IDB WORKING PAPER SERIES Nº IDB-WP-1394

Debt and Economic Growth: Does Size Matter? Evidence from Dynamic Parametric and Static Non-Parametric Approaches

Gerardo Reyes-Tagle
Jorge Muñoz

Inter-American Development Bank
Institutions for Development Sector
Fiscal Management Division

April 2023

Inter-American Development Bank

Debt and Economic Growth: Does Size Matter? Evidence from Dynamic Parametric and Static Non-Parametric Approaches

Gerardo Reyes-Tagle
Jorge Muñoz

April 2023

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Reyes-Tagle, Gerardo.
Debt and economic growth: does size matter? evidence from dynamic parametric and static non-parametric approaches / Gerardo Reyes-Tagle, Jorge Muñoz-Ayala.
p. cm. — (IDB Working Paper Series ; 1394)
1. Budget deficits-Econometric models. 2. Debts, Public-Econometric models. 3. Economic development-Econometric models. 4. Coronavirus infections-Economic aspects. I. Muñoz A., Jorge E. II. Inter-American Development Bank. Fiscal Management Division. III. Title. IV. Series.
IDB-WP-1394

http://www.iadb.org

DEBT AND ECONOMIC GROWTH

DOES SIZE MATTER?

Evidence from Dynamic Parametric and Static Non-Parametric Approaches

Gerardo Reyes-Tagle
Jorge Muñoz

IDB

CONTENTS

ABSTRACT V

1. INTRODUCTION 1

2. BACKGROUND 3

3. METHODOLOGY 5

4. RESULTS 11

5. CONCLUSIONS 31

REFERENCES 33

ANNEX. PANEL ARDL COEFFICIENTS: EQUATION (5) 37

ABSTRACT*

This paper provides new evidence on the effect of debt on economic growth through two alternative methodological approaches. On the one hand, by using a panel error correction model with a sample of 130 countries between 1980 and 2020, we found evidence of the existence of a range of debt-to-GDP ratios for which economic growth remains positive after debt surges. This threshold may lie between 32 percent and 136 percent, with optimal economic growth achieved at an 84 percent debt-to-GDP ratio for the whole sample of countries. The error correction form for the economic growth was dynamically consistent and non-linear with respect to the debt-to-GDP ratio. On the other hand, recent evidence has shown that commodity price volatility increases external debt accumulation for commodity-exporting countries. Still, there is no evidence of the effects of debt surges on these countries' economic growth. This paper provides original insights into the relationship between economic growth and the debt-to-GDP ratio for commodity and non-commodity-driven economies by employing a regression discontinuity design (RDD) approach. This method allows us to estimate differences in economic growth around an estimated threshold without assuming any specific function for the underlying relationship between the two variables. Our findings suggest that non-commodity-driven economies benefit from a higher threshold (85 percent) than commodity-exporting economies (50 percent).

JEL Codes: C22, C23, E62, F43, G18, H63
Keywords: debt thresholds, optimal debt, economic growth, ECM/ARDL panel, panel cointegration, RDD, commodity-exporting and non-commodity-exporting economies

* Gerardo Reyes-Tagle is a principal fiscal economist at the Fiscal Management Division of the IDB and Jorge Muñoz is a research consultant. We are thankful to three anonymous referees and to Hunt Howell, Hyunjoon Joo, Philip Keefer, Amy Scott, and Oscar Valencia for their valuable comments on previous versions of this paper.

1

INTRODUCTION

Debt instruments are useful tools for governments to finance their budget deficits. In emergencies like the pandemic caused by COVID-19, governments have had to resort to several debt instruments to inject liquidity into the economy. Notwithstanding the long-run effects, governments worldwide increased their debt levels mainly to support small businesses and household consumption while also purchasing massive amounts of vaccine to administer to the population at no cost. Providing liquidity for the economy was key during the period 2020–2022, but it is also important to revisit the effects on economic growth after periods of tight fiscal space have triggered increases in the debt-to-GDP ratio. In this line of research, the literature provides evidence of the existence of a possible threshold between the debt-to-GDP ratio and economic growth after major increases in the public debt stock.

Debt itself is not bad per se; what presumably is bad is that when public debt surges the funds are persistently spent on current expenditure instead of on public investment, or when new debt is exclusively used to repay debt for prolonged periods of time. For instance, since 2000, Japan had increased its debt-to-GDP ratio to such an extent that by 2022 it was the most indebted country in the world; nonetheless, the economic growth of Japan has been relatively stable since then, and its government investment compared to the mean of OECD countries has been higher (OECD, 2021).[1] Moreover, Japan has paid miniscule interest rates to bondholders, which has helped to repay its debt without entering into default.[2] However, the story may be different when a country increases its debt for prolonged periods of time and is not able to pay interest on its debt without refinancing. This may trigger financial panic in both domestic and international markets, increasing the risk of default and consequently hampering the country's path of economic growth.

[1] The rise of the debt-to-GDP ratio is also due to the cessation of GDP growth per capita in Japan since the mid-1990s compared to the previous rate of growth since the mid-1970s and the increase in public works by the national government as an economic stimulus during the long recession through the 1990s, when many local governments started to face fiscal constraints that obligated them to issue bonds to sustain the maintenance of public works and public services (Kriss et al., 2021).

[2] Specifically, the condition is that the interest rate for the debt service is smaller than the rate of economic growth; otherwise, debt levels can change erratically with indeterminate equilibriums or grow exponentially. The latter situation can theoretically happen when a government pursues a Ponzi scheme resulting in public debt growing consistently faster than the economy.

A vast literature documenting the relationship between the debt-to-GDP ratio and economic growth has been published following the iconic paper of Reinhardt and Rogoff (2010), in which surpassing a debt-to-GDP threshold of 90 percent was, after some technical controversies, found to be associated with lower economic growth. We identified 56 papers on this subject, in which different methodologies as well as varying samples of countries and time spans were employed to address this subject.

Our paper provides new evidence in this regard by investigating the relationship between debt and economic growth based on two alternative approaches: a parametric approach using a panel error correction model (ECM) and a non-parametric approach employing a regression discontinuity design (RDD). While the ECM provides findings on the whole sample of countries, the RDD allows us to split the sample into commodity-driven and non-commodity-driven economies.

Recent evidence suggest that commodity price volatility increases external debt accumulation for commodity-exporting countries, especially when countries have fixed exchange rate regimes (Vespignani, Kumar, and Raghavan, 2021). To the best of our knowledge, there is no evidence on the effect of debt on economic growth for these economies. We investigate this relationship by using the RDD approach for two specific reasons: (i) it is quite common that commodity-driven economies fail to have long time series, and therefore under the dynamic parametric approach (utilizing ECM) the statistical results for these countries have been of a low statistical quality; and (ii) the RDD approach imposes less restriction on the underlying function that depicts the relationship between the debt-to-GDP ratio and economic growth. This helps to clarify whether there are statistical differences in growth around a threshold by describing the systematic part of the variation in the data through local polynomial regressions. Finally, in contrast with other studies, we provide evidence on the relationship between debt-to-GDP ratio and economic growth by controlling for the most important macroeconomic rates (namely, inflation rate, exchange rate, short-term interest rate, debt payment interest rate, unemployment rate, and population growth rate).

