Revisiting the resource curse: Does volatility matter?

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Abstract

This paper analyzes the impacts of both natural-resource abundance and natural-resource volatility on economic growth. We apply the panel smooth transition regression (PSTR) approach of González et al. (2005), which is more flexible than the standard fixed-effects model, to data on 87 countries over the 1989-2015 period. Our results suggest that: (i) greater natural-resource abundance significantly raises economic growth, contrary to the resource-curse paradox; (ii) the impact of natural-resource abundance, investment and human capital on GDP growth rate per capita is non-linear, and varies by the level of natural-resource abundance volatility; and (iii) the subsequent GDP growth loss may reach 17 percentage points per year for countries with the highest natural-resource abundance volatility, compared to those with the lowest natural-resource abundance volatility. Volatility in natural-resource revenues and poor governmental responses then seem to drive the resource-curse paradox, instead of natural-resource abundance as such.

Keywords: Growth, resource curse, natural resources volatility, PSTR.

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1 Introduction

In the resource-curse paradox highlighted by Sachs and Warner (1995), countries rich in natural resources have worse performance than those that are not endowed with natural resources. Resource abundance is then identified as a significant determinant of economic failure. While most work on the so-called "resource curse" paradox has looked at the negative growth effects of commodity abundance/dependence, the impact of volatility has with only few exceptions been overlooked. Our main objective here is to see whether the abundance of natural resources *per se* is a curse, or rather whether the observed negative growth effect reflects the volatility of natural-resource revenues. We also consider whether and how the volatility of natural resource rents affects the traditional channels of economic growth such as investment, human capital and institutional quality. The answers to these questions are particularly important for primary-product abundant countries, where resource revenues are very volatile. A number of transmission channels of the resource curse have been identified in the literature, which can be divided into two different but overlapping categories: economic and political.

The first classic economic explanation of the resource curse is based on the "Dutch disease", from the Netherlands' experience of a declining Manufacturing sector after the discovery of large natural-gas reserves in the 1950s. The Dutch-disease models developed by Corden and Neary (1982) and Van Wijnbergen (1984) show how the discovery of new natural resources in a country may reduce national income via the negative consequences in the Manufacturing sector. The adverse effects can result from natural-resource exploitation drawing labor out of Manufacturing towards the extractive sector, due to higher wages, leading to labor shortages and higher input costs in Manufacturing. Equally, greater extractive revenue leads the government to increase spending, part of which will go on non-traded goods such as Construction and Services. The prices of non-traded goods and services then rise, leading to an appreciation in the real exchange rate. Economic growth then falls as

Manufacturing output and non-commodity exports drop as a result of both the higher labor costs in Manufacturing, and the higher real exchange rate that makes non-commodity exports more expensive and less competitive.

Krugman (1987) and Matsuyama (1992) consequently developed a series of theoretical "Dutch disease" models in which it is assumed that Manufacturing productivity growth is driven by learning by doing. Dutch disease can appear through a variety of channels, such as increasing returns to scale in trade, agricultural productivity, and exchange-rate volatility. More-recent work has expanded on these models to suggest additional channels (Torvik, 2001; Sachs and Warner, 2001; Matsen and Torvik, 2005; Van der Ploeg and Venables, 2013; Cherif, 2013), including resource-price volatility. The primary source of revenue in resource-rich countries is often the extractive sector. However, commodity prices can fluctuate significantly, hindering the government's ability to manage the rent. The macroeconomic instability that results from resource-price volatility can also discourage investment. Van der Ploeg and Poelhekke (2009) argue that the positive effects of natural resources on growth are trumped by their adverse indirect effects via volatility. Natural resources are known to exacerbate macroeconomic volatility (Bleaney and Halland, 2009; Malik and Temple, 2009; Frankel, 2010), while empirical work has shown that volatility reduces growth and increases inequality and poverty (Aizenman and Pinto, 2004; Loayza and Hnatkovska, 2004; Ramey and Ramey, 1994).

Moving along the spectrum from the economic to political causal channels behind the resource curse, we come to rent-seeking, or what Lam and Wantchekon (2003) labeled the "Political Dutch Disease". Individuals seek political rents when trying to benefit themselves through their political influence. Sachs and Warner (2001), Hodler (2006) and Iimi (2007) suggest that natural-resource revenues increase the power of elites, who have the capacity to produce greater income inequality in some countries. The elites or powerful groups generally take a considerable share of these revenues and distribute then for the benefit of their

immediate circles rather than investing in infrastructure or sustainable economic development. Natural-resource revenues may then be a major source of conflict between domestic stakeholders such as politicians, local tribes, and more broadly citizens (Sala-i Martin and Subramanian, 2013; Davis and Tilton, 2005). Collier and Hoeffler (2004) find that the probability of civil war in Africa ranges from under 1% in resource-poor countries to nearly 25% in resource-rich countries.

The other main political channel suggested for the resource curse is that natural resources may weaken institutions (Arezki and van der Ploeg, 2010; Robinson et al., 2006): resource-rich countries tend to have centralized governments, with collusion between the government and the extractive industry. In addition, resource revenues can be used to pacify the population, repress opposition and avoid accountability pressure (Karl, 1997). Natural-resource abundance increases corruption in countries where democratic institutions are weak, but not where democratic institutions are strong (Bhattacharyya and Hodler, 2010). Tornell and Lane (1999) identify weak institutions as the culprits for the slow growth following the discovery of oil in Nigeria, Mexico and Venezuela. Sala-i Martin and Subramanian (2013) suggest that the corruption that emerged after the discovery of oil was behind the slow growth seen in Nigeria. Last, Mehlum et al. (2006) emphasize that good institutions are essential to lift the resource curse.

The empirical findings on the natural-resource curse paradox are mixed. The jury is still out, with approximately 40% of empirical results indicating an adverse effect, 40% no effect, and 20% a positive impact (Havranek et al., 2016). Rodriguez and Sachs (1999); Gylfason (2001), among others, confirm Sachs and Warner's negative correlation between resource abundance and economic growth. However, Brunnschweiler and Bulte (2008) claim that the resource curse no longer holds when the correct measure of resource abundance (rather than dependence) is applied. A growing number of papers also provide evidence against the resource-curse paradox: Alexeev and Conrad (2009) and Cotet and Tsui (2013) find that

countries with large oil reserves have higher income growth, and Smith (2015) concludes that major oil discoveries since 1950 increased long-run GDP growth using a variety of quasi-experimental methods (such as synthetic controls).

The results in the literature are therefore mixed regarding the roles of natural-resource abundance or dependence in the resource curse. Almost all work has focused on either abundance or dependence: we argue that a distinction should be made between the abundance/dependence and the volatility of natural resources. We therefore consider both the direct growth impact of natural-resource abundance and the indirect effect via natural-resource revenue volatility. By including the volatility channel of natural resources, we hope to reconcile the results in the existing literature and show that it is volatility that triggers the adverse growth effects of being either abundant/dependent on a resource whose revenues can be highly volatile. We also examine additional channels via which the volatility of natural resources may operate, notably investment, human capital and institutional quality.

