we only report results for low- and lower-middle-income countries, as these are the most relevant countries from a development policy perspective. Some results for higher-income countries are shown in Appendix 6.

4.4.1. Pre-defined grouping

In this subsection we further divide countries into groups to check for heterogeneity in effects of shocks. For each group we run FE regressions with three shocks: exchange rate pressure, terms of trade and natural disaster intensity. Initially we consider two pre-defined groups. First, we divide countries by their natural resource endowment (as classified by the IMF, see IMF 2012). Second, we split countries according to their political regime characteristics, based on their Polity IV score: On a scale ranging from 10 to -10, a country is considered a democracy if its Polity IV score is higher than 6, and a non-democracy if otherwise (see Marshall / Gurr / Jaggers 2010). Results are presented in Table 15 and Table 16.

The results suggest significant heterogeneity between the groups of countries.

[17] The Chow Test shows the statistical significance of the difference between coefficient estimates in two groups of countries considered. We test the joint significance of coefficients on shock and on our structural variables. The tests are performed the following way. First, we create interactions of a group dummy and the variables of interest, including time dummies. Second, we run regressions of government revenue on the variables of interest and the interactions. Third, we perform the test on the joint statistical significance of all interactions excluding interactions with time dummies, as we are interested whether the effect of a shock and the association of government revenue with the structural variables is different in the two groups.

- ER pressure has a negative effect in both resource-rich (RR) and non resource-rich (non-RR) countries, but in the former group the effect is much bigger and statistically significant.

- The coefficient of terms-of-trade shocks is negative and statistically significant in both groups of countries, but the effect is more pronounced in non-RR countries. High income countries (especially those rich in natural resources) are practically unaffected, which may be the consequence of the fact that their budgets generally rely less on external trade taxes (see Appendix 6).

- The negative effect of natural disasters intensity seems to be driven entirely by non-RR countries. The reason may be that the extractive industries – the main sources of tax revenue in RR countries – are usually less affected by natural catastrophes than other types of economic activity, like agriculture, which are more important for non-RR countries.

Table 15: Effects of shocks on revenues of low- and lower-middle-income countries, resource-rich vs. non-resource-rich countries, fixed effects estimation

Shocks:	Exchange Rate Pressure		Terms of Trade (in logs)		Intensity of Natural Disasters	
	(1)	(2)	(1)	(2)	(1)	(2)
Shock Level	-0.244	-0.0735	-4.313**	-4.566***	-0.465	-13.08***
	(0.154)	(0.0680)	(2.033)	(1.339)	(8.459)	(4.146)
Agricultural Exports (% GDP)	0.157	-0.0949*	0.107	-0.107	0.139	-0.0452
	(0.163)	(0.0563)	(0.176)	(0.0701)	(0.160)	(0.0579)
Mineral Exports (% GDP)	-0.0799	-0.334	-0.134	-0.217	-0.0526	-0.311
	(0.0946)	(0.288)	(0.100)	(0.316)	(0.103)	(0.275)
Manufacturing Exports (% GDP)	-0.144	-0.117***	-0.161	-0.117**	-0.158	-0.130***
	(0.114)	(0.0391)	(0.140)	(0.0487)	(0.0973)	(0.0415)
Imports (% GDP)	0.153***	0.219***	0.129**	0.188***	0.132**	0.201***
	(0.0543)	(0.0359)	(0.0550)	(0.0356)	(0.0548)	(0.0403)
Fuel Exports (% GDP)	0.254***	0.199	0.278*	0.269	0.227**	0.302*
	(0.0793)	(0.139)	(0.143)	(0.171)	(0.0858)	(0.169)
Agriculture, Value Added (% GDP)	-0.260**	-0.0254	-0.126	-0.0384	-0.273**	-0.0308
	(0.109)	(0.0515)	(0.0895)	(0.0564)	(0.101)	(0.0528)
GDP per capita (in logs)	0.581	-0.980	-0.0220	-2.909	-0.636	0.0614
	(2.954)	(2.397)	(3.595)	(2.417)	(2.817)	(2.327)
Constant	18.03	26.21	20.24	41.14**	27.60	18.94
	(19.83)	(17.97)	(24.55)	(18.15)	(18.91)	(17.45)
R-squared:	0.369	0.244	0.361	0.281	0.360	0.241
Observations	367	801	356	737	411	831
Number of countries	29	64	32	60	32	65
Chow tests:						
a. Only shocks						
t-statistic	-1.04		0.11		1.37	
p-value	0.3		0.92		0.18	
b. Shocks and structural variables						
F-statistic	0.91		0.37		1.29	
p-value	0.508		0.932		0.257	

*Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; (1) resource-rich (2) non-resource-rich countries.*

As for tax determinants, Table 15 shows that, as expected, the positive effect of fuel exports to GDP on revenue is driven primarily by resource-rich countries. Interestingly, mineral exports have a negative effect on revenue in RR countries and practically zero in non-RR. This suggests a lack of trans-

parency (or, less probably, a low level of profitability) in the mining sector in many lower-income countries – in contrast to the hydrocarbon industry.

Despite the visible difference between the estimated coefficients for RR and non-RR countries, the Chow tests show no statistical significance. P-values get close to commonly accepted levels when only coefficients on shocks are tested, though not in the case of terms-of-trade shocks. This finding is again driven by the high standard error of a coefficient in at least one of the groups. Chow tests are even less significant when we jointly test coefficients on shocks and structural variables, suggesting that within the group of poorer countries RR and non-RR countries are not dramatically different – the difference between higher-income countries and lower-income countries is much bigger. Interestingly, the difference between RR and non-RR countries among richer countries is highly significant in statistical terms (see Appendix 6). In this group, endowment with natural resources seems to be related to very different kinds of countries (for instance, think of Qatar vs. Switzerland).

Table 16: Effects of shocks on revenues of low- and lower-middle-income countries, democratic vs. non-democratic countries, fixed effects estimation

Shocks:	Exchange Rate Pressure		Terms of Trade (in logs)		Intensity of Natural Disasters	
	(1)	(2)	(1)	(2)	(1)	(2)
Shock Level	-0.0348	-0.199**	0.920	-5.626***	-8.522	-11.69***
	(0.102)	(0.0793)	(2.688)	(1.175)	(8.224)	(4.390)
Agricultural Exports (% GDP)	-0.0819	-0.0138	-0.00736	-0.147	-0.0354	-0.00174
	(0.0837)	(0.110)	(0.102)	(0.102)	(0.0960)	(0.109)
Mineral Exports (% GDP)	-0.349**	-0.0375	-0.272	-0.148	-0.283*	-0.0606
	(0.166)	(0.105)	(0.162)	(0.0969)	(0.157)	(0.102)
Manufacturing Exports (% GDP)	-0.176***	-0.124*	-0.178***	-0.181***	-0.176***	-0.171**
	(0.0592)	(0.0711)	(0.0602)	(0.0605)	(0.0588)	(0.0758)
Imports (% GDP)	0.125	0.185***	0.0645	0.184***	0.0796	0.193***
	(0.0778)	(0.0355)	(0.0985)	(0.0272)	(0.0888)	(0.0346)
Fuel Exports (% GDP)	0.640***	0.261***	0.635***	0.187	0.609***	0.281***
	(0.123)	(0.0879)	(0.155)	(0.119)	(0.117)	(0.0830)
Agriculture, Value Added (% GDP)	0.0141	-0.207*	0.0272	-0.128	0.0103	-0.210**
	(0.0307)	(0.109)	(0.0208)	(0.0915)	(0.0313)	(0.100)
GDP per capita (in logs)	-2.655	-0.395	-4.303	-0.400	-3.015	0.698
	(3.526)	(2.548)	(2.857)	(2.462)	(3.068)	(2.387)
Constant	39.73	24.96	52.32**	25.07	43.96*	17.25
	(25.87)	(17.77)	(20.48)	(17.31)	(22.62)	(16.57)
R-squared:	0.355	0.282	0.351	0.341	0.350	0.294
Observations	402	688	382	673	412	750
Number of countries	38	66	37	70	38	71
Chow tests:						
a. Only shocks						
t-statistic	0.86		2.49		0.2	
p-value	0.39		0.02		0.84	
b. Shocks & structural variables						
F-statistic	2.27		3.27		2.6	
p-value	0.025		0.002		0.011	

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. (1) Democracies (2) Non-democracies.*

Democratic countries fare better than non-democracies in their revenue sensitivity to all three shocks we consider (see Table 16). The coefficients on shocks are smaller in magnitude and much less significant. For non-democratic countries, the effects of the three kinds of shocks are negative and statistically significant. Chow tests are insignificant, however, as coefficients on shocks in democracies have high standard errors.

In contrast to RR vs. non-RR countries, coefficients on structural variables seem to be statistically different, especially in case of terms-of-trade shocks. Imports do not seem to affect government revenue in democratic states, unlike in non-democracies, where the effect is large and significant. The coefficient on fuel exports is much bigger in democracies, and interestingly the coefficient on mineral exports is bigger and negative. The latter finding is diametrically opposed to the results from the higher-income countries, where the coefficient is much bigger and usually positive (see Appendix 6). One possible explanation could be that the stability of democratic rule is much lower in the group of lower-income countries compared to the higher-income group. As mining industries often operate with long amortisation and production periods, stability of political context factors may play a key role – independently of the regime characteristics.[18]

4.4.2. Interactions and revenue vulnerability

In this subsection we explore how the sensitivity of government revenue to external shocks depends on the position of a country prior to experiencing a shock. By position we mean not only the structural tax determinants that we used so far in this analysis, but also macroeconomic policies that the country pursues ahead of a shock. As explained in the methodology section, we do this with the help of interactions – variables of our interest (lagged one year) are interacted with the size of shock to see if they affect the sensitivity. Findings are reported in Table 17 to Table ***19***.

Results are generally similar for the three shocks we explore. The tables on ER pressure and terms-of-trade shocks both suggest that the importance of tight fiscal policy during good or normal times is high, while public debt does not seem to be important. Real exchange rate overvaluation and inflation (in case of RR countries and democracies) contribute to higher tax sensitivity. Interestingly, reserves reduce revenue sensitivity in case of terms-of-trade shocks, but not in the case of ER pressure. Results for natural disaster intensity are also similar to those for ER pressure.

We also run the regression specifications similar to Dabla-Norris / Bal Gündüz (2012) – we regress government revenue on policy and structural variables at the times when shocks are large (according to our definition). Results are reported in the Appendix 7, and they are generally in line with those when level shocks and interactions are used. Interestingly, the coefficient on public debt is negative and significant in case of terms-of-trade shocks, which suggests a non-linear relationship (the coefficient on debt-shock interaction in the main specification is practically zero, see Table 18).

[18] See Garcia / von Haldenwang (2011) for a similar argument referring to political regime type and tax revenue.

Table 17: Interactions: Exchange rate (ER) pressure shock on revenues in low- and lower-middle-income countries, fixed effects estimation

	All	RR	Non-RR	D	Non-D
Shock Level	-0.315	1.872	-0.528	0.497	-1.299
	(0.628)	(1.852)	(0.602)	(1.756)	(0.853)
Overvaluation of real ER, %	-0.0549	0.0612	0.0300	-0.108	-0.0443
	(0.0331)	(0.111)	(0.0444)	(0.0680)	(0.0399)
Overvaluation X shock	-0.0312**	0.00793	-0.0163	-0.0357	-0.0328
	(0.0130)	(0.0503)	(0.0151)	(0.0424)	(0.0196)
Structural balance (% potential GDP)	-0.0302	-0.584	-0.0914	0.0250	0.00899
	(0.180)	(0.602)	(0.231)	(0.362)	(0.249)
Structural balance X shock	-0.0882**	0.0854	-0.0577	-0.0798	-0.0677
	(0.0349)	(0.214)	(0.0347)	(0.154)	(0.0689)
Overall balance (% GDP)	-0.0758	0.708	0.0282	0.126	-0.247
	(0.189)	(0.835)	(0.262)	(0.349)	(0.270)
Overall balance X shock	0.130***	-0.0646	0.0859*	0.222	0.137*
	(0.0380)	(0.175)	(0.0466)	(0.129)	(0.0799)
Inflation	-0.00812	0.285	-0.0301	0.0938*	-0.135**
	(0.0394)	(0.258)	(0.0283)	(0.0476)	(0.0581)
Inflation X shock	-0.00427	0.0445	-0.0177	0.00294	-0.0188
	(0.0129)	(0.0466)	(0.0134)	(0.0225)	(0.0184)
Gross debt (% GDP)	0.0107	0.129**	0.0157	-0.0227	0.0226**
	(0.0150)	(0.0585)	(0.0129)	(0.0321)	(0.00971)
Gross debt X shock	0.000283	0.00794	-0.000451	-0.00895*	0.00550*
	(0.00253)	(0.0155)	(0.00145)	(0.00436)	(0.00297)
Central Bank international reserves	-0.0303	0.00108	0.0473	-0.0424	-0.00139
	(0.0347)	(0.0656)	(0.0472)	(0.0792)	(0.0397)
Reserves X shock	-0.0189**	-0.0162	0.0139	0.0180	-0.00887
	(0.00913)	(0.0186)	(0.0134)	(0.0207)	(0.00770)
Bureaucratic Quality	0.533	4.030**	-0.0950	-0.308	0.469
	(0.491)	(1.517)	(0.543)	(0.817)	(0.524)
Bureaucratic Quality X shock	-0.161	0.239	-0.0118	-0.102	-0.257*
	(0.112)	(0.340)	(0.102)	(0.213)	(0.144)
R-squared	0.300	0.512	0.648	0.343	0.507
Observations	459	178	281	217	242
Number of countries	39	18	21	22	28