This document is organized in five sections including this brief introduction. The second section presents the most recently available evidence; the third section includes the methodology proposed and data used to estimate the empirical models. The fourth section shares the results and finally, the fifth section concludes.

2

BACKGROUND

There is a consensus that government can use fiscal policy to foster economic growth. Issuing public debt on financial markets, with bonds maturing in multiple years, is part of modern fiscal policy when budgetary deficits emerge. But what is the effect on the economy of issuing public debt? This question can be traced back to Ricardo and Smith, who believed that government should not finance its expenditures with loans because it may lead to capital flight abroad in response to excessive taxation to service the debt and interfere with the "natural equilibrium" of the economy (see Churchman, 2001).

The discussion continued more than a century later in exploring the role of debt and its effects on future generations as a legacy of both rights and obligations (Buchanan, 1958; Meade, 1958; Musgrave, 1959; Bowen, Davis, and Kopf, 1960). Discussion focused on the long-run implications of debt for the economy as a burden that crowds out private capital and eventually leads to a reduction of goods and services for future generations (Modigliani, 1961). Subsequent discussion by Diamond (1965) showed that issuing domestic debt crowds out capital, but this effect does not apply for debt held by foreigners. Then Barro (1974, 1979) argued that the existence of uncertainty on future tax liabilities implies that public debt issue will increase risk contained in household balance sheets and consequently will reduce household wealth. Barro expanded the discussion in the context of determining optimal taxation and optimal public debt by a government that is trying to manage its debt to minimize the expected present value of the distortions from financing its expenditures (Barro, 1999).

Smyth and Hsing (1995) noticed that three different views were predominant in the discussion of the impact of federal deficits and debt on economic growth: (i) the stimulus view in which deficit and debt will stimulate employment, consumption, investment, and, consequently, economic growth; (ii) the crowding-out view, which states that higher deficits and debt will reduce economic growth due to rising interest rates and lower private investment and capital formation; and (iii) the so-called Ricardian view, which holds that deficits and debt do not have any impact on economic growth because the decrease in future income and consumption due to greater tax burdens will be offset by the increase in current government spending. Taking all this into account, Smyth and Hsing (1995) argued that estimating a quadratic form should be an appropriate way to test the positive, horizontal, and negative relations because these hypotheses represent different relations between debt and growth.

As information for other countries started to become available, a vast literature documenting the relationship between the debt-to-GDP ratio and economic growth emerged for a wider sample of countries. Using a sample of 44 countries, Reinhardt and Rogoff (2010) estimated a threshold of 90 percent debt-to-GDP ratio, above which countries experienced lower economic growth. After that paper was published, there were at least 56 documents published on this subject in peer-reviewed journals, in which alternate methodologies as well as different samples of countries and time spans were employed to estimate empirically the relationship between the debt-to-GDP ratio and economic growth.

According to Caner, Grennes, and Koehler-Geib (2010), when the debt-to-GDP ratio exceeds a threshold of 77 percent each additional percentage point of debt costs 0.017 percentage points of annual real growth. This effect is even worse in emerging markets where the threshold is 64 percent debt-to-GDP ratio. Using threshold regression methods, Cecchetti, Mohanty, and Zampolli (2011) estimated a critical level of 85 percent for OECD countries, beyond which public debt is harmful for economic growth. However, a review of most of the literature on this subject reveals that evidence comes in different flavors. Although some studies have found evidence of a negative effect on economic growth after increasing the debt-to-GDP ratio, other studies provide evidence of positive effects, and yet others have not found any evidence, positive nor negative. Moreover, some studies argue that the effect of increasing the debt-to-GDP ratio on economic growth is non-linear and concave—that is, the effect is initially positive until reaching a threshold (maximum) level, after which it turns negative. Meanwhile other studies do not find evidence of this concavity. When considering the evidence in favor of an inverted U-curve, the maximum point has been set at different levels.[3]

Other authors such as Panizza and Presbitero (2013) investigate the causal effect between debt and growth using an instrumental variable approach and find no evidence that high public debt levels hurt future growth in advanced economies. Pescatori, Sandri, and Simon (2014) found similar results after taking an extensive dataset developed by the IMF between 1875 and 2011 in a sample of 19 advanced economies. These authors, however, argue that the fact that there is no clear debt threshold that impairs medium-term growth should be interpreted with caution as their evidence suggests that higher debt is associated with more volatile growth.

Most recently, other studies have found evidence that commodity price volatility increases external debt accumulation for commodity-exporting countries (Vespignani, Kumar, and Raghavan, 2021), but no evidence has been provided yet on the effect of high levels of debt on economic growth for these economies. Some studies have shown a strong link between high levels of indebtedness and unfavorable terms of trade among commodity-dependent countries (Swaray, 2005), which may eventually harm economic growth, making these countries more sensitive to high levels of debt-to-GDP ratio.

In view of all this evidence, there is no doubt that discussion of the relationship between the debt-to-GDP ratio and economic growth is still open. As previously mentioned, we have identified 56 papers on this subject published in peer-reviewed journals, 50 of them published after the controversial paper of Reinhart and Rogoff (2010), and so far, no consensus has been reached.

[3] For instance at 20–25 percent (Clements, Bhattacharya, and Nguyen, 2003), 30–45 percent (Patillo, Poirson, and Ricci, 2002; Baglan and Yoldas, 2013), 59 percent (Afonso and Jalles, 2013), 75 percent (Afonso and Alves, 2014), 82–91 percent (Padoan, Sila, and van den Noord, 2012), 85 percent (Cecchetti, Mohanty, and Zampolli, 2011), 90 percent (Kumar and Woo, 2010), 94–95 percent (Bilan and Ihnatov, 2015; Checherita, Hallett, and Rother 2012; Baum, Checherita-Westphal, and Rother 2013), and 137 percent (Grennes, 2019), among many others.

3

METHODOLOGY

3.1. Parametric Dynamic Approach

Most of the parametric approaches to investigating the relationship between debt-to-GDP ratio and economic growth have employed panel, static, and dynamic models. The main challenge to address is the potential endogeneity caused by a reverse causality between the level of debt and the state of the economy within its business cycle. However, data also suggest that this relationship is not just a matter of a short-run or a cyclical phenomenon, as a few authors have found that some countries have endured prolonged debt overhang often lasting for an average duration of 23 years (Reinhart, Reinhart, and Rogoff, 2012). As most of the studies focus on the relationship between the debt-to-GDP ratio and economic growth, this paper investigates this dynamic relationship from the perspective of the level of GDP to find a long-run relationship (for the level of log GDP and debt) as well as a short-run relationship (for the first-differenced specification) between these two variables. This can be done by employing a dynamic model of the levels of GDP compared to the debt-to-GDP ratio via an autoregressive distributed lag (ARDL) panel model, which can be transformed to its error correction form if evidence of an equilibrium state is found.

