WP/12/12

IMF Working Paper

Commodity Price Volatility and the Sources of Growth

Tiago V. de V. Cavalcanti, Kamiar Mohaddes, and Mehdi Raissi

INTERNATIONAL MONETARY FUND

 WP/12/12

IMF Working Paper

Middle East and Central Asia Department

Commodity Price Volatility and the Sources of Growth[1]

Prepared by Tiago V. de V. Cavalcanti, Kamiar Mohaddes, and Mehdi Raissi

Authorized for distribution by Paul Cashin

January 2011

Abstract

This paper studies the impact of the level and volatility of the commodity terms of trade on economic growth, as well as on the three main growth channels: total factor productivity, physical capital accumulation, and human capital acquisition. We use the standard system GMM approach as well as a cross-sectionally augmented version of the pooled mean group (CPMG) methodology of Pesaran et al. (1999) for estimation. The latter takes account of cross-country heterogeneity and cross-sectional dependence, while the former controls for biases associated with simultaneity and unobserved country-specific effects. Using both annual data for 1970–2007 and five-year non-overlapping observations, we find that while commodity terms of trade growth enhances real output per capita, volatility exerts a negative impact on economic growth operating mainly through lower accumulation of physical capital. Our results indicate that the negative growth effects of commodity terms of trade volatility offset the positive impact of commodity booms; and export diversification of primary commodity abundant countries contribute to faster growth. Therefore, we argue that volatility, rather than abundance per se, drives the "resource curse" paradox.

JEL Classification Numbers: C23, F43, O13, O40.

Keywords: Growth, resource curse, commodity prices, volatility.

Authors' E-Mail Addresses: mraissi@imf.org; km418@cam.ac.uk; tvdvc2@cam.ac.uk.

---

[1] We are grateful to Joshua Aizenman, Paul Cashin, Luis Catão, Thomas Helbling, Hashem Pesaran, Abdelhak Senhadji, Jeffrey Williamson, and seminar participants at the RES Annual Conference 2011, the CSAE University of Oxford and the MCD Discussion Forum Series at the IMF, as well as conference participants at the ERF Regional Conference on Environmental Challenges in the MENA Region for constructive comments and suggestions. Financial support from the Economic Research Forum (ERF) through the `Second Environmental Economics Research Competition for MENA' is gratefully acknowledged. The views expressed in this paper are those of the authors and not necessarily those of the ERF.
Tiago V. de V. Cavalcanti and Kamiar Mohaddes: Faculty of Economics, University of Cambridge, UK.

Contents

Tables

Figures

I. INTRODUCTION

Many countries in the world specialize in the export of just a few primary products and/or depend heavily on natural resource endowments. These countries are usually exposed to substantial commodity price volatility and suffer from a high degree of macroeconomic instability, which in turn might have negative implications for their GDP per capita growth. While most studies on the so-called "resource curse" paradox look at the negative growth effects of commodity abundance/dependence (particularly, the price *trends* or the abundance *levels)*, they usually, with a few exceptions, overlook the *volatility* channel of impact. The central message of this paper is that the volatility of commodity prices and export revenues should be considered in the growth analysis alongside the levels of resource revenues (or the price trends) and other determinants of output per capita. This is particularly important for primary-product abundant countries, where resource revenues are highly volatile. In this paper, we show that the source of the resource curse is the volatility in commodity prices as opposed to the abundance of the resource itself.

Methodologically, we employ two econometric techniques: (1) a system GMM approach (a slope homogeneous panel); and (2) a Cross-sectionally augmented version of the Pooled Mean Group (CPMG) estimator (a heterogenous panel). The former corrects for biases associated with the joint endogeneity of the explanatory variables in dynamic panel data models and the problems induced by unobserved country specific effects, while the latter takes account of cross-country heterogeneity and cross-sectional dependence. We obtain annual data for the period 1970–2007 and construct a panel dataset of 118 countries. We use the annual observations for the CPMG approach to fully exploit the time series dimension of the data, but we transform our time series data into at most seven non-overlapping five-year observations for the GMM estimation. This is a standard procedure in the empirical growth literature with panel data, to abstract from business cycles effects; see Aghion et al. (2009). Moreover, we make use of a country-specific commodity-price index that depends on the composition of a particular country's commodity export- and import-baskets, and investigate the impacts on growth of commodity terms of trade level and volatility.

To investigate whether or not CTOT volatility has a negative growth effect in just primary–commodity abundant countries, we split our sample into two sets: (a) 62 primary commodity exporters, and (b) 56 other countries which have a more diversified export basket. The estimation results in both the full sample–118 countries–and the second subsample, (b), show that CTOT volatility is not significantly related to output per capita growth. This is in contrast to the experience of the 62 primary commodity exporters, subsample (a), for which our results indicate that lower volatility of the CTOT contributes to enhanced growth. We attribute this asymmetric pattern to the diversified nature of the latter group's exports. Countries with a diversified basket of exports, especially manufacturing or service-sector goods, can be expected to grow faster and be better insured against price fluctuations in individual commodities. This analysis is confirmed by our empirical results, suggesting that the export diversification of primary commodity exporting countries contribute to faster growth, and is in line with what is argued in Hausmann et al. (2007) among others.

Furthermore, having identified a negative impact of CTOT volatility on GDP per capita growth in natural resource abundant countries, we also contribute to the literature by examining the channels through which this effect operates, notably physical- and human-capital accumulation, and Total Factor Productivity (TFP). We find that CTOT volatility is associated with lower accumulation of both human- and physical-capital and hence through that with lower growth. However, we cannot find a significant negative association between volatility and total factor productivity growth which is in contrast to the argument that commodity and natural resource abundant countries have fewer possibilities for technological progress. This finding is important as the behavior of an economy experiencing a boom differs significantly from the standard Dutch disease model in the presence of a sufficiently dynamic and knowledge-intensive natural resource sector.

Finally, while the resource curse hypothesis predicts a negative effect of commodity booms on long-run growth, our empirical findings (in line with the results reported in Cavalcanti et al. (2011a) and elsewhere in the literature) show quite the contrary: a higher level of commodity terms of trade significantly raises growth. Therefore, we argue that it is volatility, rather than abundance *per se*, that drives the "resource curse" paradox. Indeed, our results confirm that the negative growth effects of CTOT volatility offset the positive impact of commodity booms on real GDP per capita.

The rest of the paper is set out as follows: Section II gives a brief review of the relevant literature, while Section III discusses the econometric model and the GMM and CPMG methodologies employed. Section IV describes the data used in our analysis. In Section V, we initially transform our annual data into five-year non-overlapping averages and employ the system GMM methodology to estimate the effects of CTOT growth and volatility on cross country real output per capita growth as well as its sources. We then make use of annual data and the cross-sectionally augmented Pooled Mean Group (CPMG) estimator, which explicitly takes into account cross-country heterogeneity, to see whether the GMM results are maintained in this setting. Finally, Section VI offers some concluding remarks.

II. Literature Review

We are certainly not the first to emphasize the importance of volatility for economic growth. Following the influential work of Ramey and Ramey (1995), the consequences of excess volatility for long-run growth have attracted some attention in both the empirical and theoretical literature. Blattman et al. (2007) investigate the impact of terms of trade volatility, arising from excessive commodity price fluctuations, on the growth performance of a panel of

35 commodity-dependent countries between 1870 and 1939. They provide evidence of the adverse effects of volatility on foreign investment and through that, on economic growth in what they call "periphery" nations. Aghion et al. (2009), using a system GMM dynamic panel data method for 83 countries over the period 1960–2000, show that higher levels of exchange rate volatility can stunt growth, especially in countries with relatively under-developed capital markets. Bleaney and Greenaway (2001) estimate a panel data model for a sample of 14 sub-Saharan African countries over 1980–1995 and show that growth is negatively affected by terms of trade volatility, and investment by real exchange rate instability.

Most closely related in motivation to our paper is van der Ploeg and Poelhekke (2009) and van der Ploeg and Poelhekke (2010), who find that the volatility of unanticipated GDP per capita growth has a significant negative impact on economic growth, but the effect depends on a country's level of financial development. Moreover, since their results suggest a direct positive effect of resource abundance on growth, they argue against the "traditional resource curse" hypothesis. Our paper differs from theirs in many dimensions: we investigate the effects of CTOT volatility instead of the volatility of unanticipated GDP growth on economic activity. Our econometric methodologies are also different from theirs, since they use the Maximum Likelihood (ML) fixed effects panel techniques, while we use GMM and CPMG approaches. Interestingly, our results are quite similar in terms of how volatility affects GDP per capita growth. Last but not least, we also explore the different channels through which CTOT volatility operates, while they concentrate only on the overall negative effects of volatility on GDP per capita growth. We show that CTOT volatility mainly harms human-, and physical-capital accumulation, but not productivity. Therefore, we see our results as complementary to theirs.

This paper is also related to a growing strand of the literature on, and interest in, the resource curse paradox, following Sachs and Warner (1995).[2] The empirical evidence on the resource curse paradox is mixed, with some confirming Sachs and Warner's results of the negative effect of the level of resource abundance on economic growth, see Rodriguez and Sachs (1999), Gylfason et al. (1999), and Bulte et al. (2005) among others. But there is also a growing number of papers providing evidence against the resource curse paradox. As an empirical challenge to this paradox, Brunnschweiler and Bulte (2008) argue that the so-called resource curse does not exist when one uses the correct measure of resource abundance (rather than dependence) in regressions. Moreover, Alexeev and Conrad (2009) show that allowing for some important omitted variables, the unconditional version of the resource curse hypothesis is rejected. In addition, Stijns (2005), using data from the same period as Sachs and Warner (1995), finds no correlation of oil and mineral reserves with growth between 1970 and 1989, and concludes that natural resource abundance has not been a structural determinant of growth. Another empirical challenge comes from Cavalcanti et al. (2011a),

[2] See also Rosser (2006) and van der Ploeg and Venables (2009) for an extensive survey of the resource curse paradox.

who use a heterogenous cointegrated panel data method for 53 oil and gas producing countries, while taking into account the cross-sectional dependence of the errors, and show that natural resource abundance *per se* is not a determinant of growth failure. The positive effect of resource abundance on both development and growth is also supported by Esfahani et al. (2009) who developed a long-run growth model for a major oil exporting economy and derived conditions under which oil revenues are likely to have a lasting impact.

Another related branch of the literature investigates the channels through which natural resource abundance affects economic growth negatively. Gylfason (2001), for instance, shows that natural resource abundance appears to crowd out human capital investment with negative effects on the pace of economic activity, while Bravo-Ortega et al. (2005) show that higher education levels can in fact offset the negative effects of resource abundance. A number of papers, such as Papyrakis and Gerlagh (2004) and Gylfason and Zoega (2006), also focus on the physical capital accumulation channel, and argue that resource abundance leads to lower investment in physical capital which then dampens GDP growth. However, all of these studies focus on the effect of the level of resource abundance on economic growth (and its sources) and as such, they do not investigate whether there are any adverse effects of the volatility in commodity prices or resource income on GDP per capita growth.

III. THE ECONOMETRIC MODEL AND METHODOLOGY

This section introduces the two econometric techniques used in our empirical analysis in Section V. They are: (1) a system GMM approach which is a slope homogeneous panel method and (2) a cross-sectionally augmented version of the Pooled Mean Group (CPMG) estimator (a heterogenous panel approach).

A. The Econometric Model

We begin with the following panel data model that can nest much of the existing work on the empirics of economic growth, from the "Barro cross-sectional regression" to the static and dynamic panel data techniques:

$$\begin{aligned} \Delta y_{it} &= (\phi - 1)\, y_{it-1} + \boldsymbol{\beta}'\mathbf{x}_{it} + \mu_i + \eta_t + \varepsilon_{it}, \\ \text{for } i &= 1, 2, ..., N \text{ and } t = 1, 2, ..., T \end{aligned} \tag{1}$$

where Δy_{it} is the growth rate of real GDP per capita in country i; and y_{it-1} is the logarithm of lagged real GDP per capita. $\mathbf{x}_{it}$ is a vector of explanatory variables; η_t is the time-specific effect; μ_i is the country-specific effect; and ε_{it} is the error term.

Much of the empirical growth literature is based on estimations of an equation similar to (1) using a cross-sectional approach, but the drawbacks of this method are well known. Cross-sectional regressions clearly suffer from endogeneity problems as by construction, the initial level of income, y_{it-1}, is correlated with the error term, ε_{it}. This endogeneity bias is larger when considering the simultaneous determination of virtually all growth determinants. Furthermore, substantial bias may be induced by the correlation of unobserved country-specific factors and the explanatory variables.