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables include the variables of our main specification, as well as their interaction term with the shock level variable (not reported). Estimations for Fixed de-facto exchange rate, Index of Economic Freedom, Tax Effort, Resource Rich dummy and constant are also not reported. RR = Resource-rich D= Democracy.*

Table 18: Interactions: Terms-of-trade shock on revenues in low- and lower-middle-income countries, fixed effects estimation

	All	RR	Non-RR	D	Non-D
Shock Level	2.797	-10.06	7.938	-36.26	11.75*
	(6.026)	(14.73)	(9.037)	(30.90)	(5.949)
Overvaluation of real ER, %	-0.0132	-0.0263	0.0327	0.106	-0.0561
	(0.0339)	(0.135)	(0.0289)	(0.0826)	(0.0428)
Overvaluation X shock	-0.177	0.0265	-0.136	-0.874*	0.217
	(0.248)	(0.459)	(0.235)	(0.435)	(0.186)
Structural balance (% potential GDP)	-0.0586	-0.629	0.0291	0.480	-0.0437
	(0.181)	(0.862)	(0.130)	(0.457)	(0.230)
Structural balance X shock	-0.548	-0.185	0.143	-4.178**	-0.0577
	(0.754)	(1.546)	(0.817)	(1.550)	(0.889)
Overall balance (% GDP)	-0.240	0.541	-0.0973	-0.690	-0.267
	(0.195)	(0.852)	(0.106)	(0.553)	(0.213)
Overall balance X shock	1.457*	1.290	-0.348	6.128**	0.118
	(0.796)	(1.561)	(0.908)	(2.907)	(0.840)
Inflation	-0.0299	0.257	-0.0488	0.138	-0.198***
	(0.0466)	(0.180)	(0.0341)	(0.127)	(0.0344)
Inflation X shock	0.101	-0.409	0.345	-0.557	0.303
	(0.161)	(0.358)	(0.206)	(0.496)	(0.190)
Gross debt (% GDP)	0.00960	0.102	-0.00117	0.00460	0.0113
	(0.0184)	(0.0653)	(0.0122)	(0.0815)	(0.0144)
Gross debt X shock	0.0116	0.103	-0.0197	0.0139	0.0384
	(0.0507)	(0.111)	(0.0473)	(0.421)	(0.0501)
Central Bank international reserves	-0.0342	-0.0356	0.0424	-0.142	-0.0697*
	(0.0338)	(0.0927)	(0.0532)	(0.139)	(0.0383)
Reserves X shock	0.322**	0.107	0.129	0.600	0.0289
	(0.136)	(0.235)	(0.154)	(0.600)	(0.129)
Bureaucratic Quality	-0.487	-2.529	-1.774	0.215	-1.198
	(1.795)	(2.850)	(1.679)	(9.524)	(1.766)
Bureaucratic Quality X shock	-0.596	0.438	-0.512	-0.685	-0.317
	(0.736)	(2.754)	(0.434)	(3.865)	(0.899)
R-squared	0.333	0.564	0.659	0.389	0.567
Observations	449	168	281	217	232
Number of id	39	18	21	22	28

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables include the variables of our main specification, as well as their interaction term with the shock level variable (not reported). Estimations for Fixed de-facto exchange rate, Index of Economic Freedom, Tax Effort, Resource Rich dummy and constant are also not reported. RR = Resource-rich D= Democracy.*

Table 19: Interactions: Natural disasters intensity shock on revenues in low- and lower-middle-income countries, fixed effects estimation

	All	RR	Non-RR	D	Non-D
Shock Level	-133.3**	-2509	-39.71	213.7	-243.5
	(62.00)	(2129)	(73.97)	(269.2)	(159.9)
Overvaluation of real ER, %	-0.0117	0.0923	0.0236	-0.0174	-0.0796**
	(0.0289)	(0.0996)	(0.0248)	(0.0931)	(0.0352)
Overvaluation X shock	2.398	2.799	-0.131	8.195	0.576
	(2.079)	(12.27)	(1.398)	(6.980)	(1.673)
Structural balance (% potential GDP)	0.0382	-1.285	-0.0799	-0.401	0.0790
	(0.169)	(1.345)	(0.136)	(0.307)	(0.247)
Structural balance X shock	19.47	-140.0	-16.48	8.935	13.28
	(12.52)	(146.9)	(11.19)	(34.24)	(16.83)
Overall balance (% GDP)	-0.193	1.283	0.00464	0.400	-0.297
	(0.217)	(1.315)	(0.121)	(0.488)	(0.228)
Overall balance X shock	-13.03	135.4	16.73	0.982	5.362
	(12.93)	(134.6)	(9.791)	(40.53)	(16.15)
Inflation	-0.00812	-0.215	-0.0193	0.0188	-0.110
	(0.0301)	(0.293)	(0.0386)	(0.0562)	(0.0700)
Inflation X shock	-2.264*	-53.27	-2.443*	1.934	-2.613
	(1.181)	(47.99)	(1.414)	(5.650)	(2.333)
Gross debt (% GDP)	0.0199	0.105**	0.000163	-0.00782	0.0216
	(0.0191)	(0.0404)	(0.0115)	(0.0419)	(0.0162)
Gross debt X shock	0.868	-1.384	-0.294	4.116	0.708
	(0.566)	(6.009)	(0.383)	(2.622)	(0.809)
Central Bank international reserves	-0.0342	-0.0356	0.0424	-0.142	-0.0697*
	(0.0338)	(0.0927)	(0.0532)	(0.139)	(0.0383)
Reserves X shock	0.000403	0.00501	0.0437	-0.0987	-0.0101
	(0.0372)	(0.0956)	(0.0524)	(0.112)	(0.0291)
Bureaucratic Quality	0.394	4.027	0.259	-0.930	1.420
	(0.556)	(2.565)	(0.348)	(1.329)	(0.858)
Bureaucratic Quality X shock	10.49	37.70	6.576	124.9	62.64
	(29.18)	(284.3)	(25.77)	(85.49)	(61.00)
R-squared	0.272	0.487	0.631	0.318	0.457
Observations	459	178	281	217	242
Number of id	39	18	21	22	28

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables include the variables of our main specification, as well as their interaction term with the shock level variable (not reported). Estimations for Fixed de-facto exchange rate, Index of Economic Freedom, Tax Effort, Resource Rich dummy and constant are also not reported. RR = Resource-rich D= Democracy.*

Only restricted inference can be drawn from tables including interaction terms (Brambor / Clark / Golder 2006) and results are not easy to interpret. Yet, the findings are not only highly suggestive, but they also enable us to explore more in detail the factors driving revenue vulnerability to external shocks. In principle it is possible to build an index of tax revenue vulnerability (RVI) based on the regressions with interactions introduced above. The index would link government revenue to the policies, structural tax determinants and exposure to exogenous shocks of a country in the previous year. The RVI is simply defined as a projected percentage decline of government revenue as a result of an adverse external shock, based on the estimations in the preceding paragraphs. It can be calculated for each of the three shocks – ER pressure, terms of trade, natural disaster intensity – by using regression estimations on the whole sample as well as on subsets defined by natural resource endowments and political regimes:

1) Calculate the cumulative effect of a shock on government revenue using the following formula:

$$CE_{it} = \beta_0 + \sum_j \beta_j x^j_{i,t-1},$$

where β_0 is the coefficient on shock in one of the regressions in Table 17 to Table ***19***; $x^j_{i,t-1}$ - is the value of the j's policy or structural variable in country i, period t-1; β_j is the coefficient on interaction of this policy variable with the shock.

2) Calculate the projected revenue drop because of an adverse shock. The adverse shock ($Shock_{it}$) can be defined as 90th percentile of a country-specific shock distribution over a certain period of time. The idea is to check how vulnerable the country is to a large, yet possible adverse event (for instance, since the maximum ER pressure in Colombia over the last ten years was 2.2, it does not make sense to test Colombia's vulnerability to ER pressure shocks of a size larger than 2.2). We use the following formula:

$$revdrop_{it} = CE_{it} * Shock_{it}$$

3) Then the RVI is calculated using the following formula:

$$RVI_{it} = -\frac{revdrop_{it}}{rev_{i,t-1}},$$

where $rev_{i,t-1}$ is government revenue in period t-1.[19]

4.4.3. Data-driven grouping methods

We use data-driven clustering methods to check whether there are relevant shock-related patterns not covered by our pre-defined groups of countries (income, natural resource endowments and political regime). In particular, we run Finite Mixture Models regressions, where the specification is similar to the one introduced in Section 4.2. To make the analysis more compact, we aggregate our three shocks into one, and we analyze only large shocks (as defined in Section 3.3). The aggregate large shock is equal to one if at least one of the shocks is one; otherwise it is zero. We also demean all variables before running FMM, which enables us to control for their long-run averages, similar to a FE estimation.[20]

[19] Note that the RVI can theoretically vary from minus infinity (large increases of revenue as a result of adverse shock) to 1 (revenue is projected to decline to zero). The negative values of RVI can be due to three reasons. First, some countries may have experienced only favourable shocks in the preceding period, so even for the 90th percentile of the shock distribution *revdrop_it* may turn out to be negative. Second, for some countries in some years an adverse external shock may actually be beneficial (i.e. *CE_it*>0). This may happen if an economy is above its potential, and the shock would neutralize the main source of distortions (for instance, aggregate demand driven up by expansionary fiscal policy and adjusted by a terms-of-trade shock, which would decrease net exports). Third, the RVI can be negative because of the statistical error in the estimation, as most of our estimates are quite imprecise. In practice, we do get several negative values, but they are usually very close to zero (which would be explained by the third reason), except for a few countries.

[20] Without demeaning FMMs produce reasonable but hardly useful results. For instance, HICs and LICs are grouped together as the former usually are low-shock and high-revenue, and the latter are high-shock and low-revenue, so the OLS regression on these two groups combined would produce the most significant results.

Table 20: 2- and 4-component Finite Mixture Models, all countries

	2 Components		4 Components			
	(1)	(2)	(1)	(2)	(3)	(4)
Large Shock	-0.656*	-1.676	0.534	-1.709	-9.334***	-0.603
	(0.369)	(1.284)	(0.427)	(1.310)	(0.606)	(0.389)
Agricultural Exports (% GDP)	-0.0230	0.00815	-0.406**	0.0853	0.740***	0.0249
	(0.0506)	(0.399)	(0.206)	(0.679)	(0.0356)	(0.0797)
Mineral Exports (% GDP)	0.119	-0.0759	0.456	-0.242	0.742***	-0.0960
	(0.0929)	(0.305)	(0.308)	(1.704)	(0.0864)	(0.209)
Manufacturing Exports (% GDP)	-0.0883***	-0.344	-0.0389	-0.354	-0.385***	-0.133***
	(0.0290)	(0.334)	(0.0514)	(0.586)	(0.0385)	(0.0331)
Imports (%GDP)	0.0796**	0.0612	0.0598*	-0.0597	0.472***	0.131***
	(0.0338)	(0.375)	(0.0352)	(0.295)	(0.0288)	(0.0311)
Fuel Exports (% GDP)	0.0743	0.775	-0.120	0.784	0.282***	0.382***
	(0.136)	(0.501)	(0.0794)	(0.720)	(0.0399)	(0.115)
Agriculture, Value Added (% GDP)	-0.0390	-0.590	-0.0240	-0.824	0.299***	-0.128
	(0.0505)	(0.473)	(0.0237)	(0.592)	(0.0386)	(0.0817)
GDP per capita (in logs)	1.585	-0.598	-6.146**	-1.397	7.855***	2.572**
	(1.172)	(5.953)	(2.727)	(11.15)	(0.666)	(1.123)
Constant	-0.222	0.893	0.745*	0.909	0.582***	-0.726**
	(0.189)	(1.721)	(0.399)	(2.205)	(0.220)	(0.288)
Posterior probability, all	0.853	0.148	0.246	0.100	0.052	0.602
Posterior probability, high- and upper-middle-income	0.846	0.154	0.252	0.109	0.051	0.589
posterior probability, non-RR	0.860	0.140	0.257	0.095	0.053	0.595
posterior probability, non-democracy	0.851	0.149	0.251	0.096	0.054	0.599

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Single large shock = 1 if at least one of three shocks (ER pressure large, log terms of trade large, natural disaster intensity large) is equal to 1. Number of observations: 1891.*

Results of FMM regressions on all countries are reported in Table 20. We present two- and four-component models, which means that we start the analysis by assuming that there are two or four distinct groups of countries. Given the large amount of variables included and the panel structure of our data (none of which is typical for data-driven clustering), the results of the estimation do not lend themselves to easy interpretation. Nevertheless, several conclusions can be drawn. The two-component model breaks our sample into two fairly different groups. The difference between these groups resembles in some aspects the difference between higher- and lower-income countries, where the first group would represent those with lower income. A notable exception refers to the effect of fuel exports, which is typically larger and more significant for lower-income countries in our main specification. The shock seems to play a more important role in the first group – the point estimate is lower than in group two, but the statistical significance is much higher. Imports increase revenue and are highly significant, unlike in group two (and unlike the group of higher-income countries). Manufacturing exports decrease revenue, which is not the case in group two – again, similar to lower- vs. higher-income countries. Other structural variables (e.g. GPD per capita, agricultural value added) also behave similarly.