In this sense, we research the relationship between the debt-to-GDP ratio and economic growth by using an alternative approach, focused on researching the empirical relationship between the log level of GDP and the debt-to-GDP ratio through a cointegration approach and then finding out its short-run dynamics by estimating an error correction form for the economic growth. Many studies focus on the empirical relationship of GDP levels and other variables without explicitly estimating any specific production function, and most of these empirical relationships were investigated using cointegration approaches (for instance, exploring the relationship between the log level of GDP and stock prices, oil prices, exchange rates, unemployment rate, CO_2 emissions, foreign direct investment, among others). These studies were conducted not only for country-specific cases but also for multi-country approaches using panel data models.[4]

[4] See Kelly, McQuinn, and Stuart (2013), Naser (2017), Alexius and Spang (2018), Carlsson and Holm (2020), Liu (2020), Mirovic, Kalas, and Milenkovic (2021), and Caporale, Claudio-Quiroga, and Alberiko Gil-Alana (2021) for multi-country approaches. See Chisti and Shakeel (2018), Zou (2018), Boga (2020), Idris, Ashemi, and Musa (2019), and Linacre (2006) for country-specific cases.

We follow this approach to try to establish the relationship between economic growth and the debt-to-GDP ratio. To do this we start by considering a model for the log level of GDP, which is expressed as the result of infinite shocks on the main markets of the economy such as the market of goods and services, the labor market, the credit market, and the foreign currency market. The proxy for these shocks is measured using the conventional variables for these markets, such as the consumer price index, the unemployment rate, the short-term interest and nominal exchange rates, and the interest rate paid on debt. Furthermore, we also assume that the log level of GDP responds to shocks observed in the level of public debt. Because we are considering several countries in our analysis, we normalize the level of public debt to the level of GDP. Likewise, taking into consideration that most of the literature posits a non-linear relationship between economic growth and the debt-to-GDP ratio, we investigate this non-linear relationship as well by assuming a polynomial with two turning points on the debt-to-GDP ratio affecting the log level of GDP. If the log GDP responds dynamically to these shocks, then there should exist an equilibrium between these variables as well. In terms of symbols, we start with the following theoretical expression:

$$log(y_{i,t}) = \sum_{l=0}^{\infty}\sum_{j=0}^{3} \beta_{jl} D_{i,t-l}^{j} + \sum_{l=0}^{\infty}\sum_{j=1}^{k} \omega_{jl} Z_{j,i,t-l} + \alpha_i^* + \in_{i,t}^* \quad (1)$$

where y represents the GDP per capita in USD, D the debt-to-GDP ratio, and z_i the variables in our model—namely, the log of consumer price index, the log of nominal exchange rate, the unemployment rate, the short-term interest rate, the debt payments interest rate, and the log of population in the i-th country. Finally, a* are the country heterogenous effects on the log of GDP, which we assume correlate with the r.h.s. variables in the model (D and z_i), while e^* is the idiosyncratic error, which we assume to be stationary.[5]

This model has an infinite number of parameters to estimate and therefore is impossible to manage with finite information unless we impose some dynamic restrictions. In the spirit of the model of Koyck (Franses and van Oest, 2004), we impose restrictions on the parameters to find the impulse response function (IRF) that shows an exponential decay pattern, as follows:

$$\beta_{jl} = \beta_{j0}\lambda^{j} \text{ and } \omega_{jl} = \omega_{j0}\lambda^{j}$$

Under these restrictions, and assuming $|\lambda| < 1$, then the infinite parameter model can be transformed into a finite representation. These restrictions guarantee that the impulse response function is absolutely summable:

$$\sum_{l=0}^{\infty} \frac{\partial log(y)_{t+l}}{\partial D_t^j} = \sum_{l=0}^{\infty} \beta_{j0}\lambda^{l} = \frac{\beta_{j0}}{(1-\lambda)}, \forall j = 1 \text{ to } 3$$

$$\sum_{l=0}^{\infty} \frac{\partial log(y)_{t+l}}{\partial z_{jt}} = \sum_{l=0}^{\infty}\omega_{j0}\lambda^{l} = \frac{\omega_{j0}}{(1-\lambda)}; \forall j = 1 \text{ to } k$$

And the model to estimate is

$$log(y_{i,t}) = \lambda log(y_{i,t-1}) + \sum_{j=0}^{3} \beta_j D_{i,t}^{j} + \sum_{j=1}^{k} \omega_j Z_{j,i,t} + \alpha_i + \in_{i,t} \quad (2)$$

where $a_i = (1-l)\, a^*_{i,}$ and e_{it} follows and MA(1) process with parameter equal to $-l$.[6]

Equation (2) suffers from endogeneity arising from five sources, namely: (i) e_{it} follows and MA(1), and the model has a lag of the dependent variable as regressor, (ii) the fixed effects are correlated with the regressors, (iii) the fixed effects in the model and the presence of a lag-dependent variable as regressor (Nickel

[5] The other indexes in (1) are l for lags, and k for all the covariates considered in the model besides debt-to-GDP ratio.

[6] This expression resembles the general dynamic panel expression for growth models proposed by Islam (1995) and employed in the vast majority of empirical growth models estimated using panel data based on the hypothesis of conditional convergence (see also Durlauf, Johnson, and Temple [2005]). The difference here is that we are not considering the traditional Solow variables, but a weighted sum of shocks experienced in the principal markets of the economy.

bias), (iv) the reverse causality in the model, and (v) the potential omission of other growth determinant variables. In view of this, we estimate this equation following a generalized method of moments (GMM) strategy,[7] including time fixed effects to partially control for cross-panel dependence. However, if variables in Equation (2) are integrated, then it is possible that a stable relationship among them exists after finding evidence of a cointegration relationship that depicts an equilibrium state. This situation is quite possible as we are considering the principal macroeconomic shocks inside the model, which we expect to be related to each other dynamically and consequently form a static-stable equilibrium.