Traditional static panel data estimators such as fixed and random effects are not consistent in the present context either, due to the inclusion of lagged dependent variables in our regressions (e.g. the initial level of GDP per capita). More specifically, the fixed effects estimator is inconsistent because it usually eliminates μ_i by a de-meaning transformation that induces a negative correlation between the transformed error and the lagged dependent variables of order $1/T$, which in short panels remains substantial. The assumption of a lack of correlation between μ_i and the explanatory variables required for random effects consistency is also violated as both Δy_{it} and y_{it-1} are functions of μ_i. Furthermore, these estimators will be inconsistent if the errors show either heteroscedasticity or serial correlation.

As it is expressed in equation (1), we specify our growth regression dynamically and include lagged GDP per capita on the right hand side. In this case, the elimination of fixed effects from the equation in any standard OLS-based estimation procedure implies the violation of the orthogonality condition between the error term and explanatory variables. For this reason, we estimate this equation with the system GMM procedure (discussed below in Section B) and contrast it with a cross-sectionally augmented pooled mean group (CPMG) approach. The system GMM procedure accounts for the endogeneity bias induced by reverse causality running from GDP per capita growth to its determinants. The CPMG estimator has a number of methodological and conceptual advantages over the classical panel data approaches (see a detailed discussion below in Section C), and thus strengthens our conclusions.

B. GMM Methodology

To correct for the biases created by lagged endogenous variables and the simultaneity of growth determinants, we use the generalized-method-of-moments (GMM) estimators developed for dynamic panel data models. Following Anderson and Hsiao (1982), and Arellano and Bond (1991), we take first-differences of equation (1) to eliminate the unobserved country fixed effects, μ_i, yielding:

$$\Delta y_{it} = \phi \Delta y_{it-1} + \boldsymbol{\beta}' \Delta \mathbf{x}_{it} + \Delta \eta_t + \Delta \varepsilon_{it}. \tag{2}$$

The first-difference of equation (1) gives the transformed error a moving-average structure that is correlated with the differenced lagged dependent variable. Assuming that the error term, ε_{it}, is not serially correlated and that the explanatory variables $\mathbf{x}_{it}$ are weakly exogenous,[3] the difference GMM estimator uses the following moment conditions:

$$E\left(y_{it-s}, \Delta\varepsilon_{it}\right) = 0 \quad \text{for } s \geq 2 \text{ and } t = 3, ...T,$$

$$E\left(\mathbf{x}_{it-s}, \Delta\varepsilon_{it}\right) = 0 \quad \text{for } s \geq 2 \text{ and } t = 3, ...T.$$

However, in growth regressions where the explanatory variables are persistent over time, lagged levels are often weak instruments for difference equations.[4] To reduce the potential biases and imprecision associated with the GMM difference estimator, we follow Arellano and Bover (1995) and Blundell and Bond (1998) in employing a system estimator that also includes equation (1) in levels, with the lagged differences of the endogenous variables as instruments (see Levine et al. (2000) and Aghion et al. (2009) among others for applications of this technique). These are appropriate instruments under the assumption that there is no correlation between the differences of the variables and the country-specific effects. Therefore, the additional moment conditions for the regression in levels are:

$$E\left(\Delta y_{it-s}, \mu_i + \varepsilon_{it}\right) = 0 \quad \text{for } s = 1,$$

$$E\left(\Delta\mathbf{x}_{it-s}, \mu_i + \varepsilon_{it}\right) = 0 \quad \text{for } s = 1.$$

The moment conditions effectively give us $T - 1$ equations in first differences followed by T equations in levels. The solutions to these equations are then weighted by the inverse of a consistent estimate of the moment condition covariance matrix in a two-step method. To test the validity of the instruments and therefore consistency of the GMM estimator, we consider two specification tests suggested by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). The first is a Hansen test of over-identifying restrictions, which tests the overall validity of the instruments, and the second test examines the hypothesis that the error term $\varepsilon_{i,t}$ is not serially correlated.[5]

The system GMM approach effectively deals with the endogeneity problem and country-specific fixed effects (by allowing the intercepts to differ across cross-sections). However, it restricts all the slope coefficients to be identical across countries; assumes that the time effects are homogenous; and that the errors are cross sectionally independent. If any of these conditions are not satisfied, the GMM method can produce "inconsistent and potentially very misleading" estimates of the average values of parameters; see Pesaran and Smith (1995) for more details. The time-specific heterogeneity is an underestimated but at the same time

[3]The explanatory variables are assumed to be uncorrelated with future realizations of the error term.

[4]For further details see Alonso-Borrego and Arellano (1999) and Blundell and Bond (1998).

[5]We test whether the differenced error term is second-order serially correlated as by construction, it is most likely first-order serially correlated even if the original error term is not.

very important concern in dynamic panel data models. Country-specific time-effects can capture a number of unobservable characteristics in macroeconomic and financial applications like (a) institutional arrangements, (b) the patterns of trade, (c) political developments, and (d) the effect of WTO, to mention a few. The time-specific heterogeneity is induced by oil price shocks and/or other global common factors, which affect all countries but to different degrees. The CPMG methodology explained below in Section C accounts for heterogenous time effects and at the same time deals with cross-sectional dependencies effectively.

C. CPMG Methodology

When panels of data are available, there exist a number of alternative estimation methods that vary on the extent to which they account for parameter heterogeneity. At one extreme is the Mean Group (MG) approach in which separate equations are estimated for each country and the average of estimated coefficients across countries is examined. Pesaran and Smith (1995) show that the MG method produces consistent estimates of the average of the parameters when the time-series dimension of the data is sufficiently large. At the other extreme are the traditional estimators in which dynamics are simply pooled and treated as homogeneous. Early and prominent examples include fixed effects (FE), random effects (RE), and generalized methods of moments (GMM), described in Section III.B. These methods are typically focused on solving the problem of fixed effect heterogeneity in the case of large N and small T panels; whereas they are not designed to correct for the endogeneity induced by the latent heterogeneity. Pesaran and Smith (1995) show that the traditional procedures for the estimation of pooled models can produce inconsistent and potentially misleading estimates of the lagged dependent variable's parameter in dynamic panel data models if latent heterogeneity is present.

In between the two extremes is the pooled mean group (PMG) estimator of Pesaran et al. (1999) which is an intermediate case between the averaging and pooling methods of estimation, and involves aspects of both. It restricts the long-run coefficients to be homogenous over the cross-sections, but allows for heterogeneity in intercepts, short-run coefficients (including the speed of adjustment) and error variances. The PMG estimator also generates consistent estimates of the mean of short-run coefficients across countries by taking the simple average of individual country coefficients. It can be argued that country heterogeneity is particularly relevant in short-run relationships, given that countries are affected by over lending, borrowing constraints, and financial crises in short-time horizons, albeit to different degrees. On the other hand, there are often good reasons to expect that long-run relationships between variables are homogeneous across countries. Estimators that impose cross-sectional restrictions (PMG) dominate the fully heterogeneous ones (MG) in terms of efficiency if the long-run restrictions are indeed valid. If the constraints are not valid, however, the restricted estimators are inconsistent.[6]

We make use of the PMG estimator because it offers the best available choice in terms of consistency and efficiency in our sample of countries, while it corrects at the same time for the shortcomings of homogeneous panel methods mentioned above. Moreover, we apply the methodology of Pesaran (2006) to the PMG estimator to correct for the cross-sectional dependencies that arise in the error terms from unobserved global factors, since we assume that countries are affected in different ways and to varying degrees by these shocks.[7]

The cross sectionally augmented pooled mean group (CPMG) estimator is based on an Autoregressive Distributive Lag (ARDL) model and thus can be used for long-run analysis. In a series of papers, Pesaran and Smith (1995), Pesaran (1997), and Pesaran and Shin (1999) show that one can use the ARDL approach to produce consistent and efficient estimates of the parameters in a long-run relationship between both integrated and stationary variables, and to conduct inference on these parameters using standard tests. This method avoids the need for pre-testing the order of integration given that they are valid whether the variables of interest are $I(0)$ or $I(1)$. The main requirements for the validity of this methodology are that, first, there exists a long-run relationship among the variables of interest and, second, the dynamic specification of the model is sufficiently augmented so that the regressors become weakly exogenous and the resulting residual is serially uncorrelated.

To explain the CPMG estimator in more details, consider the following $ARDL(p, q, q, ..., q)$ model:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{it-j} + \sum_{j=0}^{q} \boldsymbol{\delta}'_{ij} \mathbf{x}_{it-j} + \mu_i + u_{it}, \tag{3}$$

where as before $i = 1, 2, ..., N$, $t = 1, 2, ..., T$, $\mathbf{x}_{it}$ is the $k \times 1$ vector of explanatory variables for group i, μ_i represents the fixed effects; the coefficients of the lagged dependent variables, λ_{ij}, are scalars and $\boldsymbol{\delta}_{ij}$ are $k \times 1$ coefficient vectors. We assume that the error term, u_{it}, has the following multi-factor error structure:

$$u_{it} = \boldsymbol{\gamma}'_i \mathbf{f}_t + \varepsilon_{it}, \tag{4}$$

where $\mathbf{f}_t$ is a vector of unobserved common shocks, which can be stationary or nonstationary; see Kapetanios et al. (2011). The source of error term dependencies across countries is captured by $\mathbf{f}_t$, whereas the impacts of these factors on each country are governed by the idiosyncratic loadings in $\boldsymbol{\gamma}_i$. The individual-specific errors, ε_{it}, are distributed independently across i and t; they are not correlated with the unobserved common factors or the regressors;

[6] Robertson and Symons (1992) and Pesaran and Smith (1995) show that imposing invalid parameter homogeneity in dynamic models typically leads to downward biased estimates of the speed of adjustment.

[7] The same strategy in used by Binder and Offermanns (2008) in a different context.

and they have zero mean, variance greater than zero, and finite fourth moments. The common factors, or the heterogenous time effects, may be captured/proxied by adding cross sectional averages of the observables to our regressions, see Pesaran (2006) and Binder and Offermanns (2008).

More specifically, combining (3) and (4) and averaging across i yields

$$\bar{y}_t = \sum_{j=1}^{p} \bar{\lambda}_j \bar{y}_{t-j} + \sum_{j=0}^{q} \bar{\boldsymbol{\delta}}'_j \bar{\mathbf{x}}_{t-j} + \bar{\mu} + \bar{\boldsymbol{\gamma}}'\mathbf{f}_t + \bar{\varepsilon}_t, \tag{5}$$

where the variables with a bar denote the simple cross section averages of the corresponding variables in year t. Since the error term ε_{it} is by assumption independently distributed across i and t, its cross-sectional average, $\bar{\varepsilon}_t$, tends to zero in root mean square error as N becomes large. The common factors can therefore be captured through a linear combination of the cross-sectional averages of the dependent variable and of the regressors:

$$\boldsymbol{\gamma}'_i\mathbf{f}_t = a^*_i \bar{y}_t + \mathbf{b}^{*\prime}_i \bar{\mathbf{x}}_t + \sum_{j=0}^{p-1} c^*_{ij} \Delta\bar{y}_{t-j} + \sum_{j=0}^{q-1} \mathbf{d}^{*\prime}_{ij} \Delta\bar{\mathbf{x}}_{t-j} - c_i\bar{\mu}, \tag{6}$$

where $c_i = \frac{\boldsymbol{\gamma}'_i}{\bar{\boldsymbol{\gamma}}}$; $a^*_i = c_i\left(1 - \sum_{j=1}^{p} \bar{\lambda}_j\right)$; $\mathbf{b}^*_i = c_i\left(\sum_{j=0}^{q} \bar{\boldsymbol{\delta}}_j\right)$; $c^*_{ij} = c_i\left(1 - \sum_{m=j+1}^{p} \bar{\lambda}_m\right)$; and $\mathbf{d}^*_{ij} = c_i\left(\sum_{m=j+1}^{p} \bar{\boldsymbol{\delta}}_m\right)$.