To analyze the composition of the groups formally, we look at the average posterior probabilities of countries belonging to either of them. For all countries, the average probability of belonging to the first group is about 83.5%, making it much bigger than the second group. Among higher-income countries this probability diminishes to 82.5%, which means that richer countries are slightly more likely to belong to the second group. Democracies and non-democracies seem to be split among the groups

equally (the average probability of a non-democracy to belong to the first group is 83.3%), whereas resource-rich countries seem to congregate more in the second group (the probability of a non-RR country to belong to the first group is 84.4%). The coefficient on fuel exports is higher and more significant in group two, which could also point to RR countries being clustered in this group. The difference between the average probabilities in different groups is very small though – there are higher-income or RR countries with very high probabilities of belonging to the first group.

The four component FMM model produces one large group (the average probability of belonging to this group is 66%), and three smaller ones. The large group resembles the component 1 in the two-component FMM and the lower-income group in our main specification: the coefficient estimates are fairly similar. From the posterior probability distribution it follows that the group is populated by lower-income countries, RR or non-RR, and mostly non-democracies. Group 2 seems to be disproportionately populated by higher-income RR countries; its coefficients are fairly similar to group two in the two-component FMM. Groups 3 and 4 seem to be composed of democracies – either lower-income and RR (group 3) or higher-income (group 4). Regarding the effects of shocks, the four groups tell different stories. In the case of group 4, comprising one-fifth of the total sample, large shocks actually increase revenue. For group 3, the effect of shocks is particularly strong and significant while the effect of mineral exports is remarkably positive and equally significant. This group, however, is quite small, comprising less than 5 per cent of the observations.

Table 21 reports results from FMM on lower-income countries only. Again, we explore two- and four-components models. The two-components model generates one very large group (unconditional average posterior probability is 93%), and another much smaller one. The results in the smaller group resemble those of lower-income democracies from section 4.2: the effect of shocks is not articulate, nor are imports (the effect of manufacturing, however, is different, see Table 16). This conjecture is supported by the distribution of posterior probabilities: non-democracies are disproportionately placed in group two. The four-components model seems to separate countries not only by political regime, but also by resource endowment. It generates a large group of countries (group 4) with a high proportion of non-democracies and non-RRs with coefficient estimates similar to group two in the two-component model. Groups 2 and 3 seem to be populated by democracies, group 2 has probably a high representation of RR countries. Again, there is one group (group 3) with a positive effect of shocks on revenue.

Table 21: 2- and 4-components Finite Mixture Models, low- and lower-middle-income countries

	2 Components		4 Components			
	(1)	(2)	(1)	(2)	(3)	(4)
Large Shock	11.59***	-0.972***	11.50***	0.943	0.539	-1.851***
	(0.600)	(0.325)	(2.138)	(0.650)	(0.432)	(0.503)
Agricultural Exports (% GDP)	0.376***	0.00576	0.368	-0.0910	0.205***	0.0680
	(0.114)	(0.0494)	(0.272)	(0.131)	(0.0392)	(0.0829)
Mineral Exports (% GDP)	-6.631***	-0.0661	-6.640***	0.451*	-0.0229	-0.247
	(0.0593)	(0.104)	(0.108)	(0.256)	(0.0435)	(0.177)
Manufacturing Exports (% GDP)	-0.293***	-0.152***	-0.283	-0.155***	-0.107***	-0.189***
	(0.0347)	(0.0314)	(0.175)	(0.0340)	(0.0173)	(0.0436)
Imports (% GDP)	1.927***	0.177***	1.927***	0.191***	0.156***	0.171***
	(0.0201)	(0.0278)	(0.0290)	(0.0413)	(0.0199)	(0.0392)
Fuel Exports (% GDP)	0.731***	0.270***	0.723***	-0.208	0.063***	0.509***
	(0.0406)	(0.0910)	(0.159)	(0.159)	(0.0182)	(0.120)
Agriculture, Value Added (% GDP)	-4.819***	-0.0607	-4.807***	0.00815	-0.0434**	-0.180**
	(0.0464)	(0.0545)	(0.226)	(0.0187)	(0.0177)	(0.0796)
GDP per capita (in logs)	6.019***	0.383	6.219**	-7.123***	3.668***	1.988
	(0.647)	(1.522)	(3.144)	(0.955)	(0.574)	(2.080)
Constant	5.734***	-0.350*	5.792***	0.280	-0.613**	-0.642**
	(0.227)	(0.191)	(1.075)	(0.279)	(0.247)	(0.304)
posterior probability, all	0.007	0.993	0.007	0.218	0.131	0.643
posterior probability, non-RR	0.005	0.995	0.005	0.227	0.129	0.639
posterior probability, non-democracy	0.01	0.99	0.009	0.223	0.131	0.637

*Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Single large shock = 1 if at least one of three shocks (ER pressure large, log terms of trade large, natural disaster intensity large) is equal to 1. All variables are demeaned. Non-RR = Non-resource-rich. Number of observations: 1032.*

Applying FMM further down the ladder of our predefined grouping, Table 22 presents the results of two-component FMMs ran on RR/non-RR countries and non-democracies. In all three groups of countries FMMs produce dominant components (with posterior probability of around 0.9). The estimated coefficients of the dominant components are close to what we get by running FE regression on the corresponding group (see Tables 15 and 16). The posterior probabilities in the larger components are close to or above 95 per cent. The second components in these groups of countries seem to be the sets of outliers,[21] which nevertheless may have an influence on results when we pool all countries together. For instance, the negative coefficient on mineral exports among RR countries (Table 15) seems to be driven by the countries belonging to the corresponding smaller FMM component. These findings should be read with a certain amount of caution, however, as the subsets are quite small. A further breakdown of large components in each group (e.g. through three-, four-, and more-component FMMs) would perhaps reveal more structured patterns, but this approach is hardly feasible under given data availability.

To conclude, FMM regressions supported our initial logic of dividing countries according to income, resource-richness, and democratic regime. The distributions of *a posteriori* probabilities and the similarity of regression results by component to regression results in predefined groups are the main arguments. Data-driven clustering methods are fuzzy, however (i.e. the division on components is never exactly the same as in predefined groups – actually, it is often far from it). In particular, the FMM analysis on lower-income countries divided by resource endowments and political regime reveals that there is scope for further analysis, but it would require a larger amount of data and resources.

[21] Judging from the predicted country-specific posterior probabilities, among the RR countries, Bolivia and Yemen are the outliers belonging to the first component. Among democracies, the outliers include Colombia and, again, Bolivia.

Table 22: 2-Components Finite Mixture Models, low- and lower-middle-income countries, grouped by resource endowment and political regime

	Resource-rich		Non-resource-rich		Non-democracies	
	Comp.1	Comp.2	Comp.1	Comp.2	Comp.1	Comp.2
Large Shock	-0.175	9.335***	-0.993***	-3.998***	-1.354***	-15.15***
	(0.478)	(0.234)	(0.280)	(0.00646)	(0.330)	(2.017)
Agricultural Exports (% GDP)	0.130	0.925***	-0.0153	-0.165***	-0.0540	-4.729***
	(0.0875)	(0.0458)	(0.0379)	(0.00149)	(0.0527)	(0.512)
Mineral Exports (% GDP)	-0.127	1.152***	-0.138	0.582***	-0.0277	-0.238
	(0.0823)	(0.0444)	(0.162)	(0.00551)	(0.0813)	(0.318)
Manufacturing Exports (% GDP)	-0.255***	-4.954***	-0.138***	-0.447***	-0.146***	-0.809***
	(0.0743)	(0.0467)	(0.0242)	(0.000774)	(0.0307)	(0.137)
Imports (% DP)	0.121***	3.071***	0.204***	-0.382***	0.172***	0.617***
	(0.0322)	(0.0195)	(0.0186)	(0.000566)	(0.0226)	(0.107)
Fuel Exports (% GDP)	0.318***	0.0254	0.247***	4.404***	0.116**	0.904***
	(0.0516)	(0.0246)	(0.0864)	(0.00228)	(0.0532)	(0.133)
Agriculture, Value Added (% GDP)	-0.248***	-3.655***	0.00139	-0.569***	-0.117***	-1.299***
	(0.0491)	(0.0264)	(0.0233)	(0.000674)	(0.0363)	(0.282)
GDP per capita (in logs)	2.015	-1.966***	0.463	4.965***	-2.273***	-21.84***
	(1.334)	(0.506)	(0.637)	(0.0163)	(0.799)	(4.075)
Constant	-0.730***	9.371***	-0.293**	2.795***	-0.432***	1.747*
	(0.204)	(0.102)	(0.122)	(0.00469)	(0.147)	(0.991)
Posterior probability	0.040	0.960	0.983	0.017	0.947	0.053
Observations	319		713		622	

*Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Single large shock = 1 if at least one of three shocks (ER pressure large, log terms of trade large, natural disaster intensity large) is equal to 1. All variables demeaned. Estimation of FMM parameters for democracies did not yield stable results for all specifications tested. Consequently, we do not report coefficient estimates on this set of countries.*

4.5. Types of taxes

To identify possible channels through which external shocks act on government revenue, we run regressions with various types of revenue as dependent variables. Four types of government revenue are analyzed – non-tax revenue, trade taxes, sales taxes and income taxes. For each type of revenue we consider the same three shocks as in the preceding sections – ER pressure, terms of trade and natural disaster intensity. Regressions are run on a pooled sample of all low- and lower-middle-income countries; results are reported in Table 23. We also split the sample of lower-income countries with regard to resource endowments and political regime; the results are reported in Appendix 8.

The findings indeed suggest that different shocks act on government revenue through different channels, although most of the results are not statistically significant. As it appears, even within the lower-income group the effects of shocks on tax types can be quite divergent. This is corroborated by looking at the sample subsets (RR vs. non-RR countries and democracies vs. non-democracies) in Appendix 8, which do reveal different "stories". However, small sample sizes in combination with limited data access and quality lead to fuzzy results in most cases.

- For the whole sample of lower-income countries, ER pressure has a significant negative effect on trade and income tax. In contrast, its effect is negative yet not significant on indirect taxes (goods and services tax), and practically zero on non-tax revenue. Looking at individual country groups, the effect of ER pressure shocks on trade and income tax is negative in all four subsets of the sample, but particularly strong and significant in non-democratic as well as in non-resource-rich countries. Apparently, these groups experience more difficulties in absorbing the impact of ER pressure and terms of trade shocks. The effect on sales tax is negative in all four subsets, but strong and (weakly) significant only in the group of democratic countries. The point estimates for non-tax revenue are especially high (though far from significant) in the group of RR countries.

- Terms-of-trade shocks have significant negative effects on non-tax revenue. The reason is perhaps that these shocks are likely to reduce profits of public enterprises that act as commodity exporters. The effect is negative and significant for all sub-groups except democracies, but stronger for non-resource-rich compared to resource-rich countries. Terms-of-trade shocks also affect income tax revenue, although the coefficient is not significant. In this case, coefficients for resource-rich and democratic countries are positive, whereas they are negative in the other two groups. However, only the negative effect on non-resource-rich countries is weakly significant. As for trade and sales taxes, the effect is practically zero. In the case of the latter, this is probably the reflection of the fact that sales taxes are usually unit-elastic with respect to output, and the sales tax rates on imports and domestic goods are usually the same. For the former, this is likely the evidence of reduced tax revenue from exports being substituted by increased tax revenue from imports. Regarding trade tax, the point estimates of terms-of-trade shocks are positive in three of four groups (exception: non-resource-rich countries), but the findings are very weak in statistical terms.

- Natural disaster intensity affects mostly trade and income taxes, although the coefficient is not significant in any specification. One interesting finding, however, refers to the fact that the point estimates regarding the effect on the sales tax are negative and weakly significant in non-resource-rich countries and positive (yet insignificant) in the other group. This could indicate a higher resilience towards the adverse impacts of natural disasters in resource-rich countries.

Comparing the effects of ER pressure as well as terms-of-trade shocks on income tax in democratic and non-democratic countries reveals slightly different pictures. Both shocks affect income tax negatively in non-democratic countries, with significant results for ER pressure. In contrast, results are insignificant in democratic countries and the coefficient of terms-of-trade shocks is even positive. This could point to a greater capacity of democratic countries to increase revenue collection in the face of exogenous shocks. In general terms it can be said that income tax and non-tax revenue seem to be most sensitive to external shocks, while indirect (sales) taxes appear to be the most stable revenue source.

Estimated coefficients on our structural tax determinants also reveal interesting patterns (see Table 23). For instance, the negative coefficient on manufacturing exports seems to be driven solely by non-tax revenue and trade taxes, while the negative coefficient of mineral exports is driven primarily by the sales tax. In contrast, imports are important for all types of taxes. Higher levels of welfare (measured

by GDP per capita), even within one country, are associated with smaller non-tax revenue and higher income taxes – a pattern that is easy to notice in the cross-section of countries. The positive effect on income taxes is especially strong in democratic and non-resource-rich countries, corroborating existing empirical evidence.