If this equilibrium holds, we can estimate an error correction form for which we can estimate the short-run dynamics between the debt-to-GDP ratio and economic growth and the long-run equilibrium from the log level of GDP and a certain polynomial on the debt-to-GDP in the same equation. Let us assume the following equilibrium equation based on a third-degree polynomial on the debt-to-GDP ratio:

$$log(y_{i,t}) = \sum_{j=1}^{3} \beta_j D^{j}_{i,t} + \sum_{j=1}^{k} \omega_j Z_{j,i,t} + \alpha_i + \epsilon_{i,t} \qquad (3)$$

In Equation (3), $S^{3}_{j=1}$ j b_j $D^{j-1}_{i,t}$ represents the expected economic growth (E ($\Delta\%y_i$), where y is the log of GDP per capita in USD) after an increment of one percentage point in the debt-to-GDP ratio ($\Delta D_{i,t} = 1$). The coefficients ω_j apply to the z_j, which are the additional explanatory variables in our model (namely the consumer price index, the nominal exchange rate, the unemployment rate, the short-term interest rate, the interest rate on debt payments, and the log of population of the i-th country). Finally, α_i are the country heterogeneous effects over the log level of GDP, which we assume correlated with the r.h.s. variables in the model (D, and z_j), while $e_{i,t}$ is the idiosyncratic error term for which we assume weak stationarity.

There are still two sources of potential endogeneity in this model: (i) the non-observable heterogeneous effects and (ii) the simultaneity or reverse causality of the variables involved in the model. To resolve these potential sources of endogeneity, we estimate Equation (1) with a GMM estimator using as instruments a lagged vector of the r.h.s. variables including fixed effects on time and on country basis. To make sure these instruments are exogenous, we use a lag of 6 for the vector of instruments.[8] Finally, we test for unit roots in the residuals from this equation to prove evidence in favor of a panel weak stationarity. The panel error correction model is then estimated; the equation is the following:

$$\Delta log(y_{i,t}) = \sum_{j=1}^{3} \beta_j \Delta D^{j}_{i,t} + \sum_{j=1}^{k} \omega_j \Delta Z_{j,i,t} - \mu \epsilon_{i,t-1}$$
$$\epsilon_{i,t-1} = log(y_{i,t-1}) - \sum_{j=1}^{3} \beta^{+}_j D^{j}_{i,t-1} - \sum_{j=1}^{k} \omega^{+}_j Z_{j,i,t-1} - \alpha_i \qquad (4)$$

Equation (4) has a primitive representation under a panel ARDL(p, q) approach. We also estimate the model based on this approach to confirm the existence of a stable and causal relationship in the levels of the variables. This can be confirmed in two ways: (i) by determining that the speed of adjustment in the error correction model is negative and greater than −2 (otherwise unstable relationships or even explosive processes would take place) and (ii) by examining the form of the impulse response function (more specifically, an exponentially decay form on the IRF). The ARDL approach allows

[7] See Anderson and Hsiao (1982), Arellano and Bond (1991), Arellano and Bover (1995), Baum, Schaffer, and Stillman (2003), Blundell and Bond (1998), Bond (2002), Roodman (2009), and the vast and rich literature using internal instruments through GMM estimators to solve several sources of endogeneity.

[8] "The National Bureau of Economic Research (NBER) has designated nine business cycles over the years from 1945 to 1991. During this period, the average business cycle lasted about five years" (Federal Reserve Bank of San Francisco, 2002). In order to isolate short-run effects as much as possible, we use a lag of 6 for the vector of instruments.

us to construct the impulse response function with which we can see how economic growth responds to a debt shock for different time horizon analysis. If the relationship of the levels of the variables is stable, then the impulse response function will exhibit an exponential decay pattern. Let us assume an ARDL(p, q) for the variables involved in our analysis:

$$A(L)log(y_{i,t}) = \sum_{j=1}^{3} \beta_j(L)D_{i,t}^{j} + \sum_{j=1}^{k} C(L)_j z_{j,i,t} + \alpha_i + \epsilon_{i,t} \quad (5)$$

In Equation (5) $A(L)$, $B_j(L)$, and $C_j(L)$ are polynomials in the lag operator, such that $A(0) = 1$, $B_j(0) = b_{0j}$, and $C_j(0) = C_{0j}$. Polynomials $B_j(L)$ and $C_j(L)$ are assumed to be of order q, while polynomial $A(L)$ is of order p. By providing for a stable equilibrium relationship between the levels of the variables $I(1)$ such as exhibited in Equation (3), then the impulse response function of economic growth to changes in the debt-to-GDP ratio over different time horizons may be derived from the following equations:

$$\frac{\partial log(y)_t}{\partial D_t} = \sum_{j=1}^{3} j b_{0j}(L)D_{i,t}^{j-1}, \text{ automatic (instantaneous) response}$$
$$\frac{\partial log(y)_{t+j}}{\partial D_t} = A(L)^{-1}\left(\sum_{j=1}^{3} j\beta_j(L)D_{i,t}^{j-1}\right), \forall j > 0 \quad (6)$$

3.2. Non-Parametric Static Approach

Since the parametric dynamic approach requires a large amount of information when running the GMM estimator, results of the panel ARDL model for subsamples of countries are unstable and have low statistical quality. This is attributable in part to the non-OECD countries not having long historical datasets on unemployment, inflation, and the debt-to-GDP ratio. Because of that we decided to complement the evidence we found for the whole sample of countries by investigating the threshold for subsamples of countries employing a non-parametric approach.

Vespignani, Kumar, and Raghavan (2021) found evidence that commodity price volatility increases external debt accumulation for commodity-exporting countries, particularly when countries have fixed exchange rate regimes. To the best of our knowledge, there has been no analysis of the evidence of the effects of large debt-to-GDP ratios on the economic growth of these countries. To provide an initial analysis of that evidence, we divide the sample of countries into four groups: Organisation for Economic Co-operation and Development (OECD), Latin America and the Caribbean (LAC), commodity-driven, and non-commodity-driven economies. Then we segregate our data into these groups and run local regressions of economic growth as a function of the debt-to-GDP ratio. This method has the advantage over other parametric methods that it does not require assuming a specific functional form for the relationship between economic growth and the debt-to-GDP ratio. This helps to clarify the underlying relationship between both variables by describing the systematic part of the variation in the data through local polynomial regressions. In addition, this method works well when dense sample datasets are available, which is the case with our samples of countries, as the OECD sample has 992 observations, the LAC sample 438 observations, the commodity-driven economies 1,590 observations, and the non-commodity-driven economies 1,647 observations.

Assuming that we do not know the relationship between economic growth and the debt-to-GDP ratio, but that we do know that debt depends on the size of the primary balance (pb) for each country, we start by setting up a local regression:

$$D_t = m(pb_i, \Theta) + u_i$$

where Θ is a vector of parameters and u_i an error term for which classical assumptions apply over a certain data range. From this local regression, we can estimate a new set of points between growth and the expected value of debt due to primary balances, which reveals the trend in the original set of points and helps purge the potential heteroskedasticity from the linear relationship between growth and debt. Over this new set of points, we estimate a non-parametric regression to determine the expected economic growth curve due to the expected values of debt. We plot this curve with its confidence intervals at the level of 5 percent to determine the probable level of the debt-to-GDP ratio after which the expected economic growth turns negative. Finally, we corroborate our findings by estimating non-parametric regression discontinuity designs (RDD) around the estimated thresholds. The RDDs were estimated using actual data of growth and debt-to-GDP ratios.