Using (6) in (4), the error correction representation of (3) becomes:

$$\begin{aligned}\Delta y_{it} \;&=\; \mu_i - c_i\bar{\mu} + \phi_i y_{it-1} + \boldsymbol{\beta}'_i \mathbf{x}_{it} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{it-j} + \sum_{j=0}^{q-1} \boldsymbol{\delta}^{*\prime}_{ij} \Delta\mathbf{x}_{it-j} \\ &\quad + a^*_i \bar{y}_t + \mathbf{b}^{*\prime}_i \bar{\mathbf{x}}_t + \sum_{j=0}^{p-1} c^*_{ij} \Delta\bar{y}_{t-j} + \sum_{j=0}^{q-1} \mathbf{d}^{*\prime}_{ij} \Delta\bar{\mathbf{x}}_{t-j} + \varepsilon_{it},\end{aligned} \tag{7}$$

where

$$\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right), \boldsymbol{\beta}_i = \sum_{j=0}^{q} \boldsymbol{\delta}_{ij},\ \lambda^*_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}, \text{ and } \boldsymbol{\delta}^*_{ij} = -\sum_{m=j+1}^{q} \boldsymbol{\delta}_{im}.$$

As always T must be large enough so that the model can be estimated for each cross-section. In addition, the roots of equation (7) in y_{it} must lie outside the unit circle to ensure that $\phi_i < 0$, and hence that there exists a long-run relationship between y_{it} and $\mathbf{x}_{it}$ defined by

$$y_{it} = \left(\frac{\boldsymbol{\beta}'_i}{\phi_i}\right)\mathbf{x}_{it} + \eta_{it}. \tag{8}$$

Finally, the long-run coefficients on $\mathbf{x}_{it}$, defined by $\boldsymbol{\theta}_i = \left(\frac{\boldsymbol{\beta}_i}{\phi_i}\right)$ above, are restricted to be the same across countries, namely:

$$\boldsymbol{\theta}_i = \boldsymbol{\theta}, \quad i = 1, 2, ..., N. \tag{9}$$

The CPMG estimator uses a maximum likelihood approach to estimate the model based on the Newton–Raphson algorithm. The lag length for the model can be determined using, for instance, the Schwarz Criterion (SBC) and the null of long-run homogeneity:

$$H_0 : \boldsymbol{\theta}_i = \left(\frac{\boldsymbol{\beta}_i}{\phi_i}\right) = \boldsymbol{\theta},$$

can be tested using the Hausman statistic for the coefficient on each of the explanatory variables and for all of them jointly.

IV. Data

To empirically test the relationship between economic growth and commodity terms of trade (CTOT) level and volatility, we use annual data from 1970 to 2007 on: real GDP per capita, a CTOT index based on the prices of 32 primary commodities,[8] and other important determinants of growth such as trade openness, government burden, lack of price stability, and human capital.[9] Since we are also interested in testing whether or not export diversification enhances growth in our sample of countries, we use a measure of export sophistication developed by Hausmann et al. (2007) in our regressions. This index measures the benefits of diversifying the economy away from primary products to manufacturing and services, and thus towards productivity-enhancing goods. For details on the calculation and construction of these variables and sources of the data used see, Table 2.

While this paper initially investigates the growth effects of CTOT level and volatility for the full sample of 118 countries, it also tests whether this relationship is dependent on a country being a primary commodity exporter. As such, we split our sample into two subsets, with the first consisting of 62 primary commodity exporting countries, defining them as those for which the ratio of primary commodities to total exports exceeds 50 percent.[10] The second

[8]The commodities are: Shrimp, beef, lamb, wheat, rice, corn, bananas, sugar, coffee, cocoa, tea, soybean meal, fish meal, hides, soybeans, natural rubber, hardlog, cotton, wool, iron ore, copper, nickel, aluminum, lead, zinc, tin, soy oil, sunflower oil, palm oil, coconut oil, gold, and crude oil.

[9]In the growth literature government burden is defined as the ratio of government consumption to GDP, while lack of price stability is defined as log(100 + inflation rate), see for instance Aghion et al. (2009).

[10]This ratio is calculated based on data from the United Nations Conference on Trade and Development online

subsample consists of the remaining 56 countries, which have a more diversified export structure. For a complete list of all the countries, see Table 1.

A. Commodity Terms of Trade

Our country-specific measure for the CTOT index is from Spatafora and Tytell (2009), and is defined as:

$$CTOT_{it} = \prod_j \left(\frac{P_{jt}}{MUV_t} \right)^{X_{ij}} / \prod_j \left(\frac{P_{jt}}{MUV_t} \right)^{M_{ij}}, \tag{10}$$

where MUV_t is a manufacturing unit value index used as a deflator, X_{ij} (M_{ij}) is the share of exports (imports) of commodity j in country i's GDP, and P_{jt} is the individual commodity price.[11] By construction, the movements in the CTOT index are due to changes in commodity prices as the export and import shares are taken as fixed and so remain constant over time. For empirical application, we calculate X_{ij} and M_{ij} as the average value of these shares between 1970 and 2007. The CTOT index allows countries to be influenced by changes in commodity prices differently, depending on the composition of their export and import baskets. This is in contrast to the ‘standard’ commodity price indices most commonly used in the literature, such as the "All Primary Commodities Index" in International Monetary Fund (2010b), which attaches the same weight to each country in the regression analysis. Equation (10) is used to construct two important variables. The first is a commodity terms of trade growth series, a proxy for resource abundance, calculated as the annual log differences in the CTOT index, and the second is a measure of CTOT volatility; both are explained in more detail below.

To calculate CTOT growth, we first take the logarithm of (10)

$$\begin{aligned} \ln CTOT_{it} &= \sum_j X_{ij} \ln \left(P_{jt}/MUV_t \right) - \sum_j M_{ij} \ln \left(P_{jt}/MUV_t \right) \\ &= \sum_j \left(X_{ij} - M_{ij} \right) \ln \left(P_{jt}/MUV_t \right). \end{aligned} \tag{11}$$

Taking the difference of (11), we obtain the annual growth rate of the CTOT index:

$$\begin{aligned} g_{CTOT,it} &= \ln CTOT_{it} - \ln CTOT_{it-1} \\ &= \sum_j \left(X_{ij} - M_{ij} \right) \Delta \ln \left(P_{jt}/MUV_t \right), \end{aligned} \tag{12}$$

which reflects the changes in the basket of real commodity prices in country i scaled by the

---

database using SITC 0, 1, 2, 3, 4, 68, 667, and 971.

[11] A similar measure is also used by Lee et al. (2008).

importance of each commodity j in that economy's net exports for that particular good, $(X_{ij} - M_{ij})$.

Resource revenue (or rent), being calculated as the production multiplied by price (minus marginal cost), has been used extensively in a number of recent studies in the resource curse literature as a measure of abundance. Given that production levels do not change much over time and are generally persistent, most changes in resource rents or revenues in the short-run (for instance five-years) are due to price fluctuations. Moreover, the Dutch disease phenomenon focuses on the changes in natural resource prices as the main driver of the eventual drag on TFP and output growth. Therefore, the commodity terms of trade growth considered in this paper, which is a weighted measure of changes in commodity prices, can be seen as a proxy for resource abundance, as well.

In contrast to most studies in the growth literature which employ time-invariant measures of volatility, we construct two time-varying measures. First, we consider the five year non-overlapping standard deviation of $g_{CTOT,it}$, annual growth rates of the CTOT index,

$$\sigma_{CTOT,it,t+S} = \sqrt{\frac{1}{S}\sum_{s=0}^{S}\left(g_{CTOT,it+s} - \frac{1}{S+1}\sum_{s=0}^{S} g_{CTOT,it+s}\right)^2}, \tag{13}$$

where $S = 4$ as we are working with five-year averages. The volatility of $g_{CTOT,it}$, given in equation (13), indicates the extent to which CTOT growth deviates from a given mean at any point in time. Second, as annual data on CTOT volatility is required in the cross-sectionally augmented pooled mean group (CPMG) regressions, we estimate a generalized autoregressive conditional heteroscedasticity (GARCH) model using the logarithm of $CTOT_{it}$. This approach estimates the "conditional variance" of the logarithm of the CTOT for each year, independent of other observations. The computed variance series might yield periods with different volatility levels, and therefore a time varying measure. More specifically, we estimate the volatility of the commodity terms of trade from a GARCH(1,1) model on annual observations using a regression of the change in the logarithm of the CTOT variable, $g_{CTOT,it}$, on a constant (this formulation is used to avoid prejudging the issue of stationarity) as in Bleaney and Greenaway (2001) and Serven (2003):

$$\begin{aligned} g_{CTOT,it} &= \ln CTOT_{it} - \ln CTOT_{it-1} \\ &= \kappa_0 + \xi_{it} \end{aligned}$$

$$\sigma^2_{CTOT,it} = (1 - \lambda_1 - \lambda_2)\,\sigma^2_{CTOT,i} + \lambda_1 \xi^2_{it-1} + \lambda_2 \sigma^2_{it-1} \tag{14}$$

where $\xi_{it} \sim N\left(0, \sigma^2_{it}\right)$, ξ^2_{it-1} is the squared residuals, $\sigma^2_{CTOT,it}$ is the conditional variance of $g_{CTOT,it}$, $\sigma^2_{CTOT,i}$ is the unconditional variance, λ_1 is the ARCH parameter, and λ_2 is the GARCH parameter. We calculate CTOT volatility as the square root of $\sigma^2_{CTOT,it}$.

The upper graphs in Figure 1 illustrate a simple bivariate relationship between GDP per capita growth and CTOT growth over the entire period 1970–2007, suggesting a mild positive correlation between these two variables for both country groups. Examining the two lower graphs, we observe that while higher CTOT volatility is associated with lower GDP growth in primary commodity exporting countries, this relationship does not hold for the other subsample, which has a more diversified export structure. Overall, the results from Figure 1 represent preliminary evidence that while commodity booms do not reduce output per capita growth (contrary to the resource curse hypothesis), the volatility of CTOT stunts output growth only for primary commodity exporters. This is perhaps not surprising as those countries with a diversified basket of exports, especially manufacturing or service-sector goods, can be expected to grow faster and be better insured against price fluctuations in individual commodities.

In Section V.A, we will add a whole range of control variables and deal with possible endogeneity problems through the system GMM approach, to investigate whether the above results survive for the full sample and the two subsamples, as suggested by Figure 1. We will also investigate the relationship between resource abundance and/or CTOT volatility with that of output growth using annual data and applying a cross-sectionally augmented version of the Pooled Mean Group (CPMG) methodology in Section V.B. Since we also would like to investigate possible mechanisms through which CTOT volatility can harm economic growth, we focus on three channels which have been widely discussed in the literature: (i) TFP growth; (ii) physical capital accumulation; and (iii) human capital acquisition. To do this analysis, we need to construct series for physical and human capital stocks as well as for TFP. In what follows, we briefly describe how these series are constructed.

B. Physical Capital Accumulation

We apply the perpetual inventory method, as in Hall and Jones (1999) for instance, to data from the Penn World Tables (PWT) 6.3; see Heston et al. (2009), to construct the series of the physical capital stock, K_{it}. We construct the initial stock of capital, K_{it_0}, for country i as:

$$K_{it_0} = \frac{I_{it_0}}{g_I + \delta}, \tag{15}$$

where δ is the depreciation rate, g_I is the geometric average growth rate of I_{it} between t_0 and $t_0 + 10$, and I_{it} represents gross investment and is defined as:

$$I_{it} = ki_{it} \times rgdpch_{it} \times pop_{it}, \tag{16}$$

in which ki_{it} measures the investment share of real GDP per capita $(rgdpch_{it})$ and pop_{it} is population. Since we have access to data on investment from 1960 for most countries, we set

t_0 to this year.[12] Furthermore, we assume a depreciation rate, δ, of six percent and compute the subsequent values of the capital stock as:

$$K_{it} = (1 - \delta)K_{it-1} + I_{it}. \tag{17}$$

C. Human Capital Stock

To calculate the level of human capital stock in country i, we obtain data on the average years of schooling attained (total, primary, secondary, tertiary) in five-year intervals from the Barro and Lee Educational Attainment Dataset 2010. Since annual data is required to retrieve the human capital series, we linearly interpolate the Barro and Lee (2010) dataset. Moreover, we assume that labor is homogeneous within a country and that each unit of labor has s_{it} years of schooling (education). Therefore, the labor-augmenting human capital is given by:

$$H_{it} = e^{\psi(s_{it})}. \tag{18}$$

Following Psacharopoulos (1999),[13] we specify $\psi(s_{it})$ as a piecewise linear function with coefficients (returns to schooling) 0.134 for the first four years of education, 0.101 for the next four years, and 0.068 for any value of $s_{it} > 8$.[14]

D. Productivity

In constructing the total factor productivity series, we follow Hall and Jones (1999) and assume that output in country i is produced according to the following constant returns to scale production function:

$$Y_{it} = K_{it}^{\alpha}(A_{it}H_{it}L_{it})^{1-\alpha}, \tag{19}$$

where K_{it} denotes the stock of physical capital defined in (17), A_{it} is a labor-augmented productivity factor, H_{it} is a measure of the average human capital of workers defined in (18), and L_{it} is labor input in use:

$$L_{it} = \frac{rgdpch_{it} \times pop_{it}}{rgdpwok_{it}}, \tag{20}$$

---

[12]In those countries for which data on investment is missing in 1960, t_0 is the next available data point followed by other observations.

[13]See also Psacharopoulos and Patrinos (2004).