We test the above hypothesis in panel data over the 1989–2015 period covering 87 countries. The use of panel data is a significant departure from most existing work on the resource curse, which typically relies on cross-country analysis. Moreover, instead of the standard fixed-effect analysis, which imposes considerable homogeneity, we use the panel smooth transition regression (PSTR) approach developed by González et al. (2005). This is a more-intuitive and flexible method than the polynomial models that are widely used in the literature. In this approach, the impact of resource rent, investment, human capital and institutional quality can move smoothly from one regime to another depending on the value of a threshold variable (here, the volatility of resource rents). The fact that the impact of the natural-resource rent may depend on the level of rent volatility is consistent with the use of a threshold regression model. The PSTR is a simple parametric approach, and captures both the heterogeneity between countries and the temporal variability of the impact of resource rents, investment, human capital and institutional quality as a function of the degree of rent

volatility. Last, we consider resource-rent volatility rather than commodity-price volatility (see, for instance, Cavalcanti et al., 2015), as the volatility of commodity prices is not the only factor affecting resource-rich countries. In most economies, natural-resource price volatility and production/export-revenue volatility are very similar, as production and exports generally remain relatively stable over time, with some small year-to-year movements. However, political tensions and conflicts (for instance, war and sanctions) in oil-producing regions have led to a number of supply disruptions and restrictions. As a result, natural-resource price volatility is not the only phenomenon that affects economies with abundant natural resources: the volatility of natural-resource production and exports has also been an important feature post-1970. As shown in the theoretical growth model of Esfahani et al. (2014) for oil-exporting countries, it is the volatility of export revenues that matters. As such, both price and quantity volatility should be taken into account.[1]

The estimation results confirm that, in contrast to the predictions of the resource-curse and Dutch-disease literatures, greater natural-resource abundance significantly increases economic growth. However, the effect of resource abundance falls with volatility and becomes negative for highly-volatile countries. It therefore seems to be volatility, rather than abundance *per se*, that drives the resource-curse paradox. In addition to its adverse impact on natural-resource abundance, the negative effects of natural-resource volatility spread across many growth channels, such as investment, human capital, and institutional quality. Finally, when all channels are taken into account, the impact of resource-rent volatility on the output-growth loss between countries with low and high natural-resource rent volatility is of up to 17 percentage points per year.

The remainder of the paper is structured as follows. Section 2 discusses why volatility may harm output growth. Section 3 presents the data, and Section 4 the empirical specification. Section 5 then presents the empirical evidence. Last, Section 6 concludes.

[1]The Gulf war in 1990, the Iraq war in 2003, the Libyan civil war in 2011 and the persistent geopolitical tensions over Iran's nuclear program are good examples of the disruption of supply in these countries.

2 The volatility of natural-resource revenues and economic growth

In recent decades, output volatility has mainly been perceived as a fleeting business-cycle phenomenon that is of secondary concern for longer-term development objectives. Theoretical work has more recently combined short- and long-term fluctuations into a single framework, while a growing body of research suggests that greater volatility is associated with lower growth. Volatility has therefore come to occupy a more central place in the development debate. Our main message here is that natural-resource revenue volatility should enter into growth analysis alongside the other determinants of output per capita: one of the economic channels through which the resource curse can operate is the volatile nature of natural-resource prices in global markets, and natural-resource production volatility from political factors (for instance, war and sanctions).

Overall, the variability of resource income can affect economies at a global level in a number of ways, apart from the trends in commodity prices (Manley et al., 2017; Frankel, 2010). This effect will mostly be negative when volatility is associated with economic uncertainty, whether from political insecurity (Alesina and Perotti, 1996), macroeconomic instability (Judson and Orphanides, 1999) or institutional weakness (Rodrik, 1991; Serven et al., 1997). The theoretical basis for a negative effect of uncertainty on economic growth comes from risk-aversion, aversion to poor performance, clumsiness, and the irreversibility associated with investment. In addition, the distinction between the *ex-ante* and *ex-post* effects of volatility is important. The former arise from agents' decisions to transfer their allocations between risky and risk-free activities; the latter occur when agents adjust their expectations of future income to current income, or adjust their current expenditure plans to income deficits that they consider impossible or too costly to cover through borrowing. Under these conditions, uncertainty may lead companies to under-invest, or invest in "bad" projects (Bertola and

Caballero, 1994).

Davis and Tilton (2005) argue that commodity-price volatility leads to pro-cyclical fluctuations in government and export revenues, both of which fall with lower prices. This makes it more difficult to plan spending and align public-finance revenue and expenditure, which in turn can reduce the effectiveness of public and private investment. If the government spends all or most of windfall revenues, then almost all of the increase in aggregate demand from the windfall takes the form of government expenditure: the government becomes the booming sector. When revenues fall, the shock will be transmitted to the rest of the economy. Maintaining high levels of expenditure will be unsustainable, while reducing expenditure in line with falling revenues will have a direct impact on aggregate demand. With public expenditure being determined by current revenues, volatile revenues lead to volatile fiscal policy and aggregate demand. These feed through to real exchange-rate volatility, and lead governments to rely more heavily on import tariffs and other trade-distorting taxes to generate revenue and manage the resulting loss of competitiveness in the non-resource sectors. This comes about in addition to the higher production costs that are typical in oil-exporting economies.

Furthermore, natural-resource revenue volatility can reduce countries' ability to meet the conditions required for counter-cyclical expansionary monetary policy when this would be beneficial. Similarly, Humphreys et al. (2007) argue that resource-price fluctuations can be amplified by international lending. When commodity prices are high, commodity-rich countries borrow abroad, exacerbating the boom; when prices fall, international lenders demand repayment and force expenditure cuts, which exacerbate slowdowns. This response/counter-reaction pushed many resource-rich countries into debt crises in the 1980s (Van der Ploeg, 2011). Van der Ploeg and Poelhekke (2009) present causal evidence that output growth per capita falls with the volatility of unexpected output growth, which is itself caused by the volatility of world resource prices in countries that are highly dependent on them: countries

with a GDP share of natural-resource exports of over 19% have a standard deviation of output growth of 7.37%; the analogous figure for countries with this ratio under 5% is only 2.83% (see also Joya, 2015).

The motivation of Van der Ploeg and Poelhekke (2009), who challenge the "traditional resource curse" hypothesis, is closely related to our work here. We however differ by considering the effects of natural-resource rent volatility, rather than the volatility of unexpected GDP growth, on economic output, and investigating the crowding-out effect of rent volatility on the investment, human-capital and institutional-quality channels. We in addition take a different econometric approach, with panel smooth transition models (PSTR) rather than Maximum Likelihood (ML) fixed-effects panel techniques. We therefore see our article as complementary to theirs.

3 Data

We test the relationships between economic growth and both resource rents and rent volatility using a panel dataset of 87 countries over the 1989-2015 period. Our data cover real GDP growth per capita, a measure of resource rents based on quantities, prices, and the costs of production for 13 commodities, and other significant drivers of economic growth such as the initial level of GDP per capita, the share of investment in GDP, human capital, trade openness, GDP volatility, corruption and government stability.[2] A more detailed description of the data and their sources appears in Table A.2.

We follow the literature and remove business-cycle fluctuations when addressing the impact of natural-resource rent volatility by using overlapping five-year averages. This allows us to work from a long-term perspective, as advocated and applied in the literature, while having a much larger time dimension, which is a requirement for the robustness of the PSTR. Given that our data set covers the 1989-2015 period, we construct an unbalanced panel with

[2]GDP volatility is the standard deviation of GDP per capita growth over the years $t-4$ to t.

at most 27 five-yearly observations per country.

Our key independent variables are the level and volatility of natural-resource abundance. Abundance is the ratio of resource rents to GDP (NRA_{it}/GDP_{it}), where resource rents include those from energy and minerals and are based on the World Bank development indicator (WDI, 2016). The rent from a particular commodity is defined as the difference between its World price and average extraction costs, both expressed in current US Dollars. The World price of a particular commodity is global and only varies over time, while extraction costs vary over both time and country. We use this natural-resource revenue measure for the following reasons. First, by measuring resource rents, it is a good proxy for resource revenues that can potentially be appropriated by political leaders. Second, it is fairly wide in terms of country coverage, minimizing sample-selection bias, and has a reasonably-long time dimension. Third, it may help to bypass some endogeneity-related issues, as resource rents predominantly depend on the stock of natural resources and exogenous world prices. Last, the measure has been used in a number of contributions (e.g., Bhattacharyya and Hodler, 2010; Collier and Hoeffler, 2009).