3.3. Data

We use a sample of 130 countries for which we collect annual data between 1980 and 2020. Most variables came from the WEO-IMF—namely, GDP in USD, the consumer price index, the general government gross debt, population, unemployment rate—while nominal exchange rate and short-term interest rates were retrieved from the WDI-WB, the OECD database, and country databases. Finally, the interest expense on the debt outstanding as percentage of GDP was obtained as a proxy from the general government primary net lending/borrowing minus general government net lending/borrowing, both measured in terms of GDP. Then the interest rate was proxied by calculating the ratio of the interest expense to the general gross debt.

4

RESULTS

Table 1 shows estimates under Equation (2). As can be seen from the table, restrictions applied to Equation (1) are valid and the model is dynamically causal for the log GDP per capita over the entire history of shocks to the variables involved in our model, including the debt-to-GDP ratio. Our first approximation of the relationship between economic growth and the debt-to-GDP ratio in equilibrium is that of a concave relationship (i.e., growth initially rises then falls with increasing debt-to-GDP ratios), although it was found to be of low statistical significance. Concavity is deduced from the sign of the coefficient of the cube of the debt-to-GDP ratio in the level equation, which must be negative. This conclusion was reached after controlling for time and heterogeneous fixed effects and instrumenting the equation with deeper lags to control for the Nickel bias, potential reverse causality, and endogeneity due to the lagged dependent variable in the model with possible moving average errors caused by the causal restrictions. Instrumentation was done 'à la Anderson and Hsiao (1982) so as to avoid instrument proliferation given that our time sample covers more than 10 periods.[9] In non-instrumented environments (fixed effects model), the relationship between economic growth and the debt-to-GDP ratio was convex (i.e., growth increases with increasing debt-to-GDP ratios), which seems to contradict most of the literature that reports a concave relationship between these variables. Size and sign of coefficients on other variables were as expected and statistically significant for the unemployment rate, population growth, and the short-term interest rate in the GMM model with time and cross section fixed effects.

Estimates of the static relationship proposed in Equation (3) are shown in Table 2. Under this approach, concavity in the relationship between economic growth and the debt-to-GDP ratio was also found with higher statistical significance by using GMM estimators. The set of instruments behaved better with a model that includes time and heterogenous fixed effects as can be seen with the Hansen-J statistic. It is interesting that 47 percent of the GDP variance in the panel was explained with the variables included in the model (this result can be seen with the pooled OLS [POLS] and the GMM approach with non-fixed effects).

[9] Even though in our panel *N*>*T*, we did not implement any of the dynamic panel approaches due to T being greater than 10, and it is well known that GMM estimators for dynamic panel data models become inconsistent as the number of instruments becomes too large (Roodman, 2009).

TABLE 1. LONG-RUN COEFFICIENTS: EQUATION (2)

Dependent variable: log(y)						
Variable	**POLS**	**FEM**	**FEM**	**GMM**	**GMM**	**GMM**
D	−4.23***	0.05	0.00	−3.74	−0.42	−0.05
D^2	2.51	−0.32*	−0.33	3.07	0.61	0.55
D^3	−0.67	0.08+	0.08	−0.92	−0.22	−0.23*
log(u)	−0.73***	−0.24***	−0.22***	0.64	−0.93***	−0.91***
log(cpi)	0.06	1.47***	1.27***	−0.06	1.29***	0.28
log(pop)	−0.00	−0.22**	−0.36**	0.03	0.40+	0.93***
log(exr)	−0.15***	−1.28***	−1.13***	−0.01	−1.22***	−0.02
dpir	0.18*	0.00	0.01*	0.17	0.03	-0.01
irate	−7.39***	−1.19***	−1.11***	−6.53	0.30	−1.32***
lag[log(y)]	0.97***	0.65***	0.73***	0.98***	0.56***	0.55***
Cross-fixed	No	Yes	Yes	No	Yes	Yes
Time-fixed	No	No	Yes	No	No	Yes
Hansen J	—	—	—	22.20	10.58	8.29
Prob(J-stat)	—	—	—	0.00	0.10	0.22
R2	0.99	0.99	—	0.99	0.99	0.99
Obs	2031	2031	—	1553	1553	1553

*(**)[***]: 90% (95%) [99%].
y: GDP per capita (USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

Considering that the variables in our model can be integrated of order d and consequently CI(d, b) with b > 0, we then decided to test for unit roots in the variables included in the model. Because we found evidence of cross dependence in our panel, we not only estimated the first-generation panel unit root test but also the cross-sectionally augmented panel unit-root (Cross-sectionally augmented Im-Pesaran-Shin or CIPS)[10] test of second generation. We found evidence of integration of order one for all the variables (except for the debt payments interest rate) in the model with the first-generation tests. We confirmed these results with the CIPS test, but also concluded that the debt payments interest rate is I(1) as this variable also showed evidence of cross dependence in our panel of countries (see results of the Pesaran-CD test in the Annex).

Given that we found evidence that all the variables in our model are I(1), we test for a panel cointegration between them. Because the Pedroni test allows a maximum of seven covariates on the right-hand side of the equation and we have nine variables in our model, we proceeded sequentially to perform this test. First of all we check for cointegration between the log level of GDP and the debt-to-GDP ratio in four steps: (i) testing a linear cointegration in the levels (which implies a constant response of the economic growth after changes in the debt-to-GDP ratio), (ii) testing a quadratic relationship cointegration in the levels (which implies a linear trend response of the economic growth after changes in the debt-to-GDP ratio), (iii) testing a cubic relationship cointegration in the levels

[10] See Im, Pesaran, and Shin (2003).

TABLE 2. EQUILIBRIUM COEFFICIENTS: EQUATION 3

Dependent variable: log(y)						
Variable	**POLS**	**FEM**	**FEM**	**GMM**	**GMM**	**GMM**
D	-1.19***	0.39***	0.08	-2.21***	0.22	-0.57*
D^2	1.29***	-0.44***	-0.24**	2.51**	-0.03	0.62*
D^3	-0.32**	0.11***	0.05+	-0.68**	-0.04	-0.22**
log(u)	-0.32***	-0.18***	-0.12***	-0.35***	-0.41***	-0.48***
dpir	-0.04***	0.00	0.00	-0.02	0.00	-0.01
log(cpi)	0.07***	1.49***	1.15***	0.08***	1.41***	0.57**
log(pop)	-0.04***	0.09**	-0.34***	-0.05***	0.28	0.31+
log(exr)	-0.14***	-1.19***	-0.98***	-0.12***	-1.11***	-0.30
irate	-7.21***	-0.71***	-0.41***	-8.71***	-0.48	-0.84**
cons	10.84***	4.48***	6.71***	11.22***	4.75***	7.62***
Cross-fixed	No	Yes	Yes	No	Yes	Yes
Time-fixed	No	No	Yes	No	No	Yes
Hansen J	-	-	-	16.34	15.90	6.61
Prob(J-stat)	-	-	-	0.01	0.01	0.36
R2	0.48	0.99	0.99	0.47	0.98	0.98
Obs	2037	2037	2037	1573	1573	1573