[14]We also constructed the human capital series by assuming that the returns to primary, secondary, and tertiary schooling is equal to 0.134, 0.101, and 0.068 per annum, but as expected, this does not lead to any significant change in the series or the results.

where as before $rgdpch_{it}$ is real GDP per capita, pop_{it} is a measure of population and $rgdpwok_{it}$ is real GDP per worker from the PWT 6.3. The capital share, α, is assumed constant across countries and set equal to $1/3$.

Finally, using the data on output per worker, capital, population, and schooling, we can construct the level of total factor productivity as follows:

$$A_{it} = \frac{Y_{it}}{H_{it}L_{it}} \left(\frac{K_{it}}{L_{it}} \right)^{-\frac{\alpha}{1-\alpha}} . \tag{21}$$

V. Empirical Results

In this section, we initially present the system GMM estimation results of the effects of (i) commodity terms of trade growth, (ii) its volatility, (iii) an export diversification measure, and (iv) a conditioning information set, on growth and its sources. We then use the cross-sectionally augmented Pooled Mean Group (CPMG) estimator to investigate the hypothesized association between g_{CTOT}, σ_{CTOT} and economic growth as well as its sources, and contrast these results with those obtained from the GMM estimations.

A. Analysis Using Five-Year Averages

To filter out business cycle fluctuations and to focus on the long-run effects of CTOT growth and volatility, we follow the literature in transforming the annual series into non-overlapping five-year averages. Given the time span of our dataset (from 1970 to 2007), we can construct an unbalanced panel with a maximum of seven five-yearly observations per country covering 1970–2005.

A.1 Volatility and Growth

We propose to use the system GMM estimator described above, but as the two-step standard errors on estimated coefficients will be biased downward in small samples like ours, we make use of Windmeijer (2005) approach to correct for that bias. The following equation is estimated:

$$\begin{aligned} g_{y,is} &= (\phi - 1)\, y_{is-1} + \gamma_1 g_{CTOT,is} + \gamma_2 \sigma_{CTOT,is} \\ &\quad + \gamma_3 EXPY_{is} + \boldsymbol{\beta}' \mathbf{z}_{is} + \mu_i + \eta_s + \varepsilon_{is}, \end{aligned} \tag{22}$$

where $i = 1, 2, ..., N$, and $s = 1, 2, ..., S$, in which $S = \frac{T}{5}$, with T denoting the years between 1970 and 2005. $g_{y,is}$ is the geometric average growth rate of real GDP per capita between dates s and $s-1$; y_{is-1} is the logarithm real GDP per capita at the beginning of each period; $g_{CTOT,is}$ is the growth rate of the CTOT index; and $\sigma_{CTOT,is}$ is its volatility. $EXPY_{is}$ is a measure of export diversification and $\mathbf{z}_{is}$ is a set of other control variables now standard in the growth literature[15] including education, trade openness, government burden, and lack of price stability. η_s is the time-specific effect; μ_i is the country-specific effect; and ε_{it} is the error term.

Table 3 presents the estimation results of the impact of commodity terms of trade growth and volatility as well as export diversification on GDP per capita growth. In the first regression using the whole sample of 118 countries, $[1.1]$, we observe that an increase in g_{CTOT} is both growth enhancing and highly significant. On the other hand, although the coefficient of CTOT volatility is negative, this is in fact insignificant and thus there is no evidence that volatility in commodity prices harms growth for the full sample. As already discussed in Section IV.A, we expect the growth experience of primary commodity exporters to be different from those countries that are not well endowed with a handful of primary products, see Figure 1, and therefore we split the sample into two subsets.

Regression $[1.2]$ shows the opposite significant effects of g_{CTOT} and σ_{CTOT} on GDP growth for the 62 primary commodity exporting countries in our sample. While commodity price booms significantly increase economic growth, volatility affects it negatively. The positive growth effect of g_{CTOT} provides evidence against the traditional resource curse hypothesis, which argues that it is the level of resource abundance that affects economic growth negatively. Our findings are in line with results obtained in a number of recent studies in the literature such as Brunnschweiler and Bulte (2008), Cavalcanti et al. (2011a), Cavalcanti et al. (2011b), and van der Ploeg and Poelhekke (2010). The negative relationship between volatility and growth in resource-abundant countries is also documented in van der Ploeg and Poelhekke (2009) and van der Ploeg and Poelhekke (2010), who acknowledge that the source of the resource curse is the volatility of commodity prices as opposed to resource abundance, although their empirical analysis is based on the volatility of unanticipated output growth and not of commodity prices. σ_{CTOT} is a more appropriate measure to analyze the resource curse paradox as it directly affects a country's ability to extract from its resource stock and make use of the proceeds. Whereas the volatility of unanticipated output growth is most likely caused by factors that are not directly related to the abundance of natural resources.

To determine the overall growth impact of changes in the CTOT variable and its volatility, we calculate the average percentage effect of the two CTOT variables on output per capita growth using the estimates from regression $[1.2]$. The overall effect is -0.312 over five years (see Table 3), therefore the negative growth effects of CTOT volatility offset the positive impact of commodity booms, which suggests that volatility, rather than abundance per se, drives the

---

[15] See, for instance, Levine et al. (2000) and Aghion et al. (2009).

resource curse paradox.[16]

These results, however, do not hold for the second subsample that focusses on the remaining 56 non-resource abundant countries; see regression $[1.3]$ of Table 3. For these countries, changes in commodity prices (or their volatility) are not expected to have any major impact on their physical and human capital investment, or their TFP growth rates. Consequently, there should be no significant impact on economic growth stemming from changes in the CTOT variable or its volatility. In addition, these countries generally have highly diversified export and import baskets, implying that the changes in commodity prices should have a lower effect on them as opposed to primary commodity abundant countries. This argument is also supported by observing that the coefficient of export diversification variable, $EXPY_{it}$, is significant and positive in all three regressions in Table 3. This finding suggests that diversifying away from exporting only a handful of primary commodities towards technology improving exports can significantly increase the growth rate of an economy. Another related important reason for this asymmetric effect is that most of these economies are financially developed and have access to international capital markets, and so, are well positioned to absorb the shocks from commodity price variations. For instance, 27 out of the 56 countries in the net-commodity importing sample are members of the Organization for Economic Cooperation and Development (OECD).

Note that in all three regressions, the control variables have the expected signs and are all statistically significant except for the education variable in all regressions, and the government burden variable in $[1.3]$. Overall, while higher level of trade-openness is growth enhancing, price instability and government burden tend to have adverse effects on GDP growth. In addition, there is evidence of income convergence across countries with the coefficient on the lagged-dependent variable being significant for the full sample and the sample consisting of net primary commodity importers. However, this finding should be interpreted with caution as there is a large cross-country heterogeneity in our sample of 118 countries which might render the estimated coefficient on $\ln y_{it-1}$ biased. Finally, in all regressions, the Hansen and second order serial correlation test statistics, which examine the validity of the instruments used, are well above the conventional significance levels.

A.2 Volatility and the Channels Affecting Economic Growth

To determine the channel(s) through which GDP per capita growth is negatively affected by CTOT volatility in the subsample of 62 commodity exporters, we follow Beck et al. (2000) in investigating three possible sources which are widely acknowledged in the literature, namely, TFP, human-, and physical-capital investment. The importance of these channels and the

[16]Cashin and McDermott (2002) also argue that the volatility of commodity prices, as measured by *The Economist*'s index of industrial commodity prices, dominates any trend in real prices.

reasons for why they might be the means by which growth is dampened in resource abundant countries is discussed extensively in Gylfason (2006). As before, we use the system GMM dynamic panel data approach to estimate the following equation:

$$\begin{aligned} g_{W,is} &= (\phi - 1)\, w_{is-1} + \gamma_1 g_{CTOT,is} + \gamma_2 \sigma_{CTOT,is} \\ &+ \gamma_3 EXPY_{is} + \boldsymbol{\beta}'\mathbf{z}_{is} + \mu_i + \eta_s + \varepsilon_{is}, \end{aligned} \tag{23}$$

where $W = \{$TFP, or physical capital per capita, or human capital per capita$\}$; $g_{W,is}$ is the geometric average growth rate of W between dates s and $s-1$; and w_{is-1} is the logarithm of W at the beginning of each period. All other variables are as defined in equation (22).

Not surprisingly, considering the results of regression $[2.1]$ in Table 4, we observe that human capital enhances TFP and so does export diversification. However, the channel through which CTOT variables affect growth is clearly not total factor productivity, as the growth rate and the volatility of CTOT are both statistically insignificant in the TFP regression. Our results suggest that commodity price booms or CTOT volatility do not have an adverse impact on TFP growth. This finding contradicts the Dutch disease hypothesis, which predicts that an increase in commodity prices will lead to real exchange rate appreciation and through that a fall in output in the non-resource and more dynamic traded-goods sector, and in turn leads to a reduction of TFP growth and eventually the GDP growth rate.[17] This effect would most likely be present if the revenues from primary commodities were to be intrinsically temporary, like in the Netherlands in the 1960's, but this is not the case for most of the countries in our sample, which have remained exporters of a few primary products for decades. For instance, Iran has been a major crude oil exploiter and producer for over 50 years and with the current reserve to extraction ratio, is predicted to remain so for many decades to come.[18] Thus an increase in the price of primary commodities, or its volatility, does not necessarily have negative long run effects on TFP in these countries, as their economies would re-adjust after a shock to the price of primary commodities. This is the case unless there are important non-convexities in the economy, but it is not supported by the econometric evidence, given that an increase in commodity prices or volatility seems to have no significant effect on TFP growth in the long run, see regression $[2.1]$ in Table 4.

In contrast, regression $[2.2]$ shows that both commodity terms of trade growth and volatility have significant impacts on physical capital accumulation for primary commodity abundant countries. While a commodity price boom increases the physical capital stock, higher volatility of commodity prices significantly reduces it. Therefore, capital accumulation seems to be an important channel through which volatility affects GDP per capita growth. This result

[17]See, for example, Corden and Neary (1982), Krugman (1987), and Neary and van Wijnbergen (1986) among others.

[18]For more details see Esfahani et al. (2009).

is in line with what is argued in Papyrakis and Gerlagh (2004), Gylfason and Zoega (2006) and Esfahani et al. (2009) among others. A possible explanation for this finding is that economic agents tend to save less in commodity abundant countries because they perceive the revenues from primary commodity exports to be a permanent stream of future income. Another possibility is that the uncertainty arising from commodity price volatility in these economies might suppress the accumulation of physical capital by risk averse investors. Moreover, as noted by Catão and Kapur (2006) and Catão et al. (2009), TOT volatility adversely affects capital accumulation and growth by raising the country's default risk, hence widening the country spreads, and lowering its borrowing capacity.

The estimation results from regression $[2.3]$ are similar to that of regression $[2.2]$. They indicate that human capital accumulation is another channel through which volatility harms growth. A possible explanation for this finding is that uncertainty generally increases income inequality and leads to binding credit constraints on households with low net worth. But given that families finance their own education, higher volatility then leads to a reduction in human capital investment and thus lowers economic growth. This reduction in the growth rate of an economy due to the crowding out of human capital investment in resource abundant and/or volatile economies is also what is found in the literature. See, for example, Gylfason (2001), Birdsall et al. (2001), Papyrakis and Gerlagh (2004), Aizenman and Pinto (2005), and Gylfason and Zoega (2006).

Moreover, while export diversification leads to higher investment in physical capital, see regression $[2.2]$, this effect is absent in the human capital accumulation equation, $[2.3]$. This result seems to suggest that for commodity abundant countries, diversification is an important mechanism that offsets the reduction in physical capital accumulation (brought about by large primary commodity export revenues) with an increase in productivity.

Furthermore, the coefficients of the control variables in all three regressions in Table 4 generally have the expected signs, with those that are opposite to what is expected being statistically insignificant. As before, the Hansen and second order serial correlation test statistics in these three regressions confirm the validity of the instruments used and the lack of second order serial correlation in the error terms.

We also estimated regressions $[2.1]$ to $[2.3]$ for the 56 net commodity-importing countries in our sample and as expected found no significant effect of g_{CTOT} and σ_{CTOT} on the three channels of growth described above. This is consistent with our findings in regression $[1.3]$ of Table 3 in which the growth rate and the volatility of the commodity terms of trade had no significant effect on GDP growth for the group of 56 commodity importers. Given that these countries are not primary commodity abundant and have highly diversified import and export baskets, we argue that this is in fact what should be expected. These results are not reported but they available upon request.