We investigate the relationship between long-run growth and time-varying natural-resource revenue volatility (in contrast to most work in the growth literature, which employs time-invariant measures of volatility), where the latter is the five-year overlapping standard deviation of the annual resource rents (see El-Anshasy et al. (2017) for more details) $w_{R,it}$:

$$\sigma_{R,it,t+s} = \sqrt{\frac{1}{S}\sum_{s=0}^{S}(w_{R,it+s} - \frac{1}{S+1}\sum_{s=0}^{S} w_{R,it+s})^2} \tag{1}$$

where $S = 4$, as we use five-year averages.[3] The volatility ($\sigma_{R,it,t+s}$) reflects the size of the gaps between the resource rent at a point in time ($w_{R,it}$) and its mean value.

We should consider institutional quality when discussing economic growth. One of the

[3]In the PSTR approach, our measure of realized natural-resource rent volatility is then the five-year overlapping standard deviation in annual resource rents.

ways in which natural-resource abundance may inhibit economic growth is via worse institutions. There are six institution-quality indices in the International Country Risk Guide (ICRG), the most relevant of which for our purposes is the government stability and corruption index.[4] The other control variables in the growth equation include country human capital, measured as years of schooling and the returns to education, and gross capital-formation to reflect country investment - formerly referred to as gross domestic investment. This includes net changes in inventories and fixed assets, which consist of land improvement, machinery, equipment purchases, plant, private residential, railways, and the construction of offices, schools, hospitals and commercial buildings. We also control for trade openness, as the sum of the exports and imports of goods and services as a share of GDP. Sachs and Warner (1995) suggest that natural-resource rich countries are more likely to employ protectionist policies such as import substitution and State-led development plans. To combat the effect of Dutch disease and the decline of non-resource sectors, resource-rich countries may also apply quotas and high trade tariffs.

4 Empirical model

The econometric approach is a panel smooth transition model (PSTR) that allows for slope heterogeneity in time and between countries (a heterogeneous panel approach).

[4]The ICRG index of government stability and corruption comes from Political Risk Services Inc., a private firm that annually produces the ICRG database providing quantitative information on political, economic and financial risks. Government stability assesses the government's ability to deliver the programs it has declared and remain in office. The risk rating here is the sum of three sub-components: government unity, legislative force and popular support. The corruption index reflects different aspects of corruption, particularly within the political system. This includes requests for specific payments and bribes related to import and export licences, exchange controls, tax assessments, abusive favoritism, nepotism and the secret financing of supporters.

4.1 Panel smooth transition model

4.1.1 Threshold specification

The PSTR developed by González et al. (2005) relaxes the homogeneity assumption in standard panel models and is a generalization of the panel threshold regression (PTR) model of Hansen (1999).

The PSTR regression is:

$$\begin{aligned} Growth_{it} = \alpha_1 NRA_{it} + \alpha_2 INV_{it} + \alpha_3 HCI_{it} + \alpha_4 GSTAB_{it} \\ + (\alpha_1^{'} NRA_{it} + \alpha_2^{'} INV_{it} + \alpha_3^{'} HCI_{it} + \alpha_4^{'} GSTAB_{it}) * g(VNRA_{it}, \gamma, \delta)) \\ + \theta X_{it}^{'} + \lambda_i + \epsilon_{it} \end{aligned} \tag{2}$$

where $Growth_{it}$ denotes the real growth rate of gross domestic product per capita, and NRA, INV, HCI and $GSTAB$ are the explanatory variables that change across regimes, referring to natural-resource abundance, investment, the human-capital index and the government-stability index respectively. The vector X_{it} captures the regressors that do not vary across regimes: the initial level of GDP per capita, trade openness, financial development, corruption and the volatility of GDP. Last, λ_i is the country fixed effect and ϵ_{it} the idiosyncratic error.

The transition function is logistic:

$$g(VNRA_{it}, \gamma, \delta) = [1 + exp(-\gamma(VNRA_{it} - \delta))]^{-1}, \gamma > 0 \tag{3}$$

This is continuous and bounded between [0,1]. It depends on the transition variable, which is the volatility of resource rent ($VNRA_{it}$), a threshold or location parameter δ and a smoothing parameter γ. As γ tends to infinity, the transition function $g(VNRA_{it}, \gamma, \delta)$ tends to the indicator function, and the transition is sharp, as in the PTR model of Hansen

(1999). As γ tends to zero, the transition function $g(VNRA_{it}, \gamma, \delta)$ becomes constant and the model is standard linear with fixed effects (the so-called within model), implying constant and homogeneous elasticities. The PSTR has one great advantage: it allows the effect of NRA, INV, HCI, $GSTAB$ to vary with resource-rent volatility.[5] The impact of resource rents on growth, depending on the level of resource-rent volatility, is given by:

$$e_{it} = \frac{\partial Growth_{it}}{\partial NRA_{it}} = \alpha_1 + \alpha_1^{'} g(VNRA_{it}, \gamma, \delta) \tag{4}$$

The properties of the transition function are such that $\alpha_1 \leq e_{it} \leq \alpha_1 + \alpha_1^{'}$ if $\alpha_1^{'} \geq 0$, and $\alpha_1 + \alpha_1^{'} \leq e_{it} \leq \alpha_1$ if $\alpha_1^{'} \leq 0$.

The PSTR model can be generalized to $r+1$ extreme regimes as follows:

$$Growth_{it} = \alpha_1 NRA_{it} + \sum_{j=1}^{r} \alpha_j^{'} NRA_{it} * g_j(VNRA_{it}, \gamma_j, \delta_j) + \lambda_i + \epsilon_{it} \tag{5}$$

where the transition functions $g_j(VNRA_{it}, \gamma_j, \delta_j)$ depend on the slope parameters γ_j and the location parameters δ_j. In this generalization, the marginal impact of natural-resource rents on growth is:

$$e_{it} = \frac{\partial Growth_{it}}{\partial NRA_{it}} = \alpha_1 + \sum_{j=1}^{r} \alpha_j^{'} g_j(VNRA_{it}, \gamma_j, \delta_j) \tag{6}$$

4.1.2 Estimation and specification test

The estimation of the PSTR parameters in consists in eliminating the individual effects λ_i by substituting the country-specific means and then estimating the transformed model via non-linear least squares. The procedure in González et al. (2005) consists in (i) testing linearity against the PSTR model, and (ii) determining the number, r, of the transition function, *i.e.* the number $r+1$ of extreme regimes.[6] Testing the linearity of Equation(5) corresponds to

[5] In the remainder of this section, for simplicity, we will consider the PSTR model with a single time-varying variable, the resource rent.