*(**)[***]{+}: 90% (95%) [99%]{85%}.
y: GDP per capita (USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

(which implies a quadratic trend response of the economic growth after changes in the debt-to-GDP ratio), and (iv) testing a quartic relationship cointegration in the levels (which implies a cubic trend response of the economic growth after changes in the debt-to-GDP ratio). This sequential testing mechanism allows us to find the cointegrated relationship between the economic growth and the debt-to-GDP ratio. Tables 6 and 7 show the results of these tests. As can be seen from Table 6, there is evidence of cointegration between the log level of GDP and the debt-to-GDP ratio under the first three specifications, but no evidence of cointegration under a fourth-degree polynomial in the debt-to-GDP ratio.[11]

With respect to evidence of cointegration between the log GDP per capita and the other variables in our model, we check it sequentially as well, starting with the GDP per capita, the debt-to-GDP ratio, and the log of the consumer price index, and then adding variables one by one to the tests. We start with the log of prices as some countries may strive for an optimal debt level depending on the actual state of the economy through their respective business cycles; then the next variable we add is the log of the exchange rate because some countries may effectively increase the domestic value of their foreign currency debt by seeking trade benefits via exchange rate devaluations. Following this, we add the short-term interest rate to evaluate the effects of fiscal policy when financing

[11] For this specification, two out of three tests (namely, the Pedroni test and the Johansen-Fisher test) showed no evidence of cointegration; however, with the Kao test there was evidence of cointegration. We finally decided on the most appropriate specification by taking the results from the Pedroni and the Johansen-Fisher tests.

TABLE 3. FIRST-GENERATION PANEL UNIT ROOT TESTS (P-VALUES): LEVEL

	Common unit root		Individual unit root					
Variable	LLC	Breitung	IPS	ADF-Fisher	PP-Fisher	N	Max AIC	Model
y	1.000	0.990	0.069	0.007	0.999	129	9	Trend
obs	4,709	4,580	4,709	4,709	4,986			
	0.000	–	0.978	0.563	0.102	129	9	Cons
obs	4,808	–	4,808	4,808	4,986			
D	1.000	1.000	1.000	0.925	0.881	129	9	Trend
obs	3,196	3,067	3,196	3,196	3,364			
	0.987	–	1.000	0.379	0.226	129	9	Cons
obs	3,194	–	3,194	3,194	3,364			
log(u)	0.023	0.064	0.000	0.000	0.013	85	8	Trend
obs	2,788	2,703	2,788	2,788	2,918			
	0.000	–	0.000	0.000	0.000	85	8	Cons
obs	2,796	–	2,796	2,796	2,918			
dpir	1.000	0.000	0.000	0.000	0.000	129	7	Trend
obs	3,134	3,005	3,134	3,134	3,296			
	0.000	–	0.000	0.000	0.000	129	7	Cons
obs	3,147	–	3,147	3,147	3,296			
log(cpi)	0.000	1.000	0.000	0.000	0.000	129	9	Trend
obs	4,562	4,433	4,562	4,562	4,983			
	0.000	–	0.000	0.000	0.000	129	9	Cons
obs	4,596	–	4,596	4,596	4,983			
log(pop)	0.000	0.983	0.000	0.000	0.000	128	9	Trend
obs	4,586	4,457	4,586	4,586	5,014			
	0.507	–	0.044	0.000	0.000	128	9	Cons
obs	4,586	–	4,586	4,586	4,974			
log(exr)	0.000	0.821	0.000	0.000	0.000	115	9	Trend
obs	4,160	4,045	4,160	4,160	4,477			
	0.000	–	0.000	0.000	0.000	115	9	Cons
obs	4,295	–	4,295	4,295	4,477			
irate	0.000	0.172	0.000	0.000	0.000	120	9	Trend
obs	3,593	3,473	3,593	3,593	3,832			
	0.000	–	0.000	0.000	0.000	120	9	Cons
obs	3,622	–	3,622	3,622	3,832			

y: log(GDP per capita USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

TABLE 4. FIRST-GENERATION PANEL UNIT ROOT TESTS (P-VALUES): FIRST DIFFERENCE

	Common unit root		Individual unit root					
Variable	LLC	Breitung	IPS	ADF-Fisher	PP-Fisher	N	Max AIC	Model
y	0.000	0.000	0.000	0.000	0.000	129	9	Trend
obs	4,691	4,562	4,691	4,691	4,857			
	0.000	–	0.000	0.000	0.000	129	9	Cons
obs	4,760	–	4,760	4,760	4,857			
D	0.000	1.000	0.000	0.000	0.000	129	9	Trend
obs	3,112	2,983	3,112	3,112	3,235			
	0.000	–	0.000	0.000	0.000	129	9	Cons
obs	3,137	–	3,137	3,137	3,235			
log(u)	0.000	0.008	0.000	0.000	0.000	85	8	Trend
obs	2,707	2,622	2,707	2,707	2,833			
	0.000	–	0.000	0.000	0.000	85	8	Cons
obs	2,720	–	2,720	2,720	2,833			
dpir	0.000	0.000	0.000	0.000	0.000	129	7	Trend
obs	2,983	2,854	2,983	2,983	3,164			
	0.000	–	0.000	0.000	0.000	129	7	Cons
obs	3,013	–	3,013	3,013	3,164			
log(cpi)	0.000	0.000	0.000	0.000	0.000	129	9	Trend
obs	4,549	4,420	4,549	4,549	4,854			
	0.000	–	0.000	0.000	0.000	129	9	Cons
obs	4,612	–	4,612	4,612	4,854			
log(pop)	0.330	0.000	0.000	0.000	0.000	128	9	Trend
obs	4,552	4,423	4,552	4,552	4,885			
	0.000	–	0.000	0.000	0.000	129	9	Cons
obs	4,583	–	4,583	4,583	4,885			
log(exr)	0.000	0.000	0.000	0.000	0.000	115	9	Trend
obs	4,197	4,082	4,197	4,197	4,362			
	0.000	–	0.000	0.000	0.000	115	9	Cons
obs	4,197	–	4,197	4,197	4,362			
irate	0.000	0.000	0.000	0.000	0.000	120	9	Trend
obs	3,508	3,388	3,508	3,508	3,712			
	0.000	–	0.000	0.000	0.000	120	9	Cons
obs	3,533	–	3,533	3,533	3,712			

y: log(GDP per capita USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

TABLE 5. SECOND-GENERATION PANEL UNIT ROOT TEST (P-VALUES)

Variable	CIPS* Level	CIPS* Dif	Number of cross sections	Avg. time observations	Lags	Trend
y	0.000	0.000	130	40	3	no
	0.516	0.000		39	3	yes
D	1.000	0.000	130	28	2	no
	0.994	0.031		37	2	yes
log(urate)	0.000	0.000	86	37	1	no
	0.496	0.000		36	1	yes
log(cpi)	0.033	0.000	130	40	3	no
	0.453	0.000		39	3	yes
log(exr)	0.500	0.000	130	40	3	no
	0.610	0.000		39	3	yes
log(pop)	0.115	0.000	130	40	3	no
	0.993	0.004		39	3	yes
z	0.636	0.000	130	28	3	no
	0.999	0.008		27	3	yes
irate	0.505	0.000	121	35	3	no
	0.851	0.000		34	3	yes

y: log(GDP per capita USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.
* Pesaran (2007). Test assumes cross-section dependence in form of a single unobserved common factor. Computed using STATA-PESCADF.