A.3 Robustness Checks

In order to make sure that our results are not driven by the way in which commodity terms of trade volatility is measured, instead of using five-year non-overlapping standard deviation of CTOT growth, we estimate the conditional volatility of the commodity terms of trade from a GARCH(1,1) model on annual observations and use it as our alternative measure of instability, (see Section IV.A for more details). The results in Table 5 echo those obtained in Table 3. While the coefficient of CTOT volatility is negative for the full sample and for the 56 net commodity importers; see regressions $[3.1]$ and $[3.3]$ in Table 5, they are in fact statistically insignificant. In contrast, regression $[3.2]$ shows that CTOT volatility has a significantly negative effect on GDP growth for primary commodity-exporting countries. Note also that in contrast to the predictions of the resource curse hypothesis, a higher growth rate of commodity prices enhances real output per capita growth significantly for both the full sample and for the 62 primary commodity exporters. This finding is consistent with the one obtained in regressions $[1.1]$ and $[1.2]$ and with the evidence that is provided in the recent literature on the resource curse hypothesis, which argues that abundance of resources is not a curse and could even under certain conditions be a blessing. However, the impact of CTOT growth on output per capita is smaller than that of CTOT volatility, given that the overall impact of the two CTOT variables on output growth is -0.509 percent; see Table 5.

Having shown that there exists a negative association between the GARCH(1,1) measure of CTOT volatility and economic growth, we investigate the three potential channels through which this effect operates. Note that TFP is not one of these channels as neither CTOT growth nor its volatility have any significant effects on technological growth; see regression $[4.1]$ in Table 6. This is in line with the results obtained from regression $[2.1]$ and provides further evidence against Dutch disease operating in the primary commodity-abundant countries in our sample.

In addition, although the coefficient of σ_{CTOT} is negative in regression $[4.3]$, it is in fact statistically insignificant, and as such there is no evidence that CTOT volatility crowds out human capital. This finding does not fit with the results from regression $[2.3]$ in which the volatility in commodity prices did have a negative effect on human capital accumulation. Thus, the evidence surrounding the relationship between human capital investment and CTOT volatility seems to be inconclusive, and so further research on the human capital accumulation channel is warranted. However, as the coefficient of CTOT volatility (growth) is significantly negative (positive) in regression $[4.2]$, it seems safe to conclude that volatility harms growth via a reduction in physical capital accumulation.[19]

---

[19]To confirm the results in Section V.A.2, we also estimated regressions $[4.1]$ to $[4.3]$ for the 56 net commodity importing countries in our sample. As expected we found no significant effect of g_{CTOT} and σ_{CTOT} on the three channels for these countries.

Moreover, the results in Table 5 show that export diversification has a significant positive effect on output growth for the full sample of the 118 countries, as well as for the two subsamples. It is also the case that export diversification enhances both TFP growth and physical capital accumulation in commodity exporting countries; see Table 6. These results are consistent with those reported in Tables 3 and 4, implying that there is a strong evidence that diversification of the economy, away from primary products towards more productive goods, should be high on the policy agenda of commodity-abundant countries.

In all six regressions in Tables 5 and 6, the Hansen test statistic is well above the conventional significance level, meaning that the instruments used are valid, and at the same time there is no evidence of second-order serial correlation in the error terms. Moreover, the coefficients of the control variables that are statistically significant all have the expected signs. Thus overall the results obtained using the alternative measure of volatility confirm the robustness of our findings reported in Sections V.A.1 and V.A.2, and provide evidence for the negative effects of CTOT volatility on physical capital accumulation and through that on the growth rate of real GDP per capita.

Finally, in line with the literature, we have defined primary commodity exporters as those countries for which the ratio of primary commodities to total exports exceeds 50 percent, but to make sure that this particular cut-off point is not driving our results, we also estimated all the regressions using 40 and 60 percent cut-off points and found the results to be robust to these changes. This is not surprising as increasing the cut-off point to 60 percent only reduces the sample by three countries, while reducing it to 40 percent increases the number of countries by six. These estimation results are not reported but are available upon request.

B. Analysis Using Annual Data

There are a number of advantages to using non-overlapping five-year averages, including the potential for removing business cycle fluctuations. However, the averaging itself induces a loss of information with no guarantee that the business cycle fluctuations are removed entirely. Moreover, uncertainty is best measured over the business cycle and so, using five-year averages could underestimate the importance of volatility. Furthermore, as discussed in Section III.C, the traditional GMM methodology employed in Section V.A does not account for cross sectional heterogeneity or residual cross country dependencies that might be present. To overcome some of these issues and also to provide robustness checks for our GMM results, we employ the cross-sectionally augmented pooled mean group (CPMG) methodology, described in Section III.C, on annual observations from 1970 to 2007. This method allows for heterogenous error variances, short-run coefficients and intercepts while it restricts the long-run coefficients to be the same across countries.

Given the requirements on the time-series dimension of the panel, we include only countries for which we have at least 25 consecutive observations. In addition, in light of the results obtained in Section A, we only focus on the sample of commodity exporters. This implies that our analysis will include 52 countries out of the 62 primary commodity exporters in our dataset (see Table 1).

As data on secondary enrollment used in the GMM regressions is only available in five-year intervals, we cannot use the education variable in the CPMG estimations. This also implies that we are unable to look at the human capital accumulation channel in Section V.B.2,[20] and therefore we will focus on the remaining two channels of impact on growth: TFP and physical capital investment equations.

B.1 Volatility and Growth

We use the cross-sectionally augmented Pooled Mean Group (CPMG) method described in Section III.C to estimate the following equation:

$$\begin{aligned} \Delta y_{it} &= \phi_i y_{it-1} + \boldsymbol{\beta}_i' \mathbf{x}_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{it-j} + \sum_{j=0}^{q-1} \boldsymbol{\delta}_{ij}^{*\prime} \Delta \mathbf{x}_{it-j} + \mu_i - c_i \bar{\mu} + \varepsilon_{it} \\ &\quad + a_i^* \overline{y}_t + b_i^* \overline{g}_{CTOT,t} + \sum_{j=0}^{p-1} c_{ij}^* \Delta \overline{y}_{t-j} + \sum_{j=0}^{q-1} d_{ij}^* \Delta \overline{g}_{CTOT,t-j}, \end{aligned} \tag{24}$$

where Δy_{it} is the annual growth rate of real GDP per capita for country i and year t, $\mathbf{x}_{it}$ is a 5×1 vector of explanatory variables, namely the growth rate of the CTOT index, $g_{CTOT,it}$, and its volatility, $\sigma_{CTOT,it}$, and the conventional control variables: openness, government burden, and lack of price stability. $\overline{y}_t$, $\Delta\overline{y}_t$, $\overline{g}_{CTOT,t}$, and $\Delta\overline{g}_{CTOT,t}$ denote the simple cross section averages of y_{it}, Δy_{it}, $g_{CTOT,it}$, and $\Delta g_{CTOT,it}$ in year t.

The consistency and efficiency of the CPMG estimates rely on several conditions.[21] Firstly, the order of the ARDL process must be chosen to be long enough to ensure that residuals of the error-correction model are serially uncorrelated. At the same time, with a limited number of time-series observations, the ARDL order should not be overextended as this imposes excessive parameter requirements on the data. Note that the lag order is chosen on the unrestricted model, and then the homogeneity (long run) restrictions are imposed. We try to fulfill these conditions by selecting the lag order using the Schwarz Criterion (SBC) subject to

[20] In any case, our results regarding the effect of volatility on the human capital accumulation channel was inconclusive and so warrants further investigation.

[21] There is no evidence of serial correlation, non-normality, functional form misspecification, or heteroskedasticity in most of the 52 countries in the sample. The results of the diagnostic tests are not reported in the paper but are available upon request.

a maximum lag of two on each of the variables, in other words we set $p = q \leq 2$. Moreover, we allow the lag order selection to differ across countries.

The second condition is cross-sectional independence of the residuals ε_{it}. Cross-country dependencies arise from omitted common factors (e.g. time-specific effects or common shocks) that might influence the countries differently. We try to eliminate these common factors and to some extent satisfy the independence condition by augmenting our regressions with cross sectional averages of the growth rates of real GDP and the CTOT index. Ideally, we would also like to include the cross sectional averages of all the variables in $\mathbf{x}_{it}$ but given that this is not possible, as we would run into lack of degrees of freedom, we choose the two variables that we believe are highly dependent across countries in our sample.

The third condition refers to the existence of a long-run relationship (dynamic stability) between our variables and requires that the coefficient on the error-correction term (ϕ_i) be negative. Finally, the fourth condition for the efficiency of the CPMG estimator is the homogeneity of the long-run parameters across countries. In addition to the CPMG results we also report the mean group estimates in all of our tables, which are averages of the individual country coefficients. The CMG approach provides consistent estimates of the averages of long-run coefficients, although they are inefficient if homogeneity is present. Under long-run slope homogeneity, CPMG estimates are consistent and efficient. We test for long-run homogeneity using the Hausman statistic for the coefficients on each of the explanatory variables and for all of them jointly based on the null of equivalence between the CPMG and CMG estimations; see Pesaran et al. (1996) for details. If we reject the null hypothesis (i.e. we obtain a probability value of < 0.05), the homogeneity assumption on long run coefficients across countries is invalid. Note that there is no guarantee that the variance-covariance matrix of the Hausman statistic will be positive definite, and in some cases the test may not be applicable.

Table 7 presents the CMG and CPMG estimates as well as the Hausman test statistics which is distributed as chi-squared examining panel heterogeneity.[22] According to the Hausman statistics, the long-run homogeneity restriction is not rejected for individual parameters and jointly in all regressions.[23] Thus, we focus on the results obtained using the CPMG estimator, which, given its gains in consistency and efficiency over the alternative CMG estimator, is more appropriate.

---

[22]The individual country results are not reported here but are available upon request.

[23]The likelihood ratio (LR) test always suggests that homogeneity is not a reasonable assumption in our regressions, as it does in the Pesaran et al. (1999) study of aggregate consumption. On the other hand, the Hausman test typically accepts poolability in the Pesaran et al. (1999) study as it does in our regressions. We focus largely on the Hausman test statistic based on the evidence provided by Pesaran et al. (1996). They examine the properties of the Hausman test by conducting a Monte Carlo study and show that when T is small relative to N, as it is in our study, the Hausman test has reasonable size and power.

The results in Table 7 indicate that the error correction coefficients, ϕ_i, fall within the dynamically stable range (being statistically significant and negative), and therefore the null hypothesis of no long run relation is rejected. This finding indicates that there is strong evidence for conditional convergence to country-specific steady states in our sample of 52 commodity exporting countries. This is in contrast to the results from regressions $[1.2]$ and $[3.2]$ in Tables 3 and 5 respectively, and highlights that the strict homogeneity constraints imposed in the GMM estimations are too restrictive to suggest convergence to a common steady state among all commodity exporters**.**

In the long run, the growth rate of GDP per capita is, as expected, negatively related to the size of government as well as the lack of price stability, and positively related to trade openness. Most importantly for our purposes, the CPMG estimate of the commodity terms of trade volatility is negative and statistically significant, which means that growth is adversely linked to commodity price volatility in the long run. Moreover, it is still the case that our measure of resource abundance, g_{CTOT}, is significantly positively related to economic growth, but its impact on real GDP per capita is smaller than that of CTOT volatility. Quantitatively, the overall average negative impact of the two CTOT variables on output growth is -0.09 percent per year. This finding is in line with our previous results in Tables 3 and 5, suggesting that the source of the resource curse is the volatility of commodity prices as opposed to abundance *per se*. It is also interesting that the coefficient of σ_{CTOT} in the CPMG regression of Table 7 is roughly in the same magnitude as in the two GMM regressions; see $[1.2]$ and $[3.2]$. Overall, comparing the CMG and CPMG estimates, imposing long run homogeneity reduces the standard errors, increases the measured speed of adjustment and (slightly) changes the long run estimates.

Given the importance of commodity terms of trade volatility, one of the main challenges facing policy makers in resource-rich economies that experience short-lived (and frequent) terms of trade shocks, is to put in place mechanisms that help reduce the negative effects of commodity price uncertainty on real output growth; see for instance Cashin et al. (2004). The creation of commodity stabilization funds, or Sovereign Wealth Funds (SWF) in case of the countries in the Persian Gulf, might be one of the ways to offset the negative effects of commodity booms and slumps. Further research is needed in this area as the policy agenda of resource-rich economies prioritize it.