[6] The parameters α and $\alpha^{'}$ correspond to the estimated parameters for extreme regimes: α represents the coefficient as the transition function $g(VNRA_{it}, \gamma, \delta)$ tends towards 0, and the sum of α and $\alpha^{'}$ the

$H_0 : \gamma = 0$ or $H_0 : \alpha_1^{'} = 0$. However, in both cases the test is not standard, as under H_0 the PSTR model contains unidentified nuisance parameters. To avoid this problem, the transition function $g(VNRA_{it}, \gamma, \delta)$ can be replaced by its first-order Taylor expansion around $\gamma = 0$ and we can test an equivalent hypothesis in an auxiliary regression:

$$Growth_{it} = \alpha_1 NRA_{it} + \Theta_1 NRA_{it} VNRA_{it} + \lambda_i + \epsilon_{it} \tag{7}$$

In this first-order Taylor expansion, the parameter Θ_1 is proportional to the slope parameter γ, $\epsilon_{it}^* = \epsilon_{it} + R\Theta_1 VNRA_{it}$, and R is the remainder of the Taylor expansion. Testing the linearity of rent volatility against the PSTR model boils down to $H_0 : \Theta_1 = 0$ in Equation(7). Standard tests can then be applied. Let SSR_0 denote the panel sum of squared residuals under H_0 (the linear panel model with individual effects) and SSR_1 that under H_1 (the PSTR model with two regimes). Three statistics can then be calculated: the Wald test (the Lagrange-Multiplier test) LM, its Fisher-version LM_f, and the pseudo Likelihood-ratio test LRT:

$$LM = TN[SSR_0 - SRR_1]/SSR_1 \tag{8}$$

$$LM_f = [SSR_0 - SRR_1]/[SRR_1/(TN - N - 1)] \tag{9}$$

$$LRT = -NT[log(SSR_1) - log(SSR_0)] \tag{10}$$

Under the null hypothesis, H_0, the LM statistic is distributed $\chi^2(1)$, LM_f has an approximate F(1,TN-N-1) distribution, and LRT is also $\chi^2(1)$. A similar method is used to test the number of transition functions in the model, or equivalently the number of extreme regimes.

coefficient as the transition function tends towards 1. Between these two extreme regimes, the PSTR model allows the coefficients to vary across countries and over time according to the transition value: the coefficient for country i at time t is defined as a weighted average of α and $\alpha^{'}$ in Equation 2.

If linearity is rejected, the sequential approach consists in testing the null hypothesis of no remaining non-linearity in the transition function. We then test whether there is one transition function or two or more transition functions as follows:

$$Growth_{it} = \alpha_1 NRA_{it} + \alpha_1{}' NRA_{it} g_1(VNRA_{it}, \gamma_1, \delta_1) + \alpha_2{}' NRA_{it} g_2(VNRA_{it}, \gamma_2, \delta_2) + \lambda_i + \epsilon_{it} \tag{11}$$

As in the case of one transition function, the test replaces the second transition function by its first-order Taylor expansion around $\gamma_2 = 0$, and then tests the linear constraints on the parameters. Using this first-order Taylor expansion, the model becomes

$$Growth_{it} = \alpha_1 NRA_{it} + \alpha_1{}' NRA_{it} g_1(VNRA_{it}, \gamma_1, \delta_1) + \Theta_2 NRA_{it} VNRA_{it} + \lambda_i + \epsilon^*_{it} \tag{12}$$

Let SSR_0 denote the panel sum of squared residuals under H_0 (the PSTR model with one transition function), and SSR_1 that in the transformed model Equation (12). As above, the test statistics can be calculated by adjusting the number of degrees of freedom. The sequential procedure is then as follows. Given a PSTR model with $r = r^*$, test the null $H_0 : r = r^*$ against $H_1 : r = r^* + 1$. If H_0 is not rejected the procedure stops. Otherwise, the null hypothesis $H_0 : r = r^* + 1$ is tested against $H_1 : r = r^* + 2$. The testing procedure continues until the null hypothesis of no remaining non-linearity is not rejected. As noted in González et al. (2005), given the sequential aspect of this testing procedure the significance level (at each step of the procedure) should be reduced by a constant factor $0 < \tau < 1$ in order to avoid excessively large models. Following their suggestion, we set τ to 0.5.

5 Empirical results

In this section, we investigate whether natural-resource abundance *per se* is a significant driver of economic failure, or whether this latter instead depends on the volatility of natural-

resource rents. We also explore whether volatility affects economic growth via the channels of investment, human capital and institutional quality.

We carry out this analysis using an approach that differs from that in traditional panel models, which impose a strong assumption of linearity and therefore do not allow the effects of natural resources on economic growth to vary over time and between countries. However, countries differ in their natural endowments and production capacities and, by extension, resource revenues and their impact on economic growth may not be the same. The natural-resource effect is also assumed to be constant over time, which is unrealistic as natural-resource markets, and so natural-resource incomes, fluctuate over time, reflecting uncertainty. We therefore rely on the PSTR model, which is a more-appropriate linear heterogeneous panel model with coefficients that vary across units and over time.

5.1 PSTR results

Before carrying out PSTR regressions, we first test for linearity as in González et al. (2005): if the null hypothesis is not rejected, the testing process stops and a different transition variable is tested.[7] If the null hypothesis of linearity is rejected, the next step is to test the non-remaining linearity, *i.e.* the number of regimes. Last, we estimate the parameters. As previous work has shown that the Fisher-version of the test has better size properties in small samples than the asymptotic $\chi 2$-based statistic (Dijk et al., 2002), we determine the number of transition regimes (r^*) using the Fisher-version statistics (in all of the cases considered here, the LM test produces the same the number of transition regimes). The linearity-test results appear in Appendix Table A.4: the linearity hypothesis is strongly rejected for the threshold variable (here, the rent-volatility). We thus need to determine the number of transition functions required to capture non-linearity. The null hypothesis of no remaining

[7]We also check the integration-order properties of the variables. We run the linear unit-root test of Im et al. (2003) (IPS (2003)). The results in Table A.3 confirm that all variables are stationary (*i.e.* all variables are I (0))

non-linearity is not rejected for the threshold variable, so that only one transition function is required. The coefficients therefore switch between low and high rent-volatility regimes delimited by a threshold.

Table 1 lists the resulting PSTR estimated parameters. As in logit or probit models, the value of the estimated parameters is not directly interpretable, although their signs are (Fouquau et al., 2008).[8] A negative (positive) coefficient implies that the transition variable is negatively (positively) correlated with the resource-rent coefficient. To identify the channel(s) via which GDP per capita growth may be negatively affected by rent volatility independently of natural-resource abundance, we follow Beck et al. (2003) and consider investment, human capital (education) and institutional quality (the government-stability index). These channels are discussed extensively in Gylfason (2006).

Turning to our variables of interest, Model A in Table 1 presents the estimation results of the conditional impact of natural-resource rents, investment, human capital and institutions on economic growth by the level of rent volatility. The marginal impact of these variables is positive when rent volatility is below the threshold of 1.97; past this threshold there is clear evidence of a conditional resource curse through the impact of resource rents, investment, and human capital. At low volatility levels, resource rents (0.082), investment (0.162), and human capital (0.928) have a positive impact on growth, but all three turn negative in the high rent-volatility regime (0.082-0.215, 0.162-0.629, and 0.928-1.027, respectively). These results confirm the negative role of volatility: higher volatility turns the resource blessing into a resource curse. The negative growth effects of rent volatility outweigh the positive impact of resource rents, investment, human capital and institutions, again suggesting that

[8] It is important to note that the impact of NRA in a PSTR can be different from the estimated parameters for extreme regimes, *i.e.* the parameters α_1 and $\alpha_1^{'}$. As illustrated in Equation (6), these parameters do not directly correspond to the NRA parameter. The α_1 parameter corresponds to the NRA coefficient only as the transition function $g(VNRA_{it}, \gamma, \delta)$ tends towards 0. The sum of the α_1 and $\alpha_1^{'}$ parameters corresponds to the NRA coefficient only as the transition function $g(VNRA_{it}, \gamma, \delta)$ tends towards 1. Between these two extremes, the NRA coefficient is defined as a weighted average of α_1 and $\alpha_1^{'}$. It is therefore in general difficult to directly interpret the values of these parameters that correspond to extreme situations.