Table 23: Effects of shocks on different revenue types of low- and lower-middle-income countries, fixed effects estimation

	Non-tax revenue			Trade tax			Goods and services tax			Income tax		
Shocks	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Shock Level	-0.0275	-2.777***	0.403	-0.0405***	0.0535	-1.827	-0.0267	-0.303	0.00568	-0.0562***	-0.624	-2.277
	(0.0525)	(0.891)	(2.953)	(0.0148)	(0.372)	(1.825)	(0.0209)	(0.733)	(1.995)	(0.0176)	(0.661)	(1.965)
Agricultural Exports (% GDP)	-0.0212	-0.0391	-0.0268	-0.0158	0.00454	0.00564	0.00944	0.0206	0.0163	-0.00307	-0.0206	0.00327
	(0.0429)	(0.0439)	(0.0431)	(0.0267)	(0.0366)	(0.0315)	(0.0270)	(0.0230)	(0.0267)	(0.0232)	(0.0193)	(0.0230)
Mineral Exports (% GDP)	-0.122	-0.157*	-0.108	-0.0249	0.000973	-0.00673	-0.0552	-0.0878**	-0.0482	0.0512	0.00994	0.0386
	(0.0993)	(0.0903)	(0.0838)	(0.0215)	(0.0233)	(0.0208)	(0.0506)	(0.0412)	(0.0429)	(0.0460)	(0.0480)	(0.0431)
Manufacturing Exports (% GDP)	-0.0193	-0.0366	-0.0290	-0.0510***	-0.0483***	-0.0507***	-0.0296	-0.0362	-0.0335	-0.0324*	-0.0381**	-0.0309*
	(0.0349)	(0.0326)	(0.0353)	(0.0140)	(0.0161)	(0.0150)	(0.0246)	(0.0249)	(0.0243)	(0.0167)	(0.0165)	(0.0163)
Imports (% GDP)	0.0820***	0.0868***	0.0774***	0.0315***	0.0237	0.0259**	0.0288*	0.0318*	0.0272*	0.0383***	0.0430***	0.0393***
	(0.0222)	(0.0221)	(0.0226)	(0.00966)	(0.0149)	(0.0124)	(0.0165)	(0.0161)	(0.0156)	(0.0130)	(0.0132)	(0.0123)
Fuel Exports (% GDP)	0.142	0.136	0.141	0.0232	0.00814	0.0248	0.0304	0.110	0.0404	0.101	0.0753	0.106
	(0.0998)	(0.0822)	(0.0929)	(0.0225)	(0.0309)	(0.0206)	(0.0701)	(0.0924)	(0.0645)	(0.0834)	(0.0999)	(0.0822)
Agriculture, Value Added (% GDP)	-0.0255	-0.00471	-0.0323	-0.0131	-0.0153	-0.0137	-0.0165	-0.00648	-0.0188	-0.0214	-0.0247*	-0.0231
	(0.0491)	(0.0378)	(0.0504)	(0.0125)	(0.0151)	(0.0136)	(0.0185)	(0.0136)	(0.0189)	(0.0140)	(0.0129)	(0.0145)
GDP per capita (in logs)	-3.340*	-3.503*	-3.423*	0.0383	-0.0151	0.173	1.440	1.524	1.488	1.812*	1.346	1.763*
	(1.920)	(1.872)	(1.740)	(0.474)	(0.567)	(0.457)	(1.098)	(1.101)	(1.013)	(0.957)	(0.962)	(0.992)
Constant	29.17**	29.40**	30.06**	1.682	2.168	0.818	-2.503	-3.507	-2.828	-8.119	-4.609	-7.856
	(13.85)	(13.35)	(12.57)	(3.393)	(3.994)	(3.232)	(7.855)	(7.780)	(7.242)	(6.603)	(6.471)	(6.815)
R-squared	0.116	0.152	0.118	0.311	0.299	0.285	0.285	0.334	0.299	0.152	0.130	0.157
Observations	1066	999	1138	1194	1132	1270	1193	1133	1270	1197	1134	1273
No. of Countries	89	87	93	95	90	97	94	90	96	95	90	98

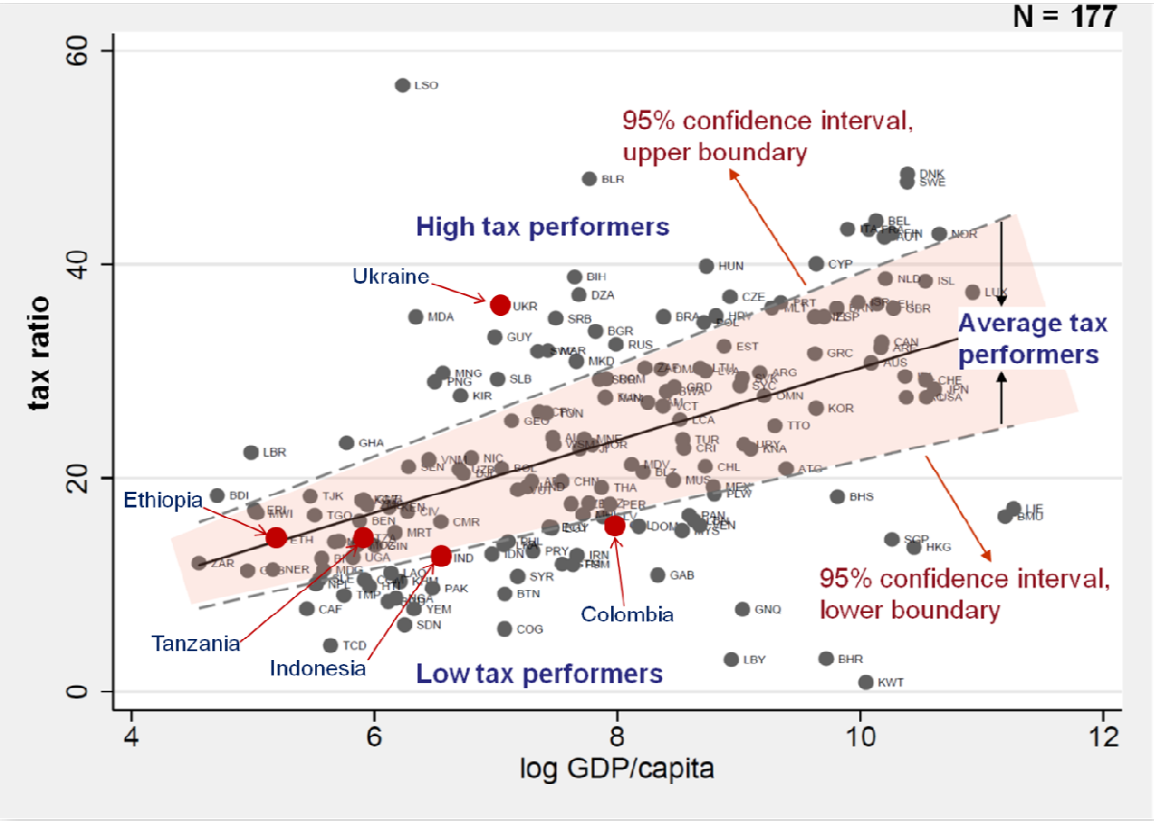
*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. (1)= Exchange Rate Pressure (2)= Terms of Trade (in logs) (3)= Intensity of Natural Disasters.*

5. Summary of country case studies

The case studies analyse the driving forces of fiscal dynamics in developing countries in order to understand constraints and leverage points for strengthening the resilience of tax revenue to external shocks as well the short and long term effect of shocks. In addition, the aim of the case studies is to analyse the fiscal dynamics in countries belonging to different income groups. We employ a VAR approach to model the equilibrium values of the main fiscal variables and identify the factors driving the existing relationship.

According to the TORs, the case studies should be selected with a view to covering the spectrum of the three pre-defined subsets of countries i.e. low income, lower-middle income and resource-rich countries. At the same time, they should present a geographically diversified set of cases, covering the main developing regions. Against this background, cases will include one Latin American country – Colombia, two African countries – Ethiopia and Tanzania, one Asian country – Indonesia and one Eastern European country – Ukraine. Of these, Colombia, Indonesia and Ukraine are lower-middle-income countries, while Ethiopia and Tanzania are low-income countries.[22] Indonesia and Tanzania are considered resource-rich countries. Colombia, Ukraine (in part) and Indonesia (in part) classify as democratic regimes. One country, Ukraine, can be considered a high tax performer in 2007-2008. The two African countries are average performers, whereas Indonesia and Colombia are low tax performers (see Figure 4).

Figure 4: Tax performance of case study countries, 2007-2008



Source: von Haldenwang / Ivanyna (2012)

It is important to note that in comparison to the cross-country analysis, the country case studies include a more limited number of variables because of the requirements of time series econometric aproaches. A minimum requirement is that we have annual observations over a reasonably long pe-

[22] As of 2007. Colombia became an upper-middle-income country in 2008.

riod (ideally more than 30 years) and there is variation over time in the variables. Thus, for example, variables such as agriculture or industry shares in GDP (that tend to evolve very slowly) and governance or institutional indicators (that tend to change infrequently even if observed annually) are not suitable. The data used in the cross-country analysis, that form the basis for the country studies, are short in a time series context, at best about 30 years from 1981 but shorter for Ukraine. Consequently we focus narrowly on the fiscal relationship between tax revenue and government expenditure (including ODA where relevant). Restricting the analysis to the fiscal relationship allows us to exploit a long time series (1966 – 2012) for Tanzania, and to make most use of the relatively limited time series for the other countries.

Restricting attention to the fiscal relationship has a number of advantages for our purposes. First, we can analyse the behaviour of tax revenue over time, in particular how it responds to a shock. Secondly, we can explore the relationship between tax and spending, and draw inferences for broader effects of shocks on the economy. Thirdly, the fiscal relationship is suited to analysis using the Vector Autoregressive (VAR) approach. The basis of our VAR approach is identifying the long-run equilibrium relationship between the variables of interest and then analysing how they respond to perturbations of the equilibrium. As there will be an equilibrium between revenue and spending in the long run (a deficit cannot be permanently increasing) we anticipate that spending revenue (tax and, if appropriate, aid) will be cointegrated and test explicitly for this. If we find cointegration (which we do in all cases) there is a relationship between spending and revenue and we can analyse this, including the response to shocks (to any of the variables). Furthermore, the cointegrated relationship is robust to omitting other variables. This does not imply that other variables are unimportant (e.g. it may be other variables that 'cause' a shock to revenue) but does mean we can analyse the fiscal relationship alone.

We conducted VAR analysis for all five countries mentioned above. We obtained similar results for the two LICs (Ethiopia and Tanzania) that differed from the (similar to each other) results for the two MICs (Colombia and Ukraine), and discuss these separately. The results for Indonesia were somewhat different to those for the LICs and MICs, which may reflect the fact that in terms of income and economic structure Indonesia is intermediate between the pairs of LICs and MICs. At the same time, access to data was more limited in Indonesia compared to the other cases.

Low income countries (LICs)

As aid is an important source of revenue for LICs the fiscal relationship comprised aid, tax revenue and government spending and these variables were found to cointegrate. The analysis showed that tax revenue in Ethiopia and Tanzania is not resilient and is slow to recover from a shock. Tax revenue is the fiscal driver, i.e. spending responds to tax revenue (and spending adjusts to fiscal disequilibrium) but revenue does not respond to the other variables. Aid also appears to respond to tax and, like spending, aid can adjust to disequilibrium. Observing that tax revenue is not a responsive variable, i.e. an increase in spending does not induce an increase in tax, implies that the government is unable to alter tax revenue in the short to medium run to adjust to a fiscal disequilibrium (such as a shortfall in aid or unanticipated increase in spending).

Changes in tax revenue do impact on spending. A shock to tax has a permanent effect, so a negative shock to tax revenue will reduce spending. This reduction in spending, especially if it affects investment, is a mechanism that transmits the tax shock to an adverse effect on the economy. As aid responds to changes in tax there may be an increase in aid, although this does not fully offset the reduction in spending. As tax is not responsive and the shock to tax has a permanent effect (including on tax) we can conclude that revenue is not resilient in LICs. The main policy implication is that because it takes time (and economic growth to generate a more diverse tax base) to build a resilient tax system, in the short to medium term LICs experiencing shocks will require assistance (aid) to compensate for the effects of lower tax revenue.

Middle income countries (MICs)

The two MICs (Colombia and Ukraine) appear to have resilient tax systems. Tax revenue is a responsive variable, implying that the government has the ability to alter tax revenue to adjust to a fiscal disequilibrium; increases in spending appear to be followed by increases in tax. Furthermore, a shock to tax has only a transitory effect; although a decline in tax will induce reductions in spending, revenue recovers fairly quickly and so does spending. It transpires that spending is the fiscal driver: govern-

ments are able to make spending decisions with some confidence that they can raise the required revenues (and that tax recovers from shocks).