B.2 Volatility and the Channels Affecting Economic Growth

To investigate the channels through which commodity terms of trade volatility harms output growth, we estimate the following regression for each of the 52 countries before imposing the long-run homogeneity restrictions:

$$\begin{aligned}\Delta w_{it} &= \phi_i w_{it-1} + \boldsymbol{\beta}_i' \mathbf{x}_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta w_{it-j} + \sum_{j=0}^{q-1} \boldsymbol{\delta}_{ij}^{*\prime} \Delta \mathbf{x}_{it-j} + \mu_i - c_i \bar{\mu} + \varepsilon_{it} \\ &\quad + a_i^* \overline{w}_t + b_i^* \overline{g}_{CTOT,t} + \sum_{j=0}^{p-1} c_{ij}^* \Delta \overline{w}_{t-j} + \sum_{j=0}^{q-1} d_{ij}^* \Delta \overline{g}_{CTOT,t-j}, \end{aligned} \tag{25}$$

where $w_{it} = \{$TFP or physical capital per capita for country i and time $t\}$; and Δw_{it} is the growth rate of w_{it} while $\overline{w}_t$ and $\Delta \overline{w}_t$ are the simple cross sectional averages of w_{it} and Δw_{it}, with all other variables as defined in equation (24). As the p-values of the Hausman tests in regressions $[5.1]$ and $[5.2]$ are well above the usual significance levels, we cannot reject the null hypothesis of long-run homogeneity and as such we concentrate on the CPMG estimates for both the TFP and the physical-capital investment equations.

Regression $[5.1]$ confirms that TFP is not the channel through which uncertainty in commodity prices dampens growth, as the coefficient of CTOT volatility is statistically insignificant, thus supporting the results in Sections V.A.2 and V.A.3. However, in contrast to our earlier findings using five-year averages, resource abundance measured by g_{CTOT} does negatively affect TFP growth and is statistically significant. But as the overall effect of this variable on real GDP per capita growth in the long run is significantly positive, see Table 7, it must be the case that the negative impact of g_{CTOT} on TFP growth is offset through other channels. Overall, there seems to be no statistical evidence that commodity booms eventually lead to lower output growth, consequently ruling out the possibility that the Dutch disease effect is operating in the countries in our sample.

Turning to the physical-capital-accumulation channel, regression $[5.2]$, we observe that the results presented in Table 8 are consistent with those obtained in Tables 4 and 6, as CTOT growth increases the capital stock and through that enhances the growth rate of real GDP per capita. More importantly, volatility reduces physical capital accumulation; indicating that this channel is one of the most important sources through which uncertainty in commodity prices dampens output growth.

The error-correction term in regression $[5.1]$ is in line with expectations, $\phi_i < 0$, suggesting that there is some convergence towards the technological frontier across countries and thus positive knowledge spillovers. This is also true for the physical capital investment regression in $[5.2]$. Finally, while both government burden and lack of price stability have significantly negative effects on TFP growth, trade openness has a significant positive effect. The lack of price stability (openness) also significantly negatively (positively) affects the growth rate of physical capital stock, while government consumption boosts investment.

Thus, overall, the results of the PMG estimations are in line with those obtained in Section V.A, suggesting that commodity price volatility has a negative impact on economic growth operating through lower investment in physical capital. This result is also supported by a number of contributions in the literature, see Section V.A.2, with emphasis on physical capital investment being the main channel through which the resource curse operates. However, the focus of those papers, as elsewhere in the resource curse literature, is on the level of the resource income, and they do not consider the volatility effects. The importance of our analysis lies in the fact that we consider both the level and the volatility of resource abundance (proxied by commodity prices) in our study.

VI. Concluding Remarks

This paper examined empirically the effects of commodity price booms and terms of trade volatility on GDP per capita growth and its sources using two econometric techniques. First, we employed a system GMM dynamic panel estimator to deal with the problems of simultaneity and omitted variables bias, derived from unobserved country-specific effects. Second, we created an annual panel dataset to exploit the time-series nature of the data and used a cross-sectionally augmented pooled mean group (PMG) estimator to account for both cross-country heterogeneity and cross-sectional dependence which arise from unobserved common factors. The maintained hypothesis was that commodity terms of trade volatility affects output growth negatively, operating mainly through the capital accumulation channel. This hypothesis is shown to be largely validated by our time series panel data method, as well as by the system GMM technique used, suggesting the importance of volatility in explaining the under-performance of primary commodity abundant countries.

While the resource curse hypothesis postulates a negative effect of resource abundance (proxied by commodity booms) on output growth, the empirical results presented in this paper show the contrary: commodity terms of trade growth seems to have affected primary-product exporters positively. Since the negative impact of CTOT volatility on GDP per capita is larger than the growth-enhancing effects of commodity booms, we argue that volatility, rather than abundance per se, drives the resource curse paradox.

An important contribution of our paper was to stress the importance of the overall negative impact of CTOT volatility on economic growth, and to investigate the channels through which this effect operates. We illustrated that commodity price uncertainty mainly lowers the accumulation of physical capital. The GMM results also implied that CTOT volatility adversely affects human capital formation. However, this latter effect was not robust when we used an alternate GARCH methodology to calculate CTOT volatility. Therefore, an important research and policy agenda is to determine how countries can offset the negative effects of commodity price uncertainty on physical and human capital investment.

Another notable aspect of our results was to show the asymmetric effects of commodity terms of trade volatility on GDP per capita growth in the two country groups considered. While

CTOT instability created a significant negative effect on output growth in the sample of 62 primary product exporters, in the case of the remaining 56 countries (or even in the full sample of 118 countries) the same pattern was not observed. One explanation for this observation is that the latter group of countries, with more diversified export structure, were better able to insure against price volatility than a sample of primary product exporters. Finally, we offered some empirical evidence on growth-enhancing effects of export diversification, especially for countries whose GDP is highly dependent on revenues from just a handful of primary products.

The empirical results presented here have strong policy implications. Improvements in the conduct of macroeconomic policy, better management of resource income volatility through sovereign wealth funds (SWF) as well as stabilization funds, a suitable exchange rate regime, and export diversification can all have beneficial growth effects. Moreover, recent academic research has placed emphasis on institutional reform. By establishing the right institutions, one can ensure the proper conduct of macroeconomic policy and better use of resource income revenues, thereby increasing the potential for growth. We await better data on institutional quality to test this hypothesis. Clearly, fully articulated structural models are needed to properly investigate the channels through which the negative growth effects of volatility could be attenuated. This remains an important challenge for future research.

References

Aghion, P., P. Bacchetta, R. Rancière, and K. Rogoff (2009). Exchange Rate Volatility and Productivity Growth: The Role of Financial Development. *Journal of Monetary Economics 56*(4), 494–513.

Aizenman, J. and B. Pinto (2005). Managing Volatility and Crises: A Practitioner's Guide Overview. In J. Aizenman and B. Pinto (Eds.), *Managing Economic Volatility and Crises: A Practitioner's Guide*. Cambridge University Press, Cambridge.

Alexeev, M. and R. Conrad (2009). The Elusive Curse of Oil. *The Review of Economics and Statistics 91*(3), 586–598.

Alonso-Borrego, C. and M. Arellano (1999). Symmetrically Normalized Instrumental-Variable Estimation Using Panel Data. *Journal of Business & Economic Statistics 17*(1), 36–49.

Anderson, T. W. and C. Hsiao (1982). Formulation and Estimation of Dynamic Models Using Panel Data. *Journal of Econometrics 18*(1), 47–82.

Arellano, M. and S. Bond (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies 58*(2), 277–297.

Arellano, M. and O. Bover (1995). Another Look at the Instrumental Variable Estimation of Error-components Models. *Journal of Econometrics 68*(1), 29–51.

Barro, R. J. and J.-W. Lee (2010). A New Data Set of Educational Attainment in the World, 1950 - 2010. *NBER Working Paper Series 15902*.

Beck, T., R. Levine, and N. Loayza (2000). Finance and the Sources of Growth. *Journal of Financial Economics 58*(1-2), 261–300.

Binder, M. and C. J. Offermanns (2008). International Investment Positions and Exchange Rate Dynamics: A Dynamic Panel Analysis. *Working Paper*.

Birdsall, N., T. Pinckney, and R. Sabot (2001). Natural Resources, Human Capital, and Growth. In R. Auty (Ed.), *Resource Abundance and Economic Growth*. Oxford University Press, Oxford.

Blattman, C., J. Hwang, and J. G. Williamson (2007). Winners and Losers in the Commodity Lottery: The Impact of Terms of Trade Growth and Volatility in the Periphery 1870-1939. *Journal of Development Economics 82*(1), 156–179.

Bleaney, M. and D. Greenaway (2001). The Impact of Terms of Trade and Real Exchange Rate Volatility on Investment and Growth in Sub-Saharan Africa. *Journal of Development Economics 65*(2), 491–500.

Blundell, R. and S. Bond (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Journal of Econometrics 87*(1), 115–143.

Bravo-Ortega, C., J. De Gregorio, and D. Paraguay (2005). The Relative Richness of the Poor? Natural Resources, Human Capital, and Economic Growth. *The World Bank: Policy Research Working Paper Series 3484*.

Brunnschweiler, C. N. and E. H. Bulte (2008). The Resource Curse Revisited and Revised: A Tale of Paradoxes and Red Herrings. *Journal of Environmental Economics and Management 55*(3), 248–264.

Bulte, E. H., R. Damania, and R. T. Deacon (2005). Resource Intensity, Institutions, and Development. *World Development 33*(7), 1029–1044.

Cashin, P. and C. J. McDermott (2002). The Long-Run Behavior of Commodity Prices: Small Trends and Big Variability. *IMF Staff Papers 49*(2), 175–199.

Cashin, P., C. J. McDermott, and C. Pattillo (2004). Terms of Trade Shocks in Africa: Are They Short-Lived or Long-Lived? *Journal of Development Economics 73*(2), 727–744.

Catão, L. A. V., A. Fostel, and S. Kapur (2009). Persistent Gaps and Default Traps. *Journal of Development Economics 89*(2), 271–284.

Catão, L. A. V. and S. Kapur (2006). Volatility and the Debt-Intolerance Paradox. *IMF Staff Papers 53*(2), 195–218.

Cavalcanti, T. V. d. V., K. Mohaddes, and M. Raissi (2011a). Growth, Development and Natural Resources: New Evidence Using a Heterogeneous Panel Analysis. *The Quarterly Review of Economics and Finance 51*, 305–318.

Cavalcanti, T. V. d. V., K. Mohaddes, and M. Raissi (2011b). Does Oil Abundance Harm Growth? *Applied Economics Letters 18*(12), 1181–1184.

Corden, W. M. and J. P. Neary (1982). Booming Sector and De-Industrialisation in a Small Open Economy. *The Economic Journal 92*(368), 825–848.

Esfahani, H. S., K. Mohaddes, and M. H. Pesaran (2009). Oil Exports and the Iranian Economy. *Cambridge Working Papers in Economics 0944*.

Gylfason, T. (2001). Natural Resources, Education, and Economic Development. *European*

Economic Review 45(4-6), 847–859.

Gylfason, T. (2006). Natural Resources and Economic Growth: From Dependence to Diversification. In H. G. Broadman, T. Paas, and P. J. Welfens (Eds.), *Economic Liberalization and Integration Policy*. Springer.

Gylfason, T., T. T. Herbertsson, and G. Zoega (1999). A Mixed Blessing. *Macroeconomic Dynamics 3*(2), 204–225.

Gylfason, T. and G. Zoega (2006). Natural Resources and Economic Growth: The Role of Investment. *World Economy 29*(8), 1091–1115.

Hall, R. and C. Jones (1999). Why Do Some Countries Produce So Much More Output Per Worker Than Others? *Quarterly Journal of Economics 114*(1), 83–116.

Hausmann, R., J. Hwang, and D. Rodrik (2007). What You Export Matters. *Journal of Economic Growth 12*(1), 1–25.

Heston, A., R. Summers, and B. Aten (2009). Penn World Table Version 6.3. *Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania*.

International Monetary Fund, (2010a). World Economic Outlook Database, IMF, Washinton DC.

International Monetary Fund, (2010b). International Financial Statistics, IMF, Washington DC.

Kapetanios, G., M. H. Pesaran, and T. Yamagata (2011). Panels with Non-stationary Multifactor Error Structures. *Journal of Econometrics 160(2)*, 326–348.

Krugman, P. (1987). The Narrow Moving Band, the Dutch Disease, and the Competitive Consequences of Mrs. Thatcher: Notes on Trade in the Presence of Dynamic Scale Economies. *Journal of Development Economics 27*(1-2), 41–55.

Lee, J., G. M. Milesi-Ferretti, J. Ostry, A. Prati, and L. A. Ricci (2008). Exchange Rate Assessments: CGER Methodologies. *IMF Occasional Paper No. 261*.

Levine, R., N. Loayza, and T. Beck (2000). Financial Intermediation and Growth: Causality and Causes. *Journal of Monetary Economics 46*(1), 31–77.

Neary, J. P. and S. J. G. van Wijnbergen (1986). *Natural Resources and the Macroeconomy*. MIT Press, Cambridge, MA.

Papyrakis, E. and R. Gerlagh (2004). The Resource Curse Hypothesis and its Transmission Channels. *Journal of Comparative Economics 32*(1), 181–193.