Table 1: PSTR Results

Dependent variable: GDP growth per capita		
Model	Model A	Model B
Threshold variable	Rent volatility	Lag of Rent volatility
Initial GDP	-0.015***	-0.013***
	(-8.12)	(-7.94)
FD	-0.040***	-0.039***
	(-28.58)	(-28.95)
Trade openness	0.004*	0.005**
	(1.73)	(2.07)
Corruption	-0.317***	-0.275***
	(-8.30)	(-6.36)
VGDP	-0.310***	-0.312***
	(-19.33)	(-20.42)
NRA	0.082***	0.062***
	(4.88)	(3.27)
Investment	0.162***	0.169***
	(20.18)	(21.12)
Human capital	0.928***	0.884***
	(5.36)	(4.18)
Government stability	0.240***	0.249***
	(12.66)	(12.67)
NRA*g	-0.215***	-0.190***
	(-12.55)	(-9.83)
Investment*g	-0.629***	-0.627***
	(-48.57)	(-46.59)
Human capital*g	-1.027***	-1.085***
	(-6.42)	(-6.80)
Government stability*g	-0.023	-0.008
	(-0.52)	(-0.16)
γ	2.92	2.94
δ	1.98	1.99

Notes: T-statistics are in (); *, ** and *** refer to the 10%, 5% and 1% significance levels, respectively. Model B uses lags for all of the variables (threshold and control variables). The vector parameters β $(\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ and $\beta^{'}$ $(\alpha_1{}', \alpha_2{}', \alpha_3{}', \alpha_4{}')$ correspond to those for the extreme regimes: β are those as the transition function $g(VNRA_{it}, \gamma, \delta)$ tends towards 0 and the sum of β and $\beta^{'}$ those as the transition function tends towards 1.

it is volatility, rather than abundance *per se*, that drives the resource curse (Ding and Field, 2005; Alexeev and Conrad, 2009; Brunnschweiler and Bulte, 2008). Volatility is also emphasized in Van der Ploeg and Poelhekke (2009) and Cavalcanti et al. (2015). In Van der Ploeg and Poelhekke (2009), the resource curse is due to the volatility of commodity prices rather than resource abundance, although their empirical analysis is based on the volatility of unexpected output growth and not on resource-rent volatility. Resource-rent volatility is probably more relevant here, as the volatility of unexpected output growth is likely driven by a large number of factors that are not directly related to the abundance of natural resources.

The harmful impact of such volatility extends beyond resource rents to growth channels such as investment and human capital. The fact that natural-resource abundance turns into a curse when volatility is high suggests that resource-rich countries' fiscal and current-account balances are adversely affected by fluctuations in their resource revenues, leading to destabilizing macroeconomic effects. Investment seems to be an important channel through which rent volatility affects GDP per capita growth, in line with Papyrakis and Gerlagh (2004); Gylfason (2006). This may reflect that economic agents save less in commodity-abundant countries, as they perceive revenues from primary commodity exports to be a permanent source of future income. Another related factor is the uncertainty arising from resource-rent volatility in these economies, which may inhibit the accumulation of physical capital by risk-averse investors. Moreover, as noted by Catão and Kapur (2006) and Catão et al. (2009), Terms of Trade volatility adversely affects capital accumulation and growth by raising the country's default risk, hence widening the country spreads and lowering borrowing capacity. The results also indicate that the crowding-out effect of rent volatility on human capital might explain the resource curse via low educational spending or the weakness of the educational system Gylfason (2001). The prosperity of resource-based industries can lead to a greater opportunity cost of education, reducing human-capital accumulation. A last channel is that uncertainty generally increases income inequality, leading to binding

credit constraints on households with low net worth. Given that families finance their own education, greater volatility reduces human-capital investment and thus economic growth. A lower growth rate from the crowding out of human capital in resource-abundant and/or volatile economies has been highlighted in the literature (see for example, Aizenman and Pinto (2004)). Finally, the government-stability index, which reflects institutional quality, positively affects growth at low levels of volatility but is insignificant at higher volatility levels.

Table 1's specifications control for other important determinants of growth, such as the initial level of GDP per capita, trade openness, corruption, GDP volatility, and financial development. These control variables attract significant coefficients with the expected signs in all regressions. Initial GDP per capita has a negative coefficient, so that there is conditional convergence: lower GDP per capita countries grow faster. The coefficient on trade openness is also positive, which is consistent with both neoclassical and endogenous growth theory. In the neoclassical case, the growth benefits of trade are based on comparative advantage (*i.e.* production factor endowments and technology); in endogenous growth theory, trade increases economic growth through, for example, technological diffusion between countries (López-Villavicencio and Mignon, 2011). Corruption has a negative impact on growth, as is widely accepted in the literature. Bank credit to the private sector, measuring financial development (King and Levine, 1993), is negatively related to growth, in line with the recent empirical research that contradicts the traditional findings. It seems reasonable to assume that financial development promotes growth where the financial system is less-developed, but has the opposite effect in countries with advanced financial sectors. Demirgüç-Kunt and Huizinga (2010) illustrate that Banks have gradually steered away from their traditional intermediation activities in recent decades. In the 1990s and 2000s, the non-interest incomes of Banks in countries with advanced financial markets rose substantially, particularly via the trading of mortgage-backed securities. Greater financial depth allows the funding of more

Table 2: Individual estimated impacts

Country	$\bar{\beta}NRA$	$\bar{\beta}INV$	$\bar{\beta}HCI$	Country	$\bar{\beta}NRA$	$\bar{\beta}INV$	$\bar{\beta}HCI$
Albania	0.066	0.114	0.851	Japan	0.082	0.160	0.924
Algeria	-0.096	-0.359	0.078	Jordan	0.055	0.083	0.799
Australia	0.048	0.062	0.765	Kazakhstan	-0.126	-0.446	-0.066
Austria	0.081	0.159	0.924	Kenya	0.075	0.141	0.895
Bahrain	0.045	0.053	0.750	Madagascar	0.053	0.078	0.790
Bangladesh	0.081	0.158	0.922	Malawi	-0.001	-0.083	0.529
Belgium	0.082	0.160	0.924	Malaysia	-0.018	-0.130	0.451
Bolivia	-0.021	-0.140	0.434	Mexico	0.049	0.064	0.768
Botswana	-0.017	-0.129	0.453	Morocco	0.055	0.083	0.798
Brazil	0.077	0.146	0.902	Netherlands	0.081	0.158	0.922
Bulgaria	0.079	0.154	0.915	New Zealand	0.080	0.156	0.919
Burkina Faso	-0.020	-0.136	0.441	Niger	0.027	-0.001	0.663
Cameroon	-0.056	-0.242	0.269	Norway	0.014	-0.037	0.603
Canada	0.078	0.148	0.906	Pakistan	0.081	0.157	0.920
Chile	-0.025	-0.151	0.418	Panama	0.081	0.159	0.924
China	0.024	-0.010	0.647	Paraguay	0.081	0.158	0.921
Colombia	0.051	0.070	0.778	Peru	-0.024	-0.148	0.421
Costa Rica	0.080	0.157	0.919	Philippines	0.076	0.144	0.898
Croatia	0.081	0.159	0.923	Poland	0.080	0.156	0.919
Cyprus	0.082	0.160	0.924	Portugal	0.081	0.159	0.924
Czechia	0.081	0.158	0.921	Republic of Korea	0.082	0.160	0.924
Côte d'Ivoire	0.058	0.091	0.813	Romania	0.077	0.146	0.902
Congo. Dem. Rep.	-0.114	-0.413	-0.011	Russian Federation	-0.011	-0.112	0.481
Denmark	0.081	0.157	0.921	Saudi Arabia	-0.125	-0.444	-0.062
Dominican Republic	0.052	0.074	0.785	Senegal	0.079	0.153	0.913
Ecuador	-0.082	-0.320	0.141	Slovakia	0.081	0.159	0.924
Egypt	-0.053	-0.233	0.283	Slovenia	0.081	0.159	0.924
El Salvador	0.081	0.159	0.923	South Africa	0.025	-0.006	0.654
Estonia	0.080	0.154	0.915	Spain	0.082	0.160	0.924
Finland	0.081	0.159	0.924	Sri Lanka	0.081	0.159	0.924
France	0.082	0.160	0.924	Sweden	0.081	0.159	0.923
Gabon	-0.130	-0.458	-0.084	Switzerland	0.082	0.160	0.924
Germany	0.081	0.160	0.924	Thailand	0.080	0.156	0.919
Greece	0.081	0.159	0.924	Togo	-0.023	-0.145	0.426
Guatemala	0.081	0.157	0.920	Tunisia	0.052	0.072	0.782
Honduras	0.079	0.152	0.911	Turkey	0.081	0.159	0.924
Hungary	0.081	0.159	0.923	Uganda	-0.068	-0.278	0.209
India	0.071	0.129	0.874	Ukraine	0.040	0.039	0.727
Indonesia	0.014	-0.039	0.601	United Arab Emirates	-0.130	-0.459	-0.086
Ireland	0.081	0.159	0.923	United Kingdom	0.081	0.157	0.921
Israel	0.081	0.159	0.924	United Republic of Tanzania	0.029	0.006	0.673
Italy	0.082	0.160	0.924	United States of America	0.081	0.157	0.921
Jamaica	0.051	0.071	0.780	Uruguay	0.081	0.158	0.922