Overall, the results suggest there is a point of transition: at low levels of income, tax revenue is stagnant and unresponsive but beyond some level of development tax becomes a policy variable amenable to short term influence. This transition is likely to reflect the emergence of a broad and buoyant tax base in the middle terms and access to international capital markets in the short term. Tax systems in LICs lack resilience because the tax base is narrow and overly reliant on resources and large taxpayers that can be difficult to tax. As economies grow and diversify to become MICs the fundamental tax base (private wage employment and private consumption) expands and revenue becomes resilient. Supporting LICs in making this transition is the perennial development challenge.

6. Conclusions and recommendations

The main purpose of the present study was to provide empirical evidence on the vulnerability or resilience of tax revenue facing exogenous shocks. Research on developing countries in general and on public finance in particular is confronted with limited data coverage and sometimes questionable data quality.[23] Even though in recent years many countries have made important progress in generating information and providing data, reflecting technological progress as well as international initiatives in this field, challenges still persist. These affect above all those countries that are most relevant from a development perspective, i.e. the poorest and most fragile countries. However, in the context of empirical methods demanding long time series the problems of poor or unavailable data extend to other countries as well. For many countries data from past decades are not easily available and even in those cases where they exist their consistency and comparability is sometimes undermined by changing rules for accounting and reporting.

The approach chosen in this study deals with these challenges by using parsimonious estimation methods and conservative standard errors. This necessarily raises the bar for achieving statistical significance and may lead to less appealing results in some instances, but it increases the robustness of findings as well as the credibility of the messages deduced from them and presented in the following paragraphs. Concerns about endogenity are certainly a major issue in many of the models presented in this study. Therefore the results should be read as identifying statistical relationships and not necessarily causal links. Where causal relationships are suggested, they are plausible to expect and theoretically grounded but due to data limitations we cannot test them properly.

Looking at **tax performance**, it becomes evident that splitting the sample into two subsets according to income groups (high- and higher-middle-income countries vs. low- and lower-middle-income countries) produces two different “stories” on tax performance. This is in line with previous research findings reported in the literature (for instance, see Teera / Hudson 2004; Gupta 2007; Profeta / Scabrosetti 2010). Perhaps less explored in the literature so far, however, is the differentiated impact of imports and various kinds of exports. Typically, research on tax effort in developing countries uses one single trade openness measure (lumping exports and imports) combined with several sectoral value-added variables (agriculture, manufacturing, mining / fuels). Our findings indicate that at least regarding manufacturing and mineral exports as well as imports the effects on tax performance are quite different, sometimes even opposite in both groups. It is particularly striking to see that manufacturing exports are associated with less revenue in the lower-income group. This could be due to lower value-added and lower productivity of this sector, leading to lower levels of taxation or higher subsidies granted by governments in order to ensure the international competitiveness of the sector.

Our data analysis confirms the initial assumption of **revenue volatility** being negatively associated with levels of revenue (in per cent of GDP) and dependence on natural resources. The effect is more pronounced in richer countries compared to poorer countries, in non-resource-rich countries compared to resource-rich countries and in democracies compared to non-democracies. We find the association to be weaker when non-tax revenue (without grants) is included (as in our base specification), meaning that non-tax revenue adds to volatility, especially in lower-income and resource-rich countries.

Regarding the **sensitivity of revenue to exogenous shocks** we observe that three shocks in particular – exchange rate (ER) pressure, terms of trade and the intensity of natural disasters have a significant negative effect on revenue. In the case of rainfall shocks (drought), our findings are inconclusive, probably due to the small sample size (only SSA countries). GDP decline as a proxy for a general output shock yields coefficients that are statistically insignificant and very close to zero, indicating that on average tax systems are neutral, i.e. the elasticity of revenue with respect to output is close to 1. Low- and lower-middle-income countries are more affected by shocks than richer countries.

As explained in Section 3.3, we operationalise shocks as continuous variables. However, most studies on shocks in developing countries part from a definition that contains a magnitude criterion – a shock being a *major* event with a *large* impact on the economy. The (usually implicit) underlying assumption is that the effects of shocks are non-linear – either assuming impacts to grow exponentially or relying

[23] A first recommendation would thus be to encourage partner governments to further invest in data infrastructure and quality. We do acknowledge, however, the important work done by the IMF in making reliable data available to the public. As a matter of fact, this study is based on IMF revenue data, in order to assure consistency and comparability across countries.

on a "tipping point"-approach where external events are irrelevant below a certain threshold, but cause major impacts once this threshold is passed. In order to account for this understanding of shocks we include a large-shock-dummy in our analysis, based on those events that lie in the upper decile (above the 90th percentile) of the respective country income group distribution. In the empirical analysis we look at both variables separately and jointly, in order to check for non-linear effects.

Our findings fail to provide evidence for the large-shock-approach, however. In most cases, large shocks are significant when (and only when) general shocks are significant as well. There is only one case where large shocks have a statistically significant effect (pointing towards the same direction as shocks in general) when both variables enter the regression jointly – this is the effect of ER pressure shocks on low- and lower-middle-income countries (see Table 10). It is certainly true that it does make sense to explore the impact of large shocks in specific contexts, as the effect is obviously more severe and may pose additional stress on governments searching for adequate policy responses. However, we do not find convincing evidence for an approach that focuses exclusively on large shocks when analysing revenue systems. In turn, a continuous variable approach such as the one chosen in this study has the important advantage of not having to rely on arbitrary threshold values.

In subsequent stages of the analysis, the effect of shocks on revenue in low- and lower-middle-income countries has been explored by introducing additional country groups, interaction terms and data driven clustering methods. Again, different "revenue stories" emerge.

For lower-income **countries rich in natural resources**, ER pressure and terms-of-trade shocks have a significant adverse effect on revenue, while natural disaster intensity does not seem to be relevant for this group. This could be due to the fact that extractive industries – the main revenue source for RR countries – are typically less affected by natural disasters than other types of economic activity and that governments in RR countries could find it more difficult to manage their exchange rate in order to avoid adverse impacts of external capital shocks. In contrast, lower income non-RR countries are heavily affected by natural disaster intensity as well as by terms-of-trade shocks (with point estimates even higher than for RR countries), while results for ER pressure are inconclusive.

Lower-income **countries with democratic regimes** fare better than non-democracies in their revenue sensitivity to all three shocks we consider. For non-democratic countries, the effects are negative and significant in all cases. This difference could be connected to a larger capacity of democratic regimes to avoid or compensate revenue losses through public policies, both on the revenue and expenditure side. Democratic countries seem to benefit more from fuel exports (coefficients being much bigger than for non-democratic countries) and suffer more from mineral exports in all three shock constellations. The positive effect of fuel exports could be related to more common-interest oriented policies under democratic rule. The contrast between the two findings could be due to different investment cycles and amortisation periods in the two sectors, with mining activities much more dependent on long-term stability compared to drilling. Compared to the higher-income group, political regimes are more dynamic and less durable in low-and lower-middle-income countries.

Introducing **interaction** terms enables us to broaden the scope of analysis beyond the structural factors of the base specification and to include macroeconomic policy variables. Results suggest that the overall balance prior to a shock could be important, whereas there is no robust evidence regarding the impact of government debt (except in the case of democracies suffering ER pressure shocks) or international reserves. In general employing interactions could represent an avenue to explore more in detail how countries expose themselves to external shocks. This could contribute to gaining a deeper understanding of the vulnerabilities of individual countries facing specific shocks.

With regard to **data-driven methods** of grouping (finite mixture models – FMM), our findings suggest that the criteria employed *ex ante* – income group, natural resource endowment and political regime type – are sufficiently well-suited to account for sample heterogeneity. This is especially obvious from the two-component models run on the low- and lower-middle-income countries split according to resource endowments and regime type (see Table 22). Each of the models (except democracies) generates one dominant component, with probabilities ranging between 95 and 98 per cent. In principle, the FMM approach could be expanded to obtain more detailed information concerning the dominant components, but limited data availability makes this approach unfeasible at this point.

External shocks act on public revenue through different channels. To account for these channels, we analyse four **types of revenue**: (i) income taxes, (ii) trade taxes, (iii) taxes on goods and services (sales) and (iv) non-tax revenue. Once again, looking at sample subsets allows us to identify specific patterns, even though few results pass the threshold of statistical significance, largely due to data constraints and the ensuing small sample size.

ER pressure shocks affect above all the trade and income taxes, especially if non-democratic and non-resource-rich countries are considered. In contrast, terms-of-trade shocks act primarily on non-tax revenue and, again, non-democracies and non-resource-rich countries are more affected. In these two groups, there is also a statistically significant negative effect of terms-of-trade shocks on income taxes. Regarding natural disaster intensity, no significant results can be observed. In general terms it can be inferred that non-democratic and non-resource-rich countries are particularly vulnerable to shocks affecting income-taxes and non-tax revenue.

In the case of **resource-rich countries**, no clear patterns emerge: their revenue structure, though more *volatile* than that of non-resource-rich countries due to a higher dependence on non-tax revenue, could be less *vulnerable* to external shocks. At least, there is no robust evidence pointing to volatility of revenue from natural resources being directly connected to increased vulnerability vis-à-vis external shocks. This finding is somewhat unexpected, as conventional wisdom and the literature on rent incomes from (principally) oil would suggest resource-rich economies to be particularly vulnerable to global price and capital shocks. From the present study we get the impression that it is much more the non-resource-rich countries we should be worried about.

From these findings, it is difficult to deduce clear-cut **policy recommendations**. Vulnerability to shocks should not be regarded exclusively as an issue of major adverse events hitting an economy. It may be important for governments, donors and international organisations to prepare for such events and to develop the appropriate financial tools to deal with them. But it is also important to keep in mind that minor events also have significant effects on revenue and that long-term structural reforms (in particular regarding income tax and non-tax revenue) are a necessary ingredient of any strategy targeting vulnerability of revenue in developing countries.

For instance, given that the various shocks propagate via various channels and thus affect respective tax types differently, policy makers should aim at establishing a **broad tax portfolio**, in terms of tax bases as well as tax types. The underlying rationale would be that different tax types and associated volatilities contribute to an overall risk diversification, making total revenue less susceptible to individual shocks inducing volatility via specific channels. This is especially relevant for countries with no substantial natural resource endowments.

Moreover, all in all we observe a "**democracy** rent" in the sense of lower vulnerability to shocks being associated with democratic rule in lower-income countries. It should be noted, however, that causality is particularly difficult to establish in this context. Reflecting the focus of this study, we have been inclined to interpret the findings as outcomes of democratic rule (for instance, assuming a higher ability of democratic governments to impose short-term hardships on their citizens). Yet, there is also evidence in the literature pointing from higher and more stable revenue to sustained democratic rule, as governments can spend more on public services. Still, reforms aiming at accountability, transparency and rule of law could have an important positive effect on revenue resilience, as governments may have more legitimacy to build broad-based revenue systems, as well as additional short-term manoeuvring space to respond to adverse external events.

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8. Appendix

Appendix 1: List of countries included in the sample (176 countries – 142 non-OECD countries)

Afghanistan, Albania, Algeria, Angola, Antigua & Barbuda, Argentina, Armenia, Australia, Austria, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia & Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Rep., Chad, Chile, China, Colombia, Comoros, Rep. of Congo, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Rep., Denmark, Djibouti, Dominica, Dominican Rep., Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Rep. of Korea, Kosovo, Kuwait, Kyrgyz Rep., Lao PDR, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Macedonia FYR, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Rwanda, Samoa, Sao Tome & Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovak Rep., Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, St. Kitts & Nevis, St. Lucia, St. Vincent & Grenadines, Swaziland, Sweden, Switzerland, Syrian Arab Rep., Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad & Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

Appendix 2: List of countries coded as being resource-rich

Afghanistan, Albania, Algeria, Angola, Bahrain, Bolivia, Botswana, Brunei Darussalam, Cameroon, Central African Republic, Chad, Chile, Congo, Rep., Cote d'Ivoire, Ecuador, Equatorial Guinea, Gabon, Ghana, Guatemala, Guinea, Guyana, Indonesia, Iran, Iraq, Kazakhstan, Kyrgyz Republic, Lao PDR, Libya, Madagascar, Mali, Mauritania, Mexico, Mongolia, Mozambique, Niger, Nigeria, Norway, Oman, Papua New Guinea, Peru, Russian Federation, Sao Tome and Principe, Saudi Arabia, Sierra Leone, Syrian Arab Republic, Tanzania, Timor-Leste, Togo, Trinidad and Tobago, Turkmenistan, United Arab Emirates, Uzbekistan, Venezuela, Vietnam, Yemen, Zambia.