TABLE 6. COINTEGRATION TESTS (P-VALUES): SEQUENTIAL (FIRST STAGE)

Relationship between y and	Pedroni - stat: Between: Panel v	Pedroni - stat: Between: Panel ADF	Pedroni - stat: Within: Group-ADF	Kao-stat	Johansen-Fisher - stat: Trace: None	Johansen-Fisher - stat: Trace: At-least (k-1)	Johansen-Fisher - stat: Max Eigenvalue: None	Johansen-Fisher - stat: Max Eigenvalue: At-least (k-1)
D	0.000	0.000	0.000	0.000	0.000	0.998	0.000	0.998
D+D2	0.000	0.001	0.001	0.001	0.000	0.996	0.000	0.996
D+D2+D3	0.000	0.026	0.040	0.004	0.000	0.521	0.000	0.521
D+D2+D3+D4	0.000	0.993	0.826	0.004	0.000	0.045	0.000	0.045
model		cons + trend		cons		cons + trend (CE) + cons (VAR)		

y: log(GDP per capita USD); D: Debt-to-GDP ratio.

a country's debt through emissions using the secondary market; finally, we add the debt payment interest rate and the log of the unemployment rate. This last variable is included at the end of the sequential process due to sample restriction—this variable has the smallest historical sample size for our sample of countries. The results of this sequence of tests shows evidence of cointegration between the log of GDP per capita, the debt-to-GDP ratio, the log of prices,

TABLE 7. COINTEGRATION TESTS (P-VALUES): SEQUENTIAL (SECOND STAGE)

Relationship between y and	Pedroni - stat			Kao-stat	Johansen-Fisher - stat			
	Between		Within		Trace		Max Eigenvalue	
	Panel v	Panel ADF	Group-ADF		None	At-least (k-1)	None	At-least (k-1)
D+log(cpi)	0.618	0.001	0.000	0.000	0.000	0.018	0.000	0.018
D+log(cpi)+log(exr)	0.000	0.001	0.000	0.000	0.000	0.296	0.000	0.296
D+log(cpi)+log(exr)+irate	0.000	0.068	0.000	0.000	0.000	0.150	0.000	0.150
D+log(cpi)+log(exr)+irate+dpir	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.013
D+log(cpi)+log(exr)+irate+ dpir+log(pop)	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D+log(cpi)+log(exr)+irate+ dpir+log(pop)+log(urate)	—	—	—	0.000	0.000	0.000	0.000	0.000
model	cons + trend			cons	none			

y: log(GDP per capita USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

TABLE 8. COINTEGRATION RELATIONSHIP: EQUATION (3)

Dependent variable: log(y)								
Variable	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**	**[8]**
D	-0.85***	-0.78***	-1.23***	-0.90***	-0.71***	-1.23***	-0.75***	-0.78***
D^2	0.50***	1.12***	1.00***	0.54***	0.40***	0.97***	0.42***	0.46***
D^3	-0.19***	-0.17***	-0.25***	-0.07***	-0.11***	-0.27***	-0.04**	-0.11**
log(cpi)	—	—	0.97***	0.87***	1.09***	0.99***	1.02***	1.04***
log(exr)	—	—	-1.12***	-1.40***	-1.12***	-1.10***	-1.21***	-0.91***
irate	—	—	-0.18***	-0.31*	-0.12*	-0.18*	-0.10***	-0.20***
D(dpir)	—	—	0.08*	-	—	0.09*	-	0.08***
D(log(pop))	—	—	—	1.12***	—	1.33***	0.91***	0.70***
D(log(u))	—	—	—	—	-0.06*	—	-0.08*	0.10***
Estimator[a]	FMOLS	FMOLS	FMOLS	FMOLS	FMOLS	FMOLS	FMOLS	FMOLS
Deterministics	cons	c+trend	c+trend	c+trend	c+trend	c+trend	c+trend	c+trend
R2	0.91	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Cross-sections	129	129	116	116	75	116	75	75
Obs	3364	3364	2710	2850	1881	2710	1881	1881
Dependent variable: log(y)								
Variable	**[9]**	**[10]**	**[11]**	**[12]**	**[13]**	**[14]**	**[15]**	**[16]**
D	-1.81***	-1.84***	-1.34***	-1.10***	-0.82***	-0.77***	-0.88***	-0.63***
D^2	1.41***	1.20***	1.31***	0.92***	0.56***	0.54***	0.49***	0.14
D^3	-0.43***	-0.29***	-0.47***	-0.31***	-0.19***	-0.20***	-0.13***	-0.03
log(cpi)	—	—	1.06***	1.04***	1.07***	1.01***	1.01***	1.01***

(continued on next page)

TABLE 8. COINTEGRATION RELATIONSHIP: EQUATION (3) *(continued)*

Dependent variable: log(y)								
Variable	**[9]**	**[10]**	**[11]**	**[12]**	**[13]**	**[14]**	**[15]**	**[16]**
log(exr)	—	—	-1.15***	-1.11***	-1.19***	-1.12***	-1.15***	-1.08***
irate	—	—	-0.021***	-0.17*	-0.23**	-0.19**	-0.29**	-0.36**
D(dpir)	—	—	0.71*	—	—	0.11*	—	0.38
D(log(pop))	—	—	—	3.00***	—	2.85***	1.26**	1.61**
D(log(u))	—	—	—	—	-0.04**	—	-0.04*	-0.07***
Estimator[a]	DOLS	DOLS	DOLS	DOLS	DOLS	DOLS	DOLS	DOLS
Deterministics	c	c+trend	c+trend	c+trend	c+trend	c+trend	c+trend	c+trend
R2	0.94	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Cross-sections	129	129	52	58	36	54	43	26
Obs	3227	3238	1188	1279	890	1338	1074	624

[a] Cointegrated regression assuming heterogenous panels.

the log of the exchange rate, and the short-term interest rate. Evidence of cointegration with the other variables is weak, as just one out of three cointegration tests suggests it.