Note: This table shows the average $\bar{\beta}$ effect of each regime-dependent variable on economic growth for each country.

investment projects, but there may be a point at which the remaining investment projects are less profitable than the development of new business fields. This is particularly true when the financial sector grows faster than the number of promising investment opportunities. The shift in Banking activities in recent decades has led to higher inflation and an increasing vulnerability of banks to economic crises, without triggering growth (Demirgüç-Kunt and Huizinga, 2010). Last, as compared to common practice, we include GDP volatility as a control variable, which attracts a significant negative coefficient. Aghion et al. (2005) argue that volatility creates uncertainty in firms' liquidity positions, discouraging them from making productivity-enhancing investments. These forgone investments keep the economy on a low-growth path. The idea that volatility and economic growth are negatively correlated is quite-widely accepted (Ramey and Ramey, 1994).

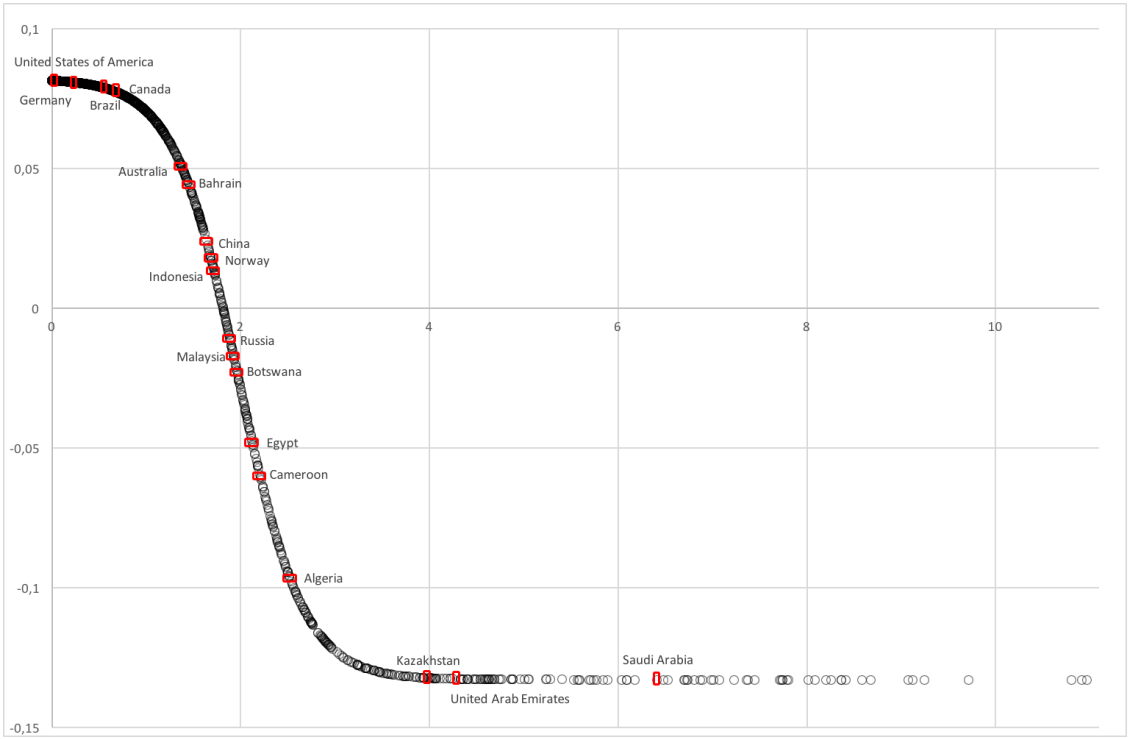

Figure 1: The estimated impact of natural-resource rents on GDP/Capita growth.
Note: The figure represents the estimated impact of natural-resource rents on GDP/Capita growth using the historical value of the transition function (the volatility of natural-resource rents). Each circle represents an observation.

Model B of Table 1 checks the robustness of our results by using the lags of both natural-

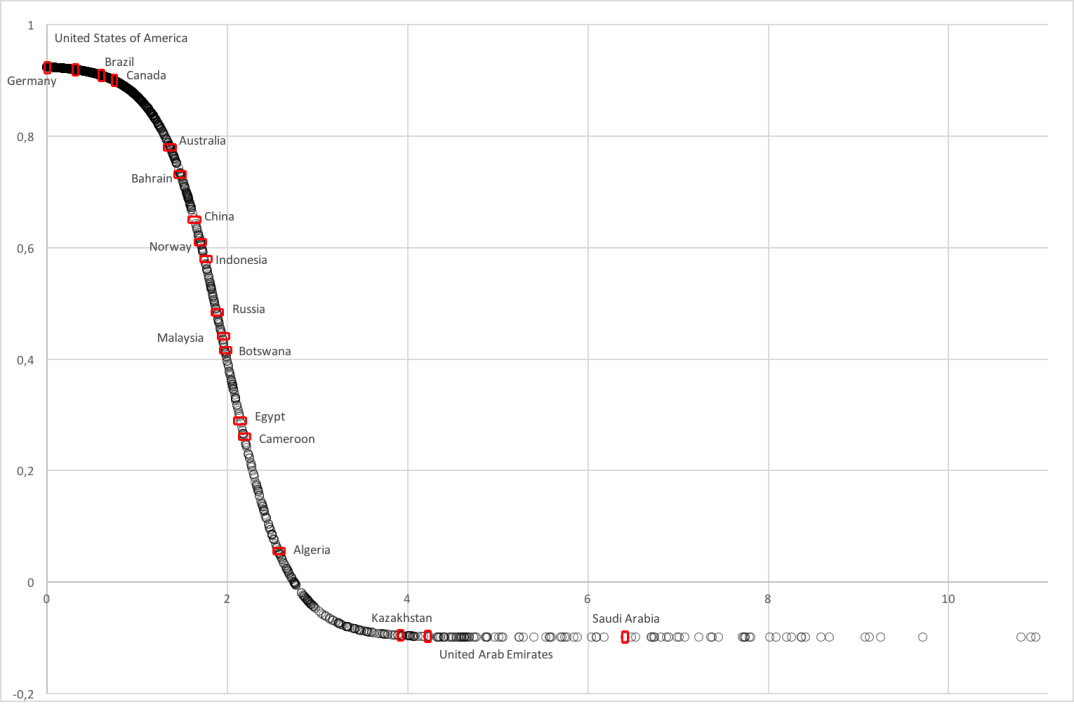

Figure 2: The estimated impact of human capital on GDP/Capita growth.
Note: The figure represents the estimated impact of human capital on GDP/Capita growth using the historical value of the transition function (the volatility of natural-resource rents). Each circle represents an observation.