Pesaran, M. H. (1997). The Role of Economic Theory in Modelling the Long Run. *The Economic Journal 107*(440), 178–191.

Pesaran, M. H. (2006). Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure. *Econometrica 74*(4), 967–1012.

Pesaran, M. H. and Y. Shin (1999). An Autoregressive Distributed Lag Modeling Approach to Cointegration Analysis, in Storm, S., ed, Econometrics and Economic Theory in the 20th Century: the Ragnar Frish Centennial Symposium.

Pesaran, M. H., Y. Shin, and R. P. Smith (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association 94*(446), 621–634.

Pesaran, M. H. and R. Smith (1995). Estimating Long-run Relationships from Dynamic Heterogeneous Panels. *Journal of Econometrics 68*(1), 79–113.

Pesaran, M. H., R. P. Smith, and K. S. Im (1996). Dynamic Linear Models for Heterogeneous Panels. In L. Matyas and P. Sevestre (Eds.), *The Economics of Panel Data: A Handbook of Theory With Applications*, Chapter 8. Kluwer Academic Publishers.

Psacharopoulos, G. (1999). Returns to Investment in Education: A Global Update. *World Development 22*(9), 1325–l343,.

Psacharopoulos, G. and H. A. Patrinos (2004). Returns to Investment in Education: A Further Update. *Education Economics 12*(2), 111–134.

Ramey, G. and V. A. Ramey (1995). Cross-Country Evidence on the Link Between Volatility and Growth. *The American Economic Review 85*(5), 1138–1151.

Robertson, D. and J. Symons (1992). Some Strange Properties of Panel Data Estimators. *Journal of Applied Econometrics 7*(2), 175–189.

Rodriguez, F. and J. D. Sachs (1999). Why Do Resource-Abundant Economies Grow More Slowly? *Journal of Economic Growth 4*, 277–303.

Rosser, A. (2006). The Political Economy of the Resource Curse: A Literature Survey. *Institute of Development Studies Working Paper 268*.

Sachs, J. D. and A. M. Warner (1995). Natural Resource Abundance and Economic Growth. *National Bureau of Economic Research Working Paper 5398*.

Serven, L. (2003). Real-Exchange-Rate Uncertainty and Private Investment in LDCs. *Review of Economics and Statistics 85*(2), 492–492.

Spatafora, N. and I. Tytell (2009). Commodity Terms of Trade: The History of Booms and Busts. *IMF Working Paper No. 09/205*.

Stijns, J.-P. C. (2005). Natural Resource Abundance and Economic Growth Revisited. *Resources Policy 30*(2), 107–130.

UNESCO, (2010). UIS Education Statistics.

van der Ploeg, F. and S. Poelhekke (2009). Volatility And The Natural Resource Curse. *Open Access Publications from University of Oxford*.

van der Ploeg, F. and S. Poelhekke (2010). The Pungent Smell of "Red Herrings": Subsoil Assets, Rents, Volatility and the Resource Curse. *Journal of Environmental Economics and Management 60(1)*, 44–55.

van der Ploeg, F. and T. Venables (2009). Symposium on Resource Rich Economies Introduction. *Oxford Economic Papers 61*(4), 625–627.

Windmeijer, F. (2005). A Finite Sample Correction for the Variance of Linear Efficient Two-step GMM Estimators. *Journal of Econometrics 126*(1), 25–51.

World Bank, (2010). World Development Indicators, Washington DC.

TABLES AND FIGURES

Table 1. List of the 118 Countries in the Sample

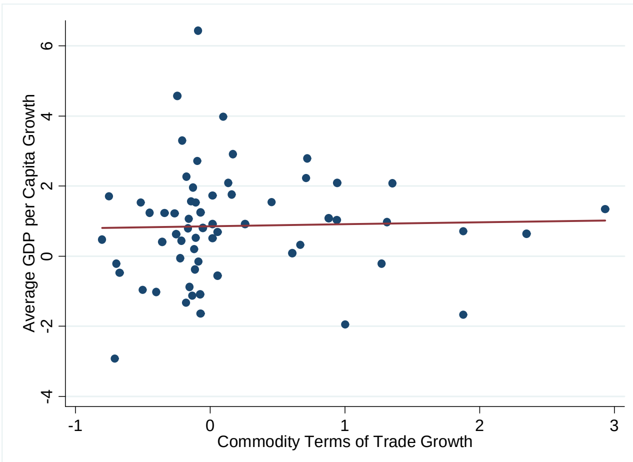
Albania	Ecuador[1,2]	Lithuania	Sierra Leone[1,2]
Algeria[1,2]	Egypt[1,2]	Malawi[1,2]	Slovak Republic
Argentina[1,2]	El Salvador	Malaysia	Slovenia
Armenia[1]	Fiji[1,2]	Mali[1,2]	South Africa
Australia[1,2]	Finland	Mauritania[1,2]	Spain
Austria	France	Mauritius	Sri Lanka
Bahrain, Kingdom of[1]	Gabon[1,2]	Mexico	Sudan[1,2]
Bangladesh	Gambia, The[1,2]	Moldova[1]	Swaziland
Belgium	Germany	Morocco	Sweden
Benin[1,2]	Ghana[1,2]	Mozambique[1,2]	Switzerland
Bolivia[1,2]	Greece	Namibia[1,2]	Syrian Arab Republic[1,2]
Botswana[1,2]	Guatemala[1,2]	Nepal	Tajikistan[1]
Brazil	Guyana[1,2]	Netherlands	Tanzania[1]
Bulgaria	Honduras[1,2]	New Zealand[1,2]	Thailand
Burundi[1,2]	Hungary	Nicaragua[1,2]	Togo[1,2]
Cambodia	India	Niger[1,2]	Trinidad and Tobago[1,2]
Cameroon[1,2]	Indonesia[1,2]	Norway[1,2]	Tunisia
Canada	Iran, I.R. of[1,2]	Pakistan	Turkey
Central African Rep.[1,2]	Ireland	Panama[1,2]	Uganda[1]
Chile[1,2]	Israel	Papua New Guinea[1,2]	Ukraine
China, People's Rep. of	Italy	Paraguay[1,2]	United Arab Emirates[1,2]
Colombia[1,2]	Japan	Peru[1,2]	United Kingdom
Congo, Republic of[1,2]	Jordan	Philippines	United States
Costa Rica	Kazakhstan[1]	Poland	Uruguay[1,2]
Côte d'Ivoire[1,2]	Kenya[1,2]	Portugal	Venezuela, Rep. Bol.[1,2]
Croatia	Korea	Romania	Vietnam
Cyprus[1]	Kuwait[1,2]	Russia[1]	Zambia[1,2]
Czech Republic	Kyrgyz Republic[1]	Rwanda[1,2]	Zimbabwe[1,2]
Denmark	Latvia	Saudi Arabia[1,2]	
Dominican Republic	Lesotho	Senegal[1,2]	

Notes: [1] indicates that the country is a commodity exporter. Countries are classified as commodity exporters if primary commodities constitute more than 50 percent of their exports. 62 countries in the sample are primary commodity exporters and 56 are not. The 52 countries that are included in the Cross-sectionally Augment Pooled Mean Group (CPMG) analysis of Section V.B are denoted by [2].

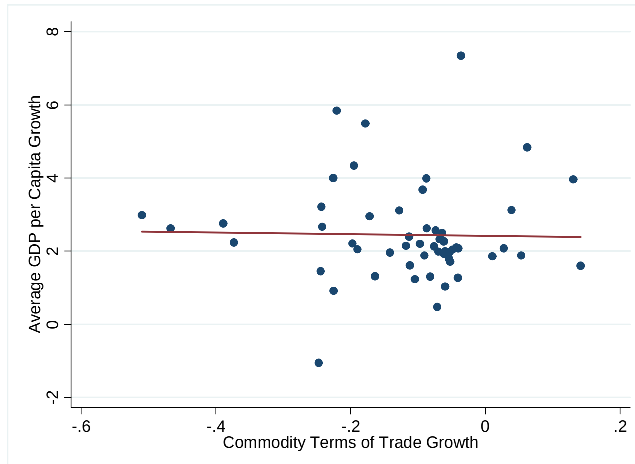
Table 2. Definitions and Sources of Variables Used in Regression Analysis

Variable	**Definition and Construction**	**Source**
Real GDP per Capita	Ratio of GDP (in 2000 US$) to population.	Authors' construction using data from the World Bank (2010) World Development Indicators (WDI).
GDP per Capita Growth	Geometric average growth rate of real GDP per capita.	
Initial GDP per Capita	Initial value of GDP per capita in the beginning of each five-year period.	
TFP	Total factor productivity (TFP).	Authors' construction using data from Heston et al. (2009). See Section IV for more details.
TFP Growth	Geometric average growth rate of TFP.	
Initial TFP	Initial value of TFP in the beginning of each five-year period.	
Physical Capital per Capita	Ratio of physical capital to population.	
Physical Capital per Capita Growth	Geometric growth rate of physical capital per capita.	
Initial Physical Capital Per Capita	Initial value of the ratio of total physical capital to total population in the beginning of each five-year period.	
Human Capital per Capita	Ratio of human capital to population.	Authors' construction using data from Barro and Lee (2010). See Section IV for more details.
Human Capital per Capita Growth	Geometric growth rate of human capital per capita.	
Initial Human Capital per Capita	Initial value of the ratio of total human capital to total population in the beginning of each five-year period.	
Commodity Terms of Trade Growth	Growth rate of commodity terms of trade index.	Authors' construction based on Spatafora and Tytell (2009).
Commodity Terms of Trade Volatility	Standard deviation of commodity terms of trade growth in five-year interval.	
Export Sophistication Measure	A measure of the productivity level associated with a country's specialization pattern.	Authors' construction based on Hausmann et al. (2007) and the World Bank (2010) WDI.
Education	Ratio of total secondary enrollment to the population of the age group that officially corresponds to that level of education.	Authors' construction using data from UNESCO (2010) UIS.
Trade Openness	Ratio of Exports and Imports to GDP.	Authors' construction using data from the World Bank (2010) WDI.
Government Burden	Ratio of government consumption to GDP.	
CPI	Consumer price index (2000=100) at the end of the year.	Author's calculations using data from the International Monetary Fund (2010a) World Economic Outlook.
Inflation rate	Annual percentage change in CPI.	
Lack of Price Stability	log(100+inflation rate).	

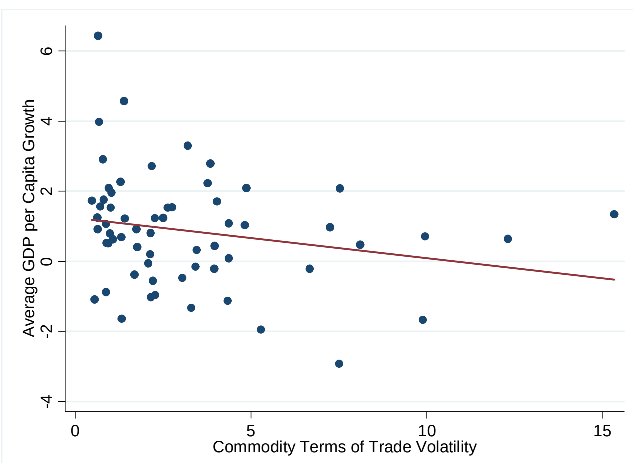
Figure 1. Commodity Terms of Trade Growth and Volatility



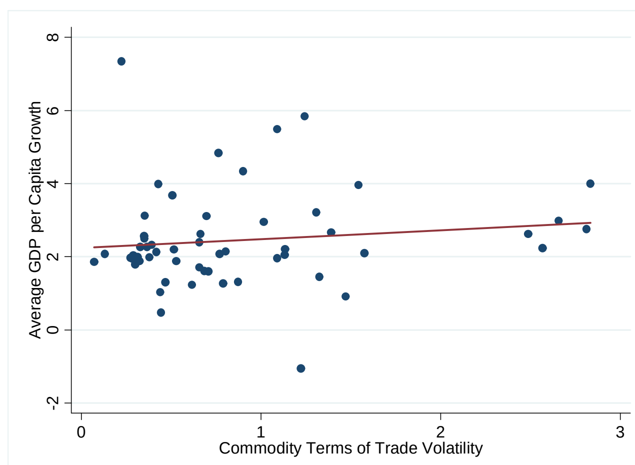
Primary Commodity Exporters (62)



All Other Countries (56)



Primary Commodity Exporters (62)



All Other Countries (56)

Notes: Average GDP per capita growth is the geometric growth rate of real per capita GDP between 1970 and 2007 and is in percent. Commodity terms of trade growth is the mean growth rate of the CTOT index, defined in (10), over 1970 to 2007. CTOT volatility is the standard deviation of the growth rate of the commodity terms of trade index and is calculated using data from 1970 to 2007. Primary commodity exporters are those countries for which the ratio of primary commodities to total exports exceed 50 percent.