Appendix 3: List of countries by income group[24]

- **High income group/ Upper middle income group**

Algeria (since 2006), Angola (since 2006), Antigua and Barbuda, Argentina (since 1996), Australia, Austria, Bahamas, Bahrain, Barbados, Belarus (since 2006), Belgium, Belize, Botswana (since 1996), Brazil, Brunei Darussalam, Bulgaria (since 2006), Canada, Chile (since 1996), China (since 2006), Colombia (since 2006), Costa Rica(since 1996), Croatia, Cyprus, Czech Republic, Denmark, Dominica (since1996), Dominican Republic (since 2006), Ecuador (since 2006), Equatorial Guinea (since 2006), Estonia, Fiji, Finland, France, Gabon, Germany, Greece, Grenada, Hong Kong, Hungary, Iceland, Iran (since 2006), Iraq (until 1995) Ireland, Israel, Italy, Jamaica (since 2006), Japan, Jordan (since 2006), Kazakhstan (since 2006), Kuwait, Latvia (since 2006), Lebanon, Libya (until 2005), Lithuania (since 2006), Luxembourg, Macedonia (since 2006), Malaysia (since 1996), Malta, Mauritius (since 1996), Mexico, Montenegro, Namibia (since 2006), Netherlands, New Zealand, Norway, Oman, Panama (since 1996), Poland (since 1996), Portugal, Rep of Korea, Romania, Russian Federation (since 2006), Saudi Arabia, Serbia, Seychelles, Singapore, Slovak Republic, Slovenia, Solomon Islands, South Africa, Spain, St. Kitts & Nevis (since 1996), St. Lucia, St. Vincent & Grenadines (since 2006), Sweden, Switzerland, Thailand (since 2006), Tonga, Trinidad & Tobago, Tunisia (since 2006), Turkey (since 1996), United Arab Emirates, United Kingdom, United States, Uruguay, Vanuatu, Venezuela.

- **Lower middle income / Low income group**

Afghanistan, Albania, Algeria (until 2005), Angola (until 2005), Argentina (until 1995), Armenia, Bangladesh, Belize, Benin, Bhutan, Bolivia, Bosnia & Herzegovina (until 2005), Botswana (until 1995), Burkina Faso, Bulgaria (until 2005), Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, Chile (until 1995), China (until 2005), Colombia (until 2005), Comoros, Costa Rica (until 1995), Cote d'Ivoire, Djibouti, Dominica (until 1995), Dominican Republic (until 2005), Ecuador (until 2005), Equatorial Guinea (until 2005) Egypt, El Salvador, Eritrea, Ethiopia, Gambia, Georgia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Iran (until 2005), Iraq (since 1996), Jamaica (until 2005) Jordan (until 2005), Kazakhstan (until 2005), Kenya, Kosovo, Kyrgyz Republic, Lao PDR, Latvia (until 2005), Lesotho, Liberia, Lithuania (until 2005), Macedonia (until 2005), Madagascar, Malaysia (until 2005), Malawi, Maldives, Mali, Mauritania, Moldova, Mongolia, Morocco, Mozambique, Myanmar (until 2005), Namibia (until 2005), Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama (until 1995), Papua New Guinea, Paraguay, Peru (until 2005), Philippines, Poland (until 1995), Rep of Congo, Russian Federation (until 2005), Rwanda, Samoa, Sao Tome & Principe, St. Lucia (until 1995), St. Vincent & Grenadines (until 2005), Senegal, Sierra Leone, Sri Lanka, Swaziland, Syrian Arab Rep., Tajikistan, Tanzania, Thailand (until 2005), Timor-Leste, Togo, Tunisia (until 2005), Turkey (until 1995), Turkmenistan (until 2005),, Uganda, Ukraine, Uzbekistan, Vietnam, Yemen, Zambia, Zimbabwe.

[24] Please note that observations of states that were newly founded during the period of time analyzed (1980-2010) are coded as missing between the foundation year and the year in which the next World Bank classification employed in this study is published (1995, 2005 and 2011).

Appendix 4: List of countries coded as democracies[25]

Albania (2002-2010), Argentina (1983-2010), Armenia (1991-1994), Australia (1980-2010), Austria (1980-2010), Belarus (1991-1994), Belgium (1980-2010), Benin (2006-2010), Bolivia (1982-2010), Botswana (1987-2010), Brazil (1985-2010), Bulgaria (1990-2010), Canada (1980-2010), Cape Verde (1991-2010), Chile (1989-2010), Colombia (1980-2010), Comoros (2006-2010), Costa Rica (1980-2010), Croatia (2000-2010), Cyprus (1980-2010), Czech Republic (1993-2010), Denmark (1980-2010), Dominican Republic (1996-2010), Ecuador (1980-1999; 2006), El Salvador (1991-2010), Estonia (1999-2010), Fiji (1980-1986), Finland (1980-2010), France (1980-2010), Gambia (1980-1993), Georgia (2004-2006), Germany (1980-2010), Ghana (2004-2010), Greece (1980-2010), Guatemala (1996-2010), Haiti (1990; 1994-1998), Honduras (1999-2010), Hungary (1990-2010), India (1980-2010), Indonesia (2004-2010), Ireland (1980-2010), Israel (1980-2010), Italy (1980-2010), Jamaica (1980-2010), Japan (1980-2010), Kenya (2002-2010), Rep. of Korea (1998-2010), Kosovo (2008-2010), Latvia (1991-2010), Lebanon (2005-2010), Lesotho (1993-1997; 2002-2010), Lithuania (1991-2010), Luxembourg (1980-2010), Macedonia (2002-2010), Madagascar (1992-2008), Mali (1992-1996; 2002-2010), Mauritius (1980-2010), Mexico (2000-2010), Moldova (1993-2010), Mongolia (1992-2010), Montenegro (2006-2010), Netherlands (1980-2010), New Zealand (1980-2010), Nicaragua (1995-2010), Niger (1992-1995), Nigeria (1980-1983), Norway (1980-2010), Pakistan (1988 1998), Panama (1989-2010), Paraguay (1992-1997; 1999-2010), Peru (1980-1991; 2001-2010), Philippines (1987-2010), Poland (1991-2010), Portugal (1980-2010), Romania (1996-2010), Senegal-(2000-2010), Serbia (2006-2008), Sierra Leone (2007-2010), Slovak Republic (1993-2010), Slovenia (1991-2010), Solomon Islands (1980-1999; 2004-2010), South Africa (1993-2010), Spain (1980-2010), Sweden (1980-2010), Switzerland (1980-2010), Thailand (1992-2005), Timor-Leste (2006-2010), Trinidad & Tobago (1980-2010), Turkey (1983-2010), Ukraine (1994-1999; 2006-2009), United Kingdom (1980-2010), United States (1980-2010), Uruguay (1985-2010), Venezuela (1980-2000), Zambia (2008-2010).

[25] The polity IV database can be found at http://www.systemicpeace.org/polity/polity4.htm

Appendix 5: Data

Table 24: Variables and Operationalisation

Concept	Variable name in the dataset	Indicator	Source
Total Revenue	**Rev**	Total revenue (per cent of GDP)	"Revenue Data for IMF Member Countries as of 2011" Fiscal Affairs Department, Tax Policy Division, IMF ("IMF Tax- database")
Total Tax Revenue	**Tax**	Total tax revenue (per cent of GDP)	IMF Tax- database
Trade Taxes	**Trd**	Tax revenue from international trade and transactions (per cent of GDP)	IMF Tax- database
General Sales Tax	**Gs**	Tax revenue from goods and services (per cent of GDP)	IMF Tax- database
Income Tax	**Inc**	Income tax revenue (per cent of GDP)	IMF Tax- database
Non Tax Revenue	**non_tax**	Non- tax revenue (per cent of GDP)	Own calculation based on the IMF Tax- database. Non_tax= Rev-tax
GDP per capita	**gdp_pc**	GDP per capita	World Development Indicators 2012 ("WDI 2012"). Available online: http://data.worldbank.org/data-catalog/world-development-indicators
Agricultural exports	**agr_exp**	Exports of agricultural commodities and food (per cent of GDP)	Own construction based on data from WDI 2012
Mineral Ex-ports	**min_exp**	Exports of mineral (non-fuel) commodities (per cent of GDP)	Own construction based on data from WDI 2012
Fuel Exports	**fuel_exp**	Export of fuels (per cent of GDP)	Own construction based on data from WDI 2012
Manufacturing Exports	**manuf_exp**	Exports of manufactured commodities (per cent of GDP)	Own construction based on data from WDI 2012
Imports	**imports**	Merchandise imports (per cent of GDP)	Own construction based on Merchan-dise imports in current USD and GDP in current USD (WDI 2012)
Terms of trade	**tot_wdi**	Terms of trade	Net barter terms of trade index (2000 = 100), export / import (WDI 2012)
Intensity of Natural Disas-ter	**intensity**	Measure of intensity of natural disaster based on people killed and affected by natural disaster in every year t and every country j. Formula: $Intensity_{j,t} = \frac{people\ killed_{j,t} + 0.3 * Total\ affected_{j,t}}{population_{j,t}}$	Own construction based on Fomby / Ikeda / Loayza 2009, 12-14. Data from the EM-DAT Database (http://www.emdat.be/)
Income groups	**inc_groups**	Income groups. 4 groups: low income, lower-middle income, upper-middle in-come and high income	Period 1980 to 95 - classification as of 1990; period 1996 to 2005 - classi-fication as of 2000; period 2006 to 2010 - classification as of 2011.) Classifications are available online: http://data.worldbank.org/ about/country-classifications/country-and-lending-groups
Resource rich countries	**RR_dummy**	Resource-rich country dummy	Based on "Macroeconomic policy frameworks for resource rich develop-ing countries" (IMF 2012)
Official devel-opment aid	**oda_togni**	Net ODA received (per cent of GNI)	WDI 2012
Drought	**rainfall_dev**	Annual standardized rainfall deviation from the long-term (1979–2008) panel mean of rainfall for a given country	Hendrix / Salehyan (2012)
Democracy	**demo_dummy**	1= democracy 0 =non democratic	Based on Polity II Dataset. Values above 6 are considered democracies
Exchange rates pressure	**ER_pressure**	Weighted average of percentage changes of policy variables in response to current account or financial account shock. We use the following definition: $PI_{it} = w_{E,i}\frac{\Delta E_{it}}{E_{i,t-1}} - w_{RES,i}\frac{\Delta RES_{it}}{RES_{i,t-1}}$ where i identifies the country, t is the year, E is the exchange rate in local currency units per USD, RES – size of reserves,	Own calculation. Source: IMF WEO

		$w_{E,i}$ and $w_{RES,i}$ are country-specific weights: $w_{E,i} = \frac{\sigma_{RES,i}}{\sigma_{RES,i}+\sigma_{E,i}}, w_{RES,i} = \frac{\sigma_{E,i}}{\sigma_{RES,i}+\sigma_{E,i}}$. Here $\sigma_{RES,i}$ is the standard deviation of $\frac{\Delta RES_{it}}{RES_{i,t-1}}$ in country i in 1980-2012, $\sigma_{E,i}$ is the same for $\frac{\Delta E_{it}}{E_{i,t-1}}$.	
Exchange rate classifications	**Era**	The classification codes are: (1) No separate legal tender. Pre announced peg or currency board arrangement. Pre announced horizontal band narrower than or equal to +/-2%. De facto peg. (2) Pre announced crawling peg. Pre announced crawling band narrower than or equal to +/-2%. De facto crawling peg. De facto crawling band narrower than or equal to +/-2%. (3) Pre announced crawling band wider than or equal to +/-2%. De facto crawling band narrower than or equal to +/-5%. Moving band narrower than or equal to +/-2%. Managed floating. (4) Freely floating. (5) Freely falling. (6) Dual market in which parallel market data is missing	Ilzetzki / Reinhart / Rogoff (2010)
Bureaucracy Quality	**bureaucratic_qual**	Bureaucracy Quality, values between 1 and 4	ICRG Dataset
Gross debt	**ggDebtGr_gdp**	General government gross debt, (per cent of GDP)	IMF WEO
Overall balance	**ggLending_gdp_weo**	General government overall balance, (per cent of GDP) = Total Revenue - Total Expenditure	IMF WEO
Inflation	**inflation_weo**	Annual growth of Consumer Prices Index, average over period, %	IMF WEO
Central Bank International reserves	**reserves_gdp**	Central Bank's international reserve assets, bln USD	IMF IFS. USD = US dollar
Exchange rate	**exrusdav**	Exchange rate, LCU per USD, average over period	IMF IFS. LCU = local currency units. USD = US dollar
Real exchange rate	**rer_cpius**	Real exchange rate, CPI-based, relative to US, index 2005=1 rer_cpius=cpi/exrusdav/cpius, where cpi is local CPI, cpius is CPI in US	Own calculations
Overvaluation of real exchange rate	**rer_overvaluation**	Overvaluation of real exchange rate, % rer_overvaluation = percent difference between actual rer_cpius and its value on the trend after using Hodrick-Prescott filter (separately for each country, lambda = 6.25)	Own calculations
Structural balance	**strBal_gdp_implied**	General government structural balance, (per cent of potential GDP) strBal = Structural Revenue - Total Expenditures. Structural Revenue = Total Revenue * (potential GDP/actual GDP). Potential GDP is the trend value of current GDP in LCU after using Hodrick-Prescott filter (separately for each country, lambda = 6.25)	Own calculations
Economic Freedom	**ief_frasimp**	Index of Economic Freedom	Fraser Institute. www.freetheworld.com/release.html Continuous variable between 1 and 10
Fixed exchange rate	**fixed**	fixed=1 if era<3; 0 if era>2; missing if era is missing	Own calculations
Tax effort	**tax_effort**	Tax effort: tax_effort = residual in OLS regression of rev on our tax determinants (column 1 of Table 5 in our empirical results)	Own calculations