resource rent volatility and the independent variables: the results remain consistent. We also test the validity of the PSTR results using a measure of natural-resource rent per capita rather than per GDP. The linearity-test and PSTR results appear in Tables A.5 and A.6, respectively. In the low resource-rent volatility regime (below the 2.67 threshold), natural-resource rents per capita improve economic performance; the opposite holds for the high natural-resource rent volatility regime. The main findings of the impact of natural-resource rent volatility on investment, human capital and institutional quality are robust to this change in the natural-resource endowment measure.

Table 2 lists (for each country) the average estimated coefficients for each regime-dependent variable on GDP growth: these differ across countries and depend negatively on resource-rent volatility. This is illustrated in Figures 1 to 2, which plot the country average impact of resource rents and human capital against country average resource-rent volatility, respectively. We also note that the transition between the growth-enhancing and the natural-resource curse regimes takes place in a smooth fashion, as illustrated by the low speed parameter (γ = 2.92: see Table 1).

Figures 1 and 2 highlight a handful of countries to illustrate whether natural-resource abundance is a blessing or a curse. The first observation is that the level of volatility plays a major role in determining whether countries benefit from natural-resource wealth or are on the contrary adversely-affected. The second is that all the countries with relatively low volatility that benefit from natural resources are developed, while those with high volatilities suffer from natural resource and are in the group of developing countries. Finally, these figures depict a fairly realistic list of countries that either benefit or suffer from the resource curse.

It is also important to quantify the overall net impact of volatility on GDP. The first step is to obtain the average estimated coefficients (over time in each country) on the explanatory variables that are a function of volatility (see Table 2). To carry out a *ceteris paribus* analysis,

we choose a reference scenario where all sample countries have the same natural-resource levels, investment and human capital (given by their averages over time and across countries). We then calculate predicted GDP growth in the reference scenario for each country, the differences in which reflect only countries' different natural-resource volatilities. There are large differences in growth rates between the countries with low natural-resource volatility (such as France, the USA, Switzerland and Japan) and those with high volatility (such as Saudi Arabia and the United Arab Emirates). The horizontal axis of Figure 3 shows the percentage-point impact of volatility, and GDP growth-loss is on the vertical axis: comparing volatility extremes, estimated GDP losses are up to 17 percentage points per year. This loss reflects the cumulative impact of all the growth channels that are negatively affected by volatility.

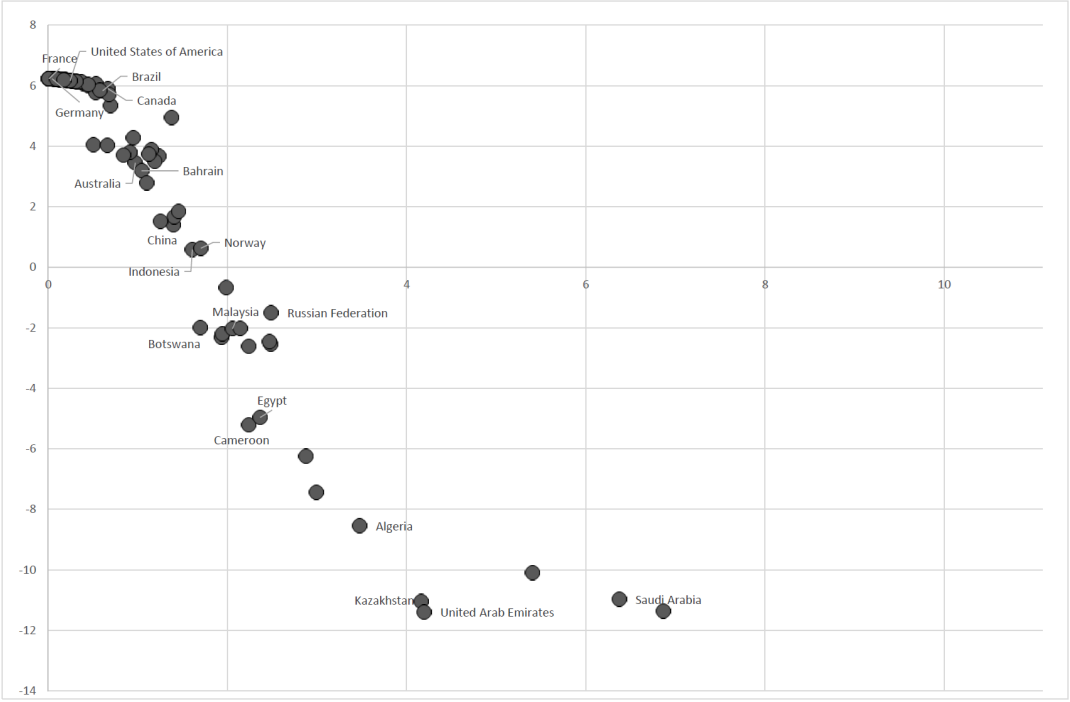

Figure 3: The estimated impact of volatility on GDP/Capita growth.
Notes: The figure represents the estimated impact of volatility on GDP/Capita growth using the historical value of the transition function (the volatility of natural-resource rents). Each circle represents the average impact for each country.

6 Conclusion

This paper has used a panel smooth transition regression model (PSTR) to analyze the resource-curse paradox. The PSTR better accounts for the conditional nature of the resource curse. While the traditional resource curse predicts lower growth with resource abundance, our results differ in that resource abundance, as represented by the ratio of resource rents to GDP, increases growth as volatility tends to 0. We do, however, find strong evidence that resource-rent volatility reduces growth: the GDP growth loss can be up to 17 percentage points per year for countries with the greatest natural-resource rent volatility (such as Saudi Arabia and the United Arab Emirates) as compared to those with low volatility (such as France, the USA, Switzerland and Japan). Volatility, rather than abundance *per se*, seems to lie behind the resource curse. We show that the marginal impact of natural-resource rents, investment, human capital and institutional quality on growth is a decreasing function of resource-rent volatility. Volatility is key in explaining the under-performance of resource-abundant countries.

More importantly, as a number of channels may produce harmful growth effects, each resource-rich country should implement economic policies to limit these specific negative impacts. These may include sovereign wealth funds, stabilization funds, export diversification and developed financial systems. Consequently, resource abundance may be a blessing as long as it is accompanied by policies enhancing diversification and financial development.