Table 3. Growth Effects of CTOT Volatility I

Estimation Method:	Two-step system GMM with Windmeijer (2005) small sample robust correction.
Unit of Observation, Period:	Non-overlapping five-year averages, 1970 - 2005.
Volatility Measure:	Five year standard deviation of annual CTOT growth.

The Dependent Variable is the Growth Rate of Output per Capita	[1.1] All 118 Countries	[1.2] 62 Commodity Exporters	[1.3] Other 56 Countries
Initial Output per Capita, in logs	-1.204**	-0.872	-1.738***
	(0.471)	(0.688)	(0.546)
Commodity Terms of Trade Growth	0.240***	0.255***	-0.156
	(0.072)	(0.078)	(0.469)
Commodity Terms of Trade Volatility	-0.105	-0.119**	-0.683
	(0.081)	(0.058)	(0.577)
Export Sophistication Measure, in logs	4.818***	2.787*	3.687**
	(1.830)	(1.638)	(1.465)
Control variables			
Education	0.812	1.256	0.054
(secondary enrollment, in logs)	(0.803)	(0.960)	(1.380)
Trade Openness	2.027**	2.587***	2.142**
(trade volume/GDP, in logs)	(1.024)	(0.860)	(0.929)
Government Burden	-2.656**	-4.007***	-0.109
(government consumption/GDP, in logs)	(1.163)	(1.064)	(1.536)
Lack of Price Stability	-6.786***	-6.264**	-11.119***
(log [100 + inflation rate])	(2.412)	(2.485)	(3.773)
Intercept	-1.568	10.872	29.013
	(17.131)	(16.023)	(19.256)
No. Countries/No. Observations	118/664	62/352	56/312
Specification tests (p-values)			
(a) Hansen Test	0.121	0.448	0.314
(b) Serial Correlation			
First-order	0.000	0.000	0.003
Second-order	0.199	0.252	0.674
Impact of CTOT Growth and Volatility	-	-0.312	-

Notes: Time and fixed effects are included in all the regressions. Standard errors are presented below the corresponding coefficients in brackets. Symbols ***, **, and * denote significance at 1%, 5%, and at 10% respectively. The impact of CTOT growth and volatility measures the overall average percentage effect of the two CTOT variables on output per capita growth. Source: Authors' estimations.

Table 4. Volatility and the Sources of Growth for Commodity Exporters I

Estimation Method:	Two-step system GMM with Windmeijer (2005) small sample robust correction.
Unit of Observation, Period:	Non-overlapping five-year averages, 1970 - 2005.
Volatility Measure:	Five year standard deviation of annual CTOT growth.

The Dependent Variable is the Growth Rate of:	[2.1] Total Factor Productivity	[2.2] Physical Capital	[2.3] Human Capital
Initial TFP, in logs	-4.221***	-	-
	(0.990)		
Initial Physical Capital Stock, in logs	-	-0.601	-
		(1.020)	
Initial Human Capital Stock, in logs	-	-	-0.999
			(0.750)
Commodity Terms of Trade Growth	0.113	0.186**	0.048
	(0.162)	(0.093)	(0.030)
Commodity Terms of Trade Volatility	0.006	-0.181**	-0.051*
	(0.102)	(0.087)	(0.029)
Export Sophistication Measure, in logs	4.130***	4.979***	-0.283
	(1.382)	(1.700)	(0.465)
Control variables			
Education	1.837*	-1.417	0.643***
(secondary enrollment, in logs)	(1.034)	(1.145)	(0.202)
Trade Openness	2.106	3.205**	0.442
(trade volume/GDP, in logs)	(1.485)	(1.521)	(0.340)
Government Burden	-2.669	-1.160	0.643
(government consumption/GDP, in logs)	(2.334)	(1.714)	(0.427)
Lack of Price Stability	-5.019*	-4.143	-0.098
(log [100 + inflation rate])	(2.897)	(3.375)	(0.445)
Intercept	18.689	-18.890	-0.533
	(19.463)	(22.793)	(4.125)
No. Countries / No. Observations	62/354	62/354	62/354
Specification tests (p-values)			
(a) Hansen Test	0.351	0.145	0.469
(b) Serial Correlation			
First-order	0.001	0.012	0.006
Second-order	0.569	0.110	0.533

Notes: Time and fixed effects are included in all the regressions. Standard errors are presented below the corresponding coefficients in brackets. Symbols ***, **, and * denote significance at 1%, 5%, and at 10% respectively. Source: Authors' estimations.

Table 5. Growth Effects of CTOT Volatility II

Estimation Method:	Two-step system GMM with Windmeijer (2005) small sample robust correction.
Unit of Observation, Period:	Non-overlapping five-year averages, 1970 - 2005.
Volatility Measure:	GARCH (1,1).

The Dependent Variable is the Growth Rate of Output per Capita	[3.1] All 118 Countries	[3.2] 62 Commodity Exporters	[3.3] Other 56 Countries
Initial Output per Capita, in logs	-1.101***	-1.053	-1.891***
	(0.402)	(0.659)	(0.492)
Commodity Terms of Trade Growth	0.250***	0.264***	-0.269
	(0.077)	(0.061)	(0.445)
Commodity Terms of Trade Volatility	-0.215	-0.198**	-0.531
	(0.141)	(0.099)	(0.663)
Export Sophistication Measure, in logs	4.062**	2.744*	4.945***
	(1.628)	(1.629)	(1.561)
Control variables			
Education	1.029	1.347	0.155
(secondary enrollment, in logs)	(0.736)	(1.029)	(1.517)
Trade Openness	2.498***	2.603***	1.614*
(trade volume/GDP, in logs)	(0.922)	(0.892)	(0.957)
Government Burden	-2.948***	-3.985***	-0.376
(government consumption/GDP, in logs)	(1.096)	(1.193)	(1.423)
Lack of Price Stability	-6.945***	-6.500**	-10.520**
(log [100 + inflation rate])	(2.521)	(2.633)	(4.091)
Intercept	3.179	13.369	18.479
	(17.047)	(18.453)	(21.873)
No. Countries/No. Observations	118/664	62/352	56/312
Specification tests (p-values)			
(a) Hansen Test	0.148	0.282	0.225
(b) Serial Correlation			
First-order	0.000	0.001	0.002
Second-order	0.340	0.435	0.853
Impact of CTOT Growth and Volatility	-	-0.509	-

Notes: Time and fixed effects are included in all the regressions. Standard errors are presented below the corresponding coefficients in brackets. Symbols ***, **, and * denote significance at 1%, 5%, and at 10% respectively. The impact of CTOT growth and volatility measures the overall average percentage effect of the two CTOT variables on output per capita growth. Source: Authors' estimations.

Table 6. Volatility and the Sources of Growth for Commodity Exporters II

Estimation Method:	Two-step system GMM with Windmeijer (2005) small sample robust correction.
Unit of Observation, Period:	Non-overlapping five-year averages, 1970 - 2005.
Volatility Measure:	GARCH (1,1).

The Dependent Variable is the Growth Rate of:	[4.1] Total Factor Productivity	[4.2] Physical Capital	[4.3] Human Capital
Initial TFP, in logs	-4.031***	-	-
	(1.182)		
Initial Physical Capital Stock, in logs	-	-0.552	-
		(0.964)	
Initial Human Capital Stock, in logs	-	-	-0.992
			(0.697)
Commodity Terms of Trade Growth	0.104	0.250*	0.024
	(0.174)	(0.145)	(0.029)
Commodity Terms of Trade Volatility	0.071	-0.401**	-0.026
	(0.262)	(0.182)	(0.042)
Export Sophistication Measure, in logs	3.870**	3.863**	-0.334
	(1.633)	(1.915)	(0.431)
Control variables			
Education	1.683	-0.975	0.660***
(secondary enrollment, in logs)	(1.150)	(1.172)	(0.225)
Trade Openness	2.405	3.961***	0.496
(trade volume/GDP, in logs)	(1.907)	(1.400)	(0.388)
Government Burden	-3.076	-1.333	0.498
(government consumption/GDP, in logs)	(2.500)	(1.825)	(0.341)
Lack of Price Stability	-5.845	-5.138	-0.153
(log [100 + inflation rate])	(3.729)	(3.423)	(0.390)
Intercept	23.160	-8.444	0.143
	(25.121)	(23.846)	(3.614)
No. Countries / No. Observations	62/354	62/354	62/354
Specification tests (p-values)			
(a) Hansen Test	0.259	0.168	0.477
(b) Serial Correlation			
First-order	0.001	0.024	0.014
Second-order	0.660	0.127	0.791

Notes: Time and fixed effects are included in all the regressions. Standard errors are presented below the corresponding coefficients in brackets. Symbols ***, **, and * denote significance at 1%, 5%, and at 10% respectively. Source: Authors' estimations.

Table 7. Growth Effects of CTOT Volatility for Commodity Exporters III

Estimation Method:	Cross Sectionally Augmented Mean Group (CMG) and Pooled Mean Group (CPMG) Estimators.	
Unit of Observation, Period:	Annual, 1971 - 2007.	
Volatility Measure:	GARCH (1,1).	
The Dependent Variable is the Growth Rate of Output per Capita	CMG	CPMG
Error Correction Term	-0.248***	-0.131***
	(0.037)	(0.017)
Commodity Terms of Trade Growth	0.011	0.003*
	(0.133)	(0.002)
Commodity Terms of Trade Volatility	0.589	-0.034***
	(0.645)	(0.008)
Control variables		
Trade Openness	-0.004	0.249***
(trade volume/GDP, in logs)	(0.464)	(0.023)
Government Burden	0.060	-0.274***
(government consumption/GDP, in logs)	(0.417)	(0.027)
Lack of Price Stability	-0.536	-0.544***
(log [100 + inflation rate])	(1.033)	(0.059)
No. Countries / No. Observations	52/1813	52/1813
Specification test		
Joint Hausman Test	7.68	$[p = 0.17]$
Impact of CTOT Growth and Volatility	-	-0.090

Notes: All estimations include a constant country specific term. Standard errors are presented below the corresponding coefficients in brackets. Symbols ***, **, and * denote significance at 1%, 5%, and at 10% respectively. The dependent variable is the growth rate of real GDP per capita. The Schwarz Bayesian Criterion (SBC) has been used to select the lag orders for each group in which the maximum lag is set to two. The *p*-value is presented next to the corresponding h-test in square-brackets. The impact of CTOT growth and volatility measures the overall average percentage effect of the two CTOT variables on output per capita growth. Source: Authors' estimations.

Table 8. Volatility and the Sources of Growth for Commodity Exporters III

Estimation Method:	Cross Sectionally Augmented Mean Group (CMG) and Pooled Mean Group (CPMG) Estimators.
Unit of Observation, Period:	Annual, 1971 - 2007.
Volatility Measure:	GARCH (1,1).

The Dependent Variable is the Growth Rate of:	[5.1] Total Factor Productivity		[5.2] Physical Capital	
	CMG	CPMG	CMG	CPMG
Error Correction Term	-0.376***	-0.279***	-0.136***	-0.075***
	(0.045)	(0.033)	(0.022)	(0.015)
Commodity Terms of Trade Growth	0.013	-0.012***	0.107	0.007***
	(0.033)	(0.003)	(0.129)	(0.002)
Commodity Terms of Trade Volatility	-0.130	0.005	-0.633	-0.018***
	(0.197)	(0.007)	(0.816)	(0.005)
Control variables				
Trade Openness	-0.059	0.133***	0.755	0.542***
(trade volume/GDP, in logs)	(0.288)	(0.031)	(0.486)	(0.032)
Government Burden	-0.362	-0.267***	4.279	0.135***
(government consumption/GDP, in logs)	(0.401)	(0.026)	(3.696)	(0.025)
Lack of Price Stability	-1.359	-0.424***	-5.131*	-0.047*
(log [100 + inflation rate])	(1.984)	(0.058)	(2.791)	(0.027)
No. Countries / No. Observations	52/1816	52/1816	52/1819	52/1819
Specification test				
Joint Hausman Test	2.31	$[p = 0.80]$	6.43	$[p = 0.27]$

Notes: All estimations include a constant country specific term. Standard errors are presented below the corresponding coefficients in brackets. Symbols ***, **, and * denote significance at 1%, 5%, and at 10% respectively. The Schwarz Bayesian Criterion (SBC) has been used to select the lag orders for each group in which the maximum lag is set to two. The *p*-values are presented next to the corresponding h-tests in square-brackets. The dependent variables are the growth rate of TFP in regression [5.1] and physical capital in regression [5.2]. Source: Authors' estimations.