Table 25: Variables: descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Max	Min	10th Percentile	Median	90th Percentile
Rev	3831	30.250	18.610	556.100	0.000	14.600	28.500	46.800
tax	4110	18.140	8.970	92.100	0.100	8.000	17.200	29.600
trd	3845	11.120	169.690	5169.200	0.000	0.300	1.900	7.800
gs	3913	10.190	68.790	1947.900	0.000	1.600	6.300	12.500
inc	3984	44.620	791.660	25605.000	0.000	1.400	4.800	14.200
gdp_pc	4937	6085.040	9060.890	61374.750	54.505	256.740	1811.872	20424.270
agr_exp	3435	6.300	6..594	57.471	0.000	0.961	3.973	14.762
min_exp	3435	2.059	5.101	64.762	0.000	0.026	0.554	4.577
fuel_exp	3435	5.433	11.926	150.634	0.000	0.001	0.659	18.271
manuf_exp	3435	13.614	18.250	151.706	0.000	0.968	7.142	31.629
imports	4852	37.140	25.580	413.315	2.884	15.323	31.066	63.658
tot_wdi	3488	111.000	40.370	721.050	21.280	81.150	100.000	156.000
inc_group	5456	2.523	1.113	4	1	1	3	4
Tax_effort	2664	-1.040	7.800	46.390	-29.486	-8.402	-0.521	8.496
oda_togni	3673	7.970	11.180	181.014	-2.701	0.100	4.010	19.961
rainfall_dev	875	0.040	1.000	3.376	-3.734	-1.170	0.030	1.323
exr_pressure	4362	-0.910	28.620	698.163	-815.771	-18.793	-0.210	16.503
Bureacratic_qual	3330	2.196	1.180	4.000	0.000	1.000	2.000	4.000
ggDebtGr_gdp	2496	66.316	87.362	1380.990	0.000	15.200	53.135	115.680
ggLending_~o	3241	-2.110	7.430	125.450	-151.310	-7.880	-2.520	3.280
inflation_~o	4866	38.560	361.920	13109.500	-72.730	0.910	6.100	29.460
reserves_gdp	4311	13.417	14.581	156.935	0.020	1.997	9.674	26.294
exrusdav_i~d	4858	324.477	1363.757	19124.480	0.000	0.720	5.814	559.612
rer_overva~n	4817	-0.198	24.417	972.562	-1077.135	-8.541	-0.010	7.456
strBal_gdp~d	3233	-2.312	11.874	128.002	-528.073	-8.093	-2.497	3.577
ief_frasimp	3526	6.051	1.330	9.140	1.780	4.310	6.100	7.710
Rer_cpius	4817	1.164	0.763	23.473	0	0.750	1.031	1.580

Table 26: Democracy and resource-rich dummies: descriptive statistics

Variable	Observations	Positive cases	Negative case
demo_dummy	4449	1857	2592
RR_dummy	5456	1736	3720

Table 27: Political regime and resource endowment by income group, no. of observations

	High and upper-middle-income countries	Low and lower-middle-income countries
Democracy	1158	655
Non-democracy	425	2062
Resource-rich	422	1298
Non-resource-rich	1513	1842

Table 28: Political regime by resource endowment, no. of observations

	Non-resource-rich	Resource-rich
Democracy	1537	320
Non-democracy	1339	1253

Appendix 6: Predefined groups in high- and upper-middle-income countries

Table 29: Effects of shocks on revenues of high- and upper-middle-income countries, resource-rich vs. non-resource-rich countries, fixed effects estimation

Shocks:	Exchange Rate Pressure		Terms of Trade (in Logs)		Intensity of Natural Disasters	
	(1)	(2)	(1)	(2)	(1)	(2)
Shock Level	-0.0709	-0.122*	-3.017	-1.518	57.12	0.914
	(0.125)	(0.0695)	(2.140)	(3.615)	(111.9)	(9.259)
Agricultural Exports (% GDP)	-0.137	-0.0314	0.507	-0.128	1.024*	-0.0435
	(0.401)	(0.108)	(0.492)	(0.106)	(0.554)	(0.108)
Mineral Exports (% GDP)	0.520***	0.538**	0.0728	0.284	0.0642	0.487*
	(0.0746)	(0.257)	(0.0984)	(0.249)	(0.0996)	(0.267)
Manufacturing Exports (% GDP)	0.274***	-0.0918	0.319**	-0.150**	0.184	-0.0917
	(0.0788)	(0.0835)	(0.147)	(0.0607)	(0.136)	(0.0858)
Imports (% GDP)	-0.164**	-0.0140	-0.195**	0.0771	-0.407***	-0.00811
	(0.0593)	(0.0695)	(0.0831)	(0.0548)	(0.105)	(0.0691)
Fuel Exports (% GDP)	0.434***	-0.0478	0.370***	-0.253	0.522***	-0.0562
	(0.0685)	(0.155)	(0.0597)	(0.216)	(0.111)	(0.154)
Agriculture, Value Added (% GDP)	-0.0363	-0.504	-0.416	-0.105	-1.724	-0.612
	(0.556)	(0.435)	(0.517)	(0.345)	(1.043)	(0.479)
GDP per capita (in logs)	-6.612	-2.143	-6.685*	-1.654	-0.441	-3.337
	(3.980)	(3.389)	(3.588)	(3.042)	(3.018)	(3.678)
Constant	86.65**	61.53*	86.07**	52.13*	39.95	73.60**
	(36.04)	(32.06)	(31.84)	(29.49)	(29.29)	(35.09)
R-squared	0.651	0.063	0.681	0.239	0.647	0.071
observations	210	1122	162	731	200	1150
Sample size	17	66	17	66	16	65
Chow tests:						
Only shock						
t-statistic	0.38		-0.36		0.55	
p-value	0.7		0.72		0.581	
Shock & structural variables						
F-statistic	2.27		5		3.34	
p-value	0.030		0		0.002	

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. (1) Resource-rich (2) Non-resource-rich countries.*

Table 30: Effects of shocks on revenues of high- and upper-middle-income countries, democratic vs. non-democratic countries, fixed effects estimation

Shocks:	Exchange Rate Pressure		Terms of Trade (in Logs)		Intensity of Natural Disasters	
	(1)	(2)	(1)	(2)	(1)	(2)
Shock Level	-0.144**	-0.177	-2.671	-2.857	-2.965	48.52*
	(0.0667)	(0.156)	(2.125)	(2.113)	(13.27)	(26.04)
Agricultural Exports (% GDP)	0.258**	-0.155	0.141**	-0.385**	0.267**	-0.146
	(0.116)	(0.378)	(0.0673)	(0.158)	(0.123)	(0.114)
Mineral Exports (% GDP)	0.265**	0.326**	0.0151	0.286	0.254**	0.251
	(0.129)	(0.141)	(0.148)	(0.415)	(0.125)	(0.531)
Manufacturing Exports (% GDP)	-0.0249	0.0346	0.0589	0.0240	-0.0312	-0.0351
	(0.135)	(0.0855)	(0.0645)	(0.0357)	(0.134)	(0.0687)
Imports (% GDP)	-0.166	-0.116**	-0.0931	-0.107**	-0.163	-0.138**
	(0.132)	(0.0527)	(0.0685)	(0.0412)	(0.130)	(0.0539)
Fuel Exports (% GDP)	0.357**	0.162	0.358***	0.217	0.357**	0.287
	(0.150)	(0.155)	(0.117)	(0.157)	(0.150)	(0.189)
Agriculture, Value Added (% GDP)	-0.547	-1.115*	-0.148	-0.449	-0.694	-0.336
	(0.523)	(0.579)	(0.424)	(0.280)	(0.567)	(0.529)
GDP per capita (in logs)	-2.069	-9.912**	2.181	-8.615***	-3.276	-6.381
	(5.344)	(4.554)	(3.615)	(3.052)	(5.716)	(5.255)
Constant	63.38	126.0**	15.95	107.3***	75.67	91.22*
	(49.28)	(45.17)	(34.39)	(27.47)	(53.07)	(50.42)
R-squared	0.087	0.341	0.379	0.547	0.089	0.346
observations	934	213	583	181	967	199
sample size	52	25	52	24	52	25
Chow tests:						
Only shock						
t-statistic	0,37		1,29		-1,7	
p-value	0,72		0,2		0,09	
Shock & structural variables						
F-statistic	0,7		6,87		3,33	
p-value	0,705		0,000		0,002	

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 (1) Democracies (2) Non-democracies.*

Appendix 7: Interactions with large shocks

Table 31: Revenues responses to large shocks in low and lower middle income countries, fixed effects estimation.

	Terms-of-trade shock (log)	Intensity of natural disasters shock
Large shock	-46.46	9.012
	(30.72)	(6.321)
Structural Balance (% potential GDP)	13.11**	0.567
	(4.949)	(0.435)
Overvaluation of real ER (%)	1.412	0.0489*
	(2.220)	(0.0287)
Inflation (%)	2.544	-0.0470
	(2.144)	(0.0587)
Overall balance (% GDP)	-10.89**	-0.608
	(3.727)	(0.439)
Government Debt (% GDP)	-0.411***	0.0174
	(0.124)	(0.0139)
Index of Economic Freedom	-48.30	-0.385
	(32.50)	(0.881)
Central Bank International Reserves	-2.388	0.0139
	(1.355)	(0.0441)
Democracy	15.23	0.507
	(10.43)	(0.763)
Tax Effort	-0.532	0.668***
	(0.493)	(0.158)
Agricultural Exports (% GDP)	6.758	-0.0533
	(8.645)	(0.441)
Mineral Exports (% GDP)	5.997	0.0375
	(7.534)	(0.167)
Manufacturing Exports (% GDP)	-2.925	-0.100**
	(1.946)	(0.0369)
Imports (% GDP)	1.407	0.106***
	(1.567)	(0.0330)
Fuel Exports (% GDP)	0.391	-0.137
	(3.369)	(0.289)
Agriculture, Value Added (% GDP)	1.092	-0.0226
	(1.396)	(0.0677)
GDP per capita (log)	7.245	2.230*
	(66.50)	(1.193)
Constant	284.3	4.487
	(521.2)	(13.31)
R-squared	0.884	0.851
Observations	47	104
Number of countries	12	30

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are lagged one year. ER pressure shocks not included due to the small number of observations.*

Appendix 8: Different tax types (predefined groups):

Table 32: Effects of shocks on different revenue types of low- and lower-middle-income resource-rich countries, fixed effects estimation

	Non Tax Revenues			Trade Tax			Goods and services Tax			Income Tax		
Shocks	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Shock Level	-0.0730	-2.274*	0.219	-0.0336	0.327	-1.229	-0.0415	-0.0663	5.778	-0.0649	0.465	-5.986
	(0.100)	(1.277)	(8.664)	(0.0247)	(0.410)	(1.247)	(0.0349)	(1.149)	(4.926)	(0.0401)	(1.064)	(3.786)
Agricultural Exports (% GDP)	0.135	0.0701	0.117	0.00663	0.0335	0.0154	0.0293	0.00170	0.0101	-0.00662	-0.000962	0.0134
	(0.135)	(0.136)	(0.129)	(0.0323)	(0.0409)	(0.0409)	(0.0571)	(0.0601)	(0.0577)	(0.0573)	(0.0615)	(0.0574)
Mineral Exports (% GDP)	-0.156	-0.251**	-0.143	-0.0160	-0.00191	-0.0103	-0.0193	-0.0987*	-0.0178	0.0623	0.107*	0.0699*
	(0.128)	(0.110)	(0.103)	(0.0187)	(0.0255)	(0.0217)	(0.0494)	(0.0561)	(0.0431)	(0.0397)	(0.0574)	(0.0380)
Manufacturing Exports (% GDP)	-0.0344	-0.125	-0.0981	-0.0187	-0.0342	-0.0335	0.110**	0.0488	0.0875*	-0.165***	-0.126*	-0.104*
	(0.0912)	(0.0802)	(0.0760)	(0.0275)	(0.0216)	(0.0233)	(0.0458)	(0.0555)	(0.0459)	(0.0261)	(0.0660)	(0.0542)
Imports (% GDP)	0.0438	0.0661	0.0410	0.0314***	0.0331***	0.0334***	0.0183	0.00521	0.00149	0.0739***	0.0814***	0.0841***
	(0.0515)	(0.0476)	(0.0526)	(0.0109)	(0.0100)	(0.0103)	(0.0275)	(0.0293)	(0.0272)	(0.0266)	(0.0227)	(0.0266)
Fuel Exports (% GDP)	0.133	0.156	0.125	-0.00313	-0.00475	-0.00305	0.0849	0.198*	0.0756	0.0839	0.0459	0.0910
	(0.110)	(0.0932)	(0.105)	(0.0161)	(0.0283)	(0.0157)	(0.0809)	(0.111)	(0.0754)	(0.0943)	(0.0967)	(0.0888)
Agriculture, Value Added (% GDP)	-0.112	-0.00418	-0.134	-0.0245	-0.0390	-0.0231	-0.0652	-0.0440	-0.0758*	-0.0527	-0.0907*	-0.0623
	(0.0973)	(0.0731)	(0.0899)	(0.0236)	(0.0394)	(0.0303)	(0.0447)	(0.0414)	(0.0406)	(0.0445)	(0.0523)	(0.0419)
GDP per capita (in logs)	-2.347	0.502	-2.767	1.333*	1.306**	1.398**	1.567	3.266*	1.175	-1.042	-2.695	-1.301
	(2.110)	(2.118)	(2.041)	(0.669)	(0.621)	(0.579)	(1.739)	(1.876)	(1.518)	(2.147)	(2.162)	(2.085)
Constant	23.07	1.805	27.00*	-7.181	-6.757	-7.684*	-3.565	-14.10	0.0114	10.97	22.13	12.05
	(14.01)	(14.76)	(13.44)	(4.498)	(4.137)	(3.821)	(12.29)	(13.14)	(10.59)	(14.27)	(14.28)	(13.67)
R-squared	0.230	0.246	0.223	0.304	0.357	0.317	0.279	0.341	0.287	0.161	0.165	0.188
Observations	343	338	386	407	402	452	407	402	452	409	404	454
No. of countries	28	31	31	31	32	33	31	32	33	31	32	33

*Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1)= Exchange Rate Pressure (2)= Terms of Trade (in Logs) (3)= Intensity of Natural Disasters*

Table 33: Effects of shocks on different revenue types of low- and lower-middle-income non-resource-rich countries, fixed effects estimation

	Non Tax Revenues			Trade Tax			Goods and services Tax			Income Tax		
Shocks	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Shock Level	0.00703	-3.588***	-1.959	-0.0415**	-0.605	-1.649	-0.0169	-0.412	-3.006*	-0.0488**	-0.920*	-0.651
	(0.0553)	(1.247)	(2.921)	(0.0205)	(0.565)	(2.299)	(0.0274)	(0.810)	(1.775)	(0.0188)	(0.476)	(2.148)
Agricultural Exports (% GDP)	-0.0707	-0.0927*	-0.0667	-0.0406	-0.0246	-0.0154	0.00461	0.0122	0.0112	0.0176	0.00224	0.0245
	(0.0481)	(0.0527)	(0.0476)	(0.0384)	(0.0491)	(0.0416)	(0.0242)	(0.0247)	(0.0241)	(0.0279)	(0.0240)	(0.0282)
Mineral Exports (% GDP)	-0.257	-0.143	-0.274	0.0110	0.0750	0.0750	-0.200	-0.200	-0.206	-0.146	-0.161	-0.160
	(0.289)	(0.229)	(0.271)	(0.0706)	(0.111)	(0.0956)	(0.155)	(0.178)	(0.145)	(0.129)	(0.117)	(0.117)
Manufacturing Exports (% GDP)	-0.0220	-0.0249	-0.0218	-0.0440***	-0.0373*	-0.0390**	-0.0620***	-0.0646***	-0.0715***	-0.00461	-0.0185	-0.00898
	(0.0324)	(0.0362)	(0.0318)	(0.0133)	(0.0223)	(0.0182)	(0.0202)	(0.0216)	(0.0205)	(0.0168)	(0.0142)	(0.0161)
Imports (% GDP)	0.103***	0.0971***	0.0992***	0.0264**	0.0101	0.0150	0.0411**	0.0503**	0.0432**	0.0219*	0.0227**	0.0210*
	(0.0196)	(0.0192)	(0.0211)	(0.0129)	(0.0229)	(0.0187)	(0.0193)	(0.0202)	(0.0180)	(0.0117)	(0.0111)	(0.0116)
Fuel Exports (% GDP)	0.134*	0.158	0.134**	0.130***	0.109**	0.109**	-0.128**	-0.0572	-0.0547	0.112*	0.0907	0.118**
	(0.0801)	(0.0963)	(0.0663)	(0.0446)	(0.0527)	(0.0412)	(0.0526)	(0.0556)	(0.0731)	(0.0609)	(0.0643)	(0.0567)
Agriculture, Value Added (% GDP)	0.000254	-0.00456	-0.00158	-0.0118	-0.0149	-0.0137	-0.00297	0.00119	-0.00229	-0.0196	-0.0207*	-0.0181
	(0.0360)	(0.0412)	(0.0367)	(0.0125)	(0.0146)	(0.0135)	(0.0146)	(0.0129)	(0.0145)	(0.0133)	(0.0112)	(0.0141)
GDP per capita (in logs)	-3.325	-4.076	-2.989	-0.541	-0.816	-0.494	1.456	1.090	1.581	1.579*	1.179	1.652**
	(2.506)	(2.636)	(2.320)	(0.762)	(0.997)	(0.782)	(1.364)	(1.383)	(1.294)	(0.804)	(0.778)	(0.768)
Constant	28.94	34.11*	26.60	6.026	8.299	6.013	-2.527	-0.515	-3.684	-5.814	-2.701	-6.400
	(18.54)	(19.66)	(17.24)	(5.804)	(7.503)	(5.941)	(9.757)	(9.884)	(9.304)	(5.800)	(5.608)	(5.552)
R-squared	0.133	0.213	0.135	0.380	0.359	0.343	0.395	0.411	0.393	0.378	0.416	0.374
Observations	723	661	752	787	730	818	786	731	818	788	730	819
No. of countries	61	56	62	64	58	64	63	58	63	64	58	65

*Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1)= Exchange Rate Pressure (2)= Terms of Trade (in Logs) (3)= Intensity of Natural Disasters*

Table 34: Effects of shocks on different revenue types of low- and lower-middle-income democratic countries, fixed effects estimation

	Non Tax Revenues			Trade Tax			Goods and services Tax			Income Tax		
Shocks	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Shock Level	0.0159	0.219	-0.836	-0.0150	0.647	-1.800	-0.0468*	-1.045*	0.375	-0.00538	0.616	-3.099
	(0.0931)	(2.616)	(5.935)	(0.0159)	(0.902)	(3.391)	(0.0265)	(0.529)	(2.737)	(0.0245)	(0.746)	(1.991)
Agricultural Exports (% GDP)	-0.0328	-0.0724	-0.0397	-0.00518	0.0520	0.0397	-0.0269	-0.000437	-0.0243	-0.00192	-0.0191	-0.00438
	(0.0816)	(0.0727)	(0.0762)	(0.0120)	(0.0543)	(0.0449)	(0.0366)	(0.0263)	(0.0344)	(0.0332)	(0.0216)	(0.0317)
Mineral Exports (% GDP)	-0.523***	-0.507*	-0.478**	-0.0512	-0.0293	-0.0456	-0.177**	-0.162**	-0.150**	0.164	0.245***	0.165*
	(0.170)	(0.282)	(0.189)	(0.0428)	(0.0470)	(0.0382)	(0.0775)	(0.0743)	(0.0696)	(0.0997)	(0.0887)	(0.0879)
Manufacturing Exports (% GDP)	-0.0720	-0.0796	-0.0725	-0.0362*	-0.0307	-0.0293	-0.0737***	-0.0704**	-0.0773***	0.0112	-0.00908	0.0103
	(0.0508)	(0.0544)	(0.0489)	(0.0191)	(0.0243)	(0.0208)	(0.0249)	(0.0261)	(0.0251)	(0.0253)	(0.0173)	(0.0245)
Imports (% GDP)	0.0528	0.0452	0.0520	0.0135	-0.0271	-0.0246	0.0579**	0.0414	0.0562**	-0.00319	0.0250	-0.00198
	(0.0582)	(0.0568)	(0.0552)	(0.0150)	(0.0494)	(0.0423)	(0.0249)	(0.0259)	(0.0236)	(0.0296)	(0.0212)	(0.0271)
Fuel Exports (% GDP)	0.294***	0.325***	0.279***	0.0369**	0.0424	0.0298	0.229*	0.224**	0.221*	0.0584	0.0292	0.0583
	(0.0941)	(0.108)	(0.0917)	(0.0176)	(0.0299)	(0.0222)	(0.123)	(0.105)	(0.121)	(0.0609)	(0.0417)	(0.0589)
Agriculture, Value Added (% GDP)	0.0476***	0.0471***	0.0492***	0.00202	0.000308	-0.000904	-0.000177	0.0120	-0.000820	-0.0204*	-0.0207***	-0.0205*
	(0.0121)	(0.0105)	(0.0117)	(0.00441)	(0.00627)	(0.00677)	(0.0181)	(0.00916)	(0.0173)	(0.0108)	(0.00671)	(0.0106)
GDP per capita (logs)	-3.529	-6.189***	-4.042	-0.359	0.0999	-0.124	-0.144	-0.506	-0.219	3.139***	2.305***	2.853***
	(3.542)	(2.206)	(3.106)	(0.488)	(0.750)	(0.454)	(2.117)	(1.919)	(1.789)	(1.128)	(0.712)	(1.013)
Constant	31.48	50.88***	35.28	3.988	1.733	3.477	8.331	10.85	9.016	-17.83**	-12.59**	-15.79**
	(25.65)	(16.42)	(22.48)	(3.649)	(4.717)	(3.165)	(15.58)	(13.91)	(13.16)	(8.556)	(5.607)	(7.631)
R-squared	0.183	0.195	0.184	0.412	0.282	0.266	0.459	0.493	0.460	0.436	0.502	0.440
Observations	379	359	389	402	381	412	402	381	412	403	382	413
No. of countries	37	36	37	39	38	39	39	38	39	39	38	39

*Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1)= Exchange Rate Pressure (2)= Terms of Trade (in Logs) (3)= Intensity of Natural Disasters*

Table 35: Effects of shocks on different revenue types of low- and lower-middle-income non-democratic countries, fixed effects estimation

	Non Tax Revenue			Trade Tax			Goods and services Tax			Income Tax		
Shocks	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Shock Level	-0.0230	-3.321***	-2.603	-0.0736***	0.196	-2.425	-0.0282	-0.420	0.147	-0.0643**	-0.863	-2.511
	(0.0612)	(0.860)	(3.741)	(0.0223)	(0.398)	(2.516)	(0.0245)	(0.820)	(2.824)	(0.0301)	(0.736)	(2.979)
Agricultural Exports (% GDP)	-0.0351	-0.0571	-0.0424	-0.0484	-0.0483	-0.0350	0.0572	0.0559*	0.0614	0.00547	-0.0326	0.0209
	(0.0564)	(0.0526)	(0.0597)	(0.0506)	(0.0573)	(0.0501)	(0.0385)	(0.0319)	(0.0391)	(0.0368)	(0.0353)	(0.0361)
Mineral Exports (% GDP)	-0.0687	-0.111*	-0.0717	-0.0334	-0.00446	-0.0139	0.00578	-0.0497	-0.00309	0.0359	-0.0197	0.0177
	(0.0665)	(0.0566)	(0.0569)	(0.0265)	(0.0284)	(0.0247)	(0.0522)	(0.0412)	(0.0448)	(0.0345)	(0.0449)	(0.0334)
Manufacturing Exports (% GDP)	-0.0459	-0.0629	-0.0654	-0.0734***	-0.0775***	-0.0768***	0.0416	0.0186	0.0265	-0.0723***	-0.0763***	-0.0628**
	(0.0631)	(0.0441)	(0.0609)	(0.0264)	(0.0254)	(0.0243)	(0.0330)	(0.0336)	(0.0330)	(0.0230)	(0.0246)	(0.0239)
Imports (% GDP)	0.0860***	0.0851***	0.0871***	0.0403***	0.0448***	0.0439***	0.0124	0.0132	0.0125	0.0459***	0.0509***	0.0483***
	(0.0236)	(0.0193)	(0.0239)	(0.0115)	(0.0119)	(0.0111)	(0.0185)	(0.0170)	(0.0179)	(0.0152)	(0.0152)	(0.0148)
Fuel Exports (% GDP)	0.168	0.128	0.164	0.0165	-0.0162	0.0178	0.0196	0.121	0.0343	0.0790	0.0321	0.0852
	(0.111)	(0.0907)	(0.102)	(0.0246)	(0.0329)	(0.0218)	(0.0768)	(0.110)	(0.0697)	(0.0841)	(0.108)	(0.0798)
Agriculture, Value Added (% GDP)	-0.173**	-0.115**	-0.179***	-0.0362	-0.0269	-0.0260	-0.0253	-0.0270	-0.0332	-0.0131	-0.0240	-0.0178
	(0.0721)	(0.0446)	(0.0648)	(0.0234)	(0.0308)	(0.0267)	(0.0321)	(0.0288)	(0.0317)	(0.0351)	(0.0342)	(0.0332)
GDP per capita (logs)	-4.029*	-3.221	-3.990**	-0.357	-0.433	-0.0672	1.323	2.141	1.476	1.931	1.335	1.962*
	(2.109)	(2.124)	(1.868)	(0.704)	(0.799)	(0.686)	(1.374)	(1.414)	(1.306)	(1.175)	(1.119)	(1.177)
Constant	35.99**	29.25*	35.91***	5.058	5.379	2.705	-2.000	-7.401	-2.937	-8.018	-3.391	-8.506
	(14.81)	(14.98)	(13.10)	(4.753)	(5.428)	(4.520)	(9.575)	(9.609)	(9.060)	(8.156)	(7.696)	(8.035)
R-squared	0.173	0.232	0.179	0.327	0.359	0.334	0.245	0.300	0.261	0.131	0.110	0.139
Observations	629	622	689	743	740	808	743	741	809	745	741	810
No. of countries	63	67	68	70	72	73	70	72	73	70	72	74

*Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1)= Exchange Rate Pressure (2)= Terms of Trade (in Logs) (3)= Intensity of Natural Disasters.*