Appendix

Table A.1: List of countries used in the empirical analysis (87)

Developing countries		Developed countries
Albania	Kuwait	Australia
Algeria	Madagascar	Austria
Angola	Malawi	Belgium
Azerbaijan	Malaysia	Canada
Bahrain	Mali	Cyprus
Bangladesh	Mexico	Czechia
Bolivia	Morocco	Denmark
Botswana	Namibia	Estonia
Brazil	Nicaragua	Finland
Bulgaria	Niger	France
Burkina Faso	Nigeria	Germany
Cameroon	Oman	Greece
Chile	Pakistan	Ireland
China	Panama	Israel
Colombia	Paraguay	Italy
Congo	Peru	Japan
Costa Rica	Philippines	Latvia
Croatia	Poland	Lithuania
Côte d'Ivoire	Romania	Netherlands
Congo, Dem. Rep.	Russian Federation	New Zealand
Dominican Republic	Saudi Arabia	Norway
Ecuador	Senegal	Portugal
Egypt	South Africa	Republic of Korea
El Salvador	Sri Lanka	Slovakia
Gabon	Sudan	Slovenia
Gambia	Syrian Arab Republic	Spain
Ghana	Thailand	Sweden
Guatemala	Togo	Switzerland
Honduras	Tunisia	United Kingdom
Hungary	Turkey	United States of America
India	Uganda	
Indonesia	Ukraine	
Iran, Islamic Rep.	United Arab Emirates	
Iraq	United Republic of Tanzania	
Jamaica	Venezuela	
Kazakhstan	Vietnam	
Kenya		

Table A.2: List of variables and sources

Variable	Definition and Construction	Source
GDP per capita growth	Log difference of real GDP (constant 2010 US$) per capita averaged over the years $t-4$ to t.	
Volatility of GDP per capita growth	Standard deviation of GDP per capita growth over the years $t-4$ to t.	
Natural-resource rents (% of GDP)	Natural resources as a share of GDP, averaged over the years $t-4$ to t. Natural-resource rents are the sum of the rents from oil, natural gas, coal (hard and soft), minerals, and forests.	
Volatility of natural-resource rents (% of GDP)	Standard deviation of natural-resource rents (% of GDP) over the years $t-4$ to t.	Authors' calculations using data from the World Bank (2010) WDI.
Trade Openness	Trade is the sum of the exports and imports of goods and services measured as a share of GDP and averaged over the years $t-4$ to t.	
Investment	Gross fixed capital formation (formerly gross domestic fixed investment) as a share of GDP, averaged over the years $t-4$ to t.	
Private credit (% of GDP)	Private credit by banks and other financial institutions as a share of GDP, averaged over the years $t-4$ to t.	Authors' calculations using data from the Financial development 2018.
Government Stability	Government Stability is an assessment of both the government's ability to carry out its declared program(s), and its ability to stay in office averaged over the years $t-4$ to t.	Authors' calculations using data from the International country risk guide (Political Risk Services (2008)).
Corruption	This is an assessment of corruption within the political system, averaged over the years $t-4$ to t.	
Human Capital	Human-capital index, based on years of schooling and the returns to education, averaged over the years $t-4$ to t.	Authors' calculations using data from the Penn World Table 9.0.

Table A.3: Panel unit-root test results

Test	IPS	
	Statistic	P-value
GDP growth	-3.658***	(0.0001)
NRA	-2.461 ***	(0.0069)
VNRA	-10.784***	(0.0000)
VGDP	-4.531***	(0.0000)
FD	-3.697***	(0.0001)
Government stability	-5.575***	(0.0000)
Corruption	-6.008***	(0.0000)
Investment	-6.202***	(0.0000)
Human capital	-25.164***	(0.0000)
Trade openness	-4.906***	(0.0000)

Notes: P-values are in (); *, ** and *** refer to the 10%, 5% and 1% significance levels, respectively.
The Lag selection (automatic) is based on the Schwarz information criterion (SIC).

Table A.4: Linearity and no-remaining linearity tests for Models A and B

Threshold variable	Rent volatility	Lag of Rent volatility
r*	1	1
$H_0 : r = 0$ vs $H_1 : r = 1$		
Wald test (LM)	767.077 (0.000)	765.978 (0.000)
Fisher test (LM_f)	916.115 (0.000)	955.955 (0.000)
$H_0 : r = 1$ vs $H_1 : r = 2$		
Wald test (LM)	2.095 (0.078)	0.603 (0.660)
Fisher test (LM_f)	8.982 (0.061)	2.783 (0.595)
Location parameter δ	1.976	1.995
Smoothing parameter γ	2.922	2.941

Notes: Under H_0, LM and LRT have an asymptotic $\chi^2(4)$ distribution, LMF has an asymptotic $F(4, TN - N - (r + 1))$ distribution, where N is the number of individuals, T the number of periods and r the number of thresholds under H_0. For test statistics, the p-values are in parentheses. The test strategy is as follows: we first test the linear model ($r = 0$) against a model with one threshold (r = 1). If the null hypothesis is rejected, the single threshold is tested against a double threshold ($r = 2$). This latter part tests for no-remaining linearity. For each of the above models, we accept the hypothesis of one threshold and two regimes.

Table A.5: Linearity and no-remaining linearity tests for Models C and D

Threshold variable	Rent volatility	Lag of Rent volatility
r*	1	1
$H_0 : r = 0$ vs $H_1 : r = 1$		
Wald test (LM)	84.084 (0.000)	85.737 (0.000)
Fisher test (LM_f)	54.184 (0.000)	57.701 (0.000)
$H_0 : r = 1$ vs $H_1 : r = 2$		
Wald test (LM)	0.975 (0.419)	0.985 (0.414)
Fisher test (LM_f)	4.416 (0.353)	5.009 (0.286)
Location parameter δ	5.731	5.807
Smoothing parameter γ	2.676	3.603

Notes: Under H_0, LM and LRT have an asymptotic $\chi^2(4)$ distribution, LMF has an asymptotic $F(4, TN - N - (r + 1))$ distribution, where N is the number of individuals, T the number of periods and r the number of thresholds under H_0. For test statistics, the p-values are in parentheses. The test strategy is as follows: we first test the linear model ($r = 0$) against a model with one threshold (r = 1). If the null hypothesis is rejected, the single threshold is tested against a double threshold ($r = 2$). This latter part tests for no-remaining linearity. For each of the above models, we accept the hypothesis of one threshold and two regimes.

Table A.6: PSTR Results

Dependent variable: GDP growth per capita		
Model	Model C	Model D
Threshold variable	Rent volatility	Lag of Rent volatility
Initial GDP	-0.013***	-0.012***
	(-12.42)	(-11.74)
FD	-0.039***	-0.040
	(-26.82)	(-26.39)
Trade openness	0.003	0.002
	(1.48)	(1.03)
Corruption	-0.283***	-0.404***
	(-6.76)	(-9.56)
VGDP	-0.051***	-0.034**
	(-3.26)	(-2.35)
NRA	0.007***	0.007***
	(5.95)	(4.91)
Investment	0.064***	0.078***
	(8.01)	(10.31)
Human capital	0.565***	0.732***
	(2.73)	(3.28)
Government stability	0.433***	0.442***
	(24.19)	(23.69)
NRA*g	-0.026***	-0.024***
	(-21.06)	(-18.79)
Investment*g	-0.134***	-0.103***
	(-4.34)	(-4.87)
Human capital*g	-0.855**	-1.510***
	(-2.22)	(-3.70)
Government stability*g	0.026	0.123
	(0.25)	(1.03)
γ	2.67	3.60
δ	5.73	5.80

Notes: T-statistics are in (); *, ** and *** refer to the 10%, 5% and 1% significance levels, respectively. Model D uses lags for all the variables (the threshold and independent variables). This table reports the results when using a measure of natural-resource rents per capita instead of per GDP. The vector parameters β $(\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ and $\beta^{'}$ $(\alpha_1{}', \alpha_2{}', \alpha_3{}', \alpha_4{}')$ correspond to the estimated vector parameters for extreme regimes, *i.e.* β are the coefficients as the transition function $g(VNRA_{it}, \gamma, \delta)$ tends towards 0, and the sum of β and $\beta^{'}$ are the coefficients as the transition function tends towards 1.

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