Estimates from cointegrating regressions show a concave relationship between economic growth and the level of debt-to-GDP ratio. Table 8 gathers different specifications for this relationship depending on the variables considered in this study. The simplest specification considers only the variables log GDP per capita and the cubic expression for the debt-to-GDP ratio. The tipping point after which debt-to-GDP ratio may harm economic growth is estimated at 89 percent and 110 percent following fully modified ordinary least squares (FMOLS) and dynamic OLS (DOLS) approaches with a constant in the model, respectively. When a linear trend is considered, this point is reached but at a higher level in both cases.

Given that we find evidence of cointegration between the log GDP per capita and a third-degree polynomial on the debt-to-GDP ratio, we then reparametrize the ARDL model to obtain its error correction form. Following this model, a set of turning points can then be estimated for different time horizons by estimating the impulse response function (IRF) of economic growth to changes in the level of debt-to-GDP ratio. Then the sum to infinite of the partial responses obtained from the IRF allows us to estimate the tipping point above which debt-to-GDP ratio harms economic growth (this can be done if and only if the IRF shows an exponential decay pattern, see Section 3). Figure 1 shows these results. The left lower graph (1c) in this figure shows the partial effects on economic growth for a horizon of up to nine years ahead before it turns into a flat response (23 years ahead). The right lower graph (1d) shows the impulse response function for the whole effect, which shows a tipping point of 84 percent of debt-to-GDP ratio on the optimal case.

Table 9 shows the estimates of the equilibrium between the log level of GDP per capita and the debt-to-GDP ratio for an error correction model estimated using an ARDL approach (see the estimates of panel ARDL coefficients in the Annex). The model is estimated using a fixed effects model (FEM) and a GMM approach to deal with potential endogeneity. The model shows signs of a correct dynamic specification, as the velocity of adjustment is statistically different to zero and negative greater than −2. Likewise, the GMM version with individual and

TABLE 9. PANEL ERROR CORRECTION MODEL (ECM): EQUATION (4)

Dependent variable: log(y) / Dlog(y)						
Variable	**POLS**	**FEM**	**FEM**	**GMM**	**GMM**	**GMM**
			Long-run coefficients			
D	non-stable	-0.77***	-0.64***	non-stable	-2.10***	-3.11*
D2	non-stable	0.29***	-0.04**	non-stable	1.42*	3.47***
D3	non-stable	-0.09**	0.02	non-stable	-0.39	-1.24***
log(cpi)	non-stable	1.62***	1.66***	non-stable	1.42***	1.34***
log(exr)	non-stable	-1.53***	-1.57***	non-stable	-0.99***	-1.13***
irate	non-stable	-0.40	-0.33	non-stable	-2.05***	-0.93**
D(dpir)	non-stable	-0.01***	-0.01	non-stable	-0.01	-0.00
D(log(pop))	non-stable	0.06	-1.03	non-stable	-2.10	-0.54
cons	non-stable	5.56***	5.57***	non-stable	5.59***	6.24***
			Instantaneous adjustment			
D	-1.19***	-1.13***	-0.81***	-3.32***	-1.46***	-0.59*
D2	0.44***	0.50	0.28*	2.28***	0.59*	-0.01
D3	-0.06	-0.10**	-0.05	-0.51***	-0.06	0.07
log(cpi)	0.00	0.31***	0.25***	-0.00	0.61***	0.61***
log(exr)	0.001*	-0.29***	-0.23***	-0.00	-0.43***	-0.52***
irate	0.02	-0.8	-0.05	-0.01	-0.89***	-0.43**
D(dpir)	-0.00	-0.002***	-0.00	0.01	-0.00	-0.00
D(log(pop))	-0.40***	0.01	-0.15	-0.11	-1.30	-0.25
speed (m)	0.00	-0.19***	-0.15***	0.00	-0.43***	-0.46***
Cross-fixed	No	Yes	Yes	No	Yes	Yes
Time-fixed	No	No	Yes	No	No	Yes
Hansen J	—	—	—	0.00	0.00	0.00
Prob(J-stat)	—	—	—	0.00	0.00	0.00
R2	0.00	0.00	0.99	0.99	0.99	0.99
Cross-sections	120	120	120	105	105	105
Obs	2922	2922	2922	1013	1013	1013

*(**)[***]{+}: 90% (95%) [99%]{85%}.
y: log(GDP percapita USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

time effects is a suitable specification as there is evidence of instruments validity under the Hansen-J stat. As can be seen from this table, we also find evidence of concavity between economic growth and the debt-to-GDP ratio.

From Table 9 it is also interesting to see the effects of increasing the debt in the very short term (the contemporaneous effect), as it shows a convex form instead of a concave relationship between the economic growth and the debt-to-GDP ratio (see this response in the left-upper graph [1a] of Figure 1 labeled with t=0). This effect may be due to economic growth responding positively once the funds acquired by credit get into the economy and start circulating in the productive system. This positive effect seems to be greater for higher levels of debt-to-GDP ratio. While the economic growth responds convexly (positively) at time zero (contemporaneous effect), at one period ahead this effect becomes concave, and then during the following periods remains concave before turning flat. However, after depicting the response function with only the coefficients which were statistically significant, there is no evidence of a significant effect on economic growth at time zero, but it becomes concave after the first year and for the following years before turning practically flat after five years of the debt shock. Summing these partial responses up to infinity reveals the overall effect on economic growth, which is concave with a tipping point around 84.3 percent in the debt-to-GDP ratio, at which level the response of economic growth to the ratio seems to reach its optimal point.

Our results from the panel ECM are less restrictive than the traditional approach on two accounts. First, we find evidence of the best empirical relationship between growth and debt-to-GDP ratio by looking first for a cointegration relationship at the log level of GDP instead of imposing a quadratic relationship in the first log difference equation for GDP. In fact, our findings suggest strong evidence of cointegration with two turning points at the level equation for the log level of GDP. Second, we derive the impulse response function for economic growth from the consistent ARDL estimates at the level equation of log GDP, which let us know the response of economic growth at different periods after a positive shock to the debt-to-GDP ratio (Equation [6]).

The panel ARDL and the ECM approach allows us to understand that the growth response seems to be dynamically heterogeneous, which may be a confounding factor in traditional approaches that estimate statistical relationships between the two variables (growth and debt-to-GDP ratio). This may be one of the reasons for the mixed results found in more than 40 years' worth of empirical studies. Our approach, however, has a technical downside: because the IRF was derived analytically, the standard errors are not available. Bootstrapping techniques may be employed to empirically derive the standard errors estimates, but this approach is not explored in this paper.

One interesting result from the graphs that show the total effect in Figure 1 is that economic growth seems to show positive responses for a range of debt-to-GDP ratios. This special feature can be derived from the equation as follows:

$$\begin{aligned} &Lim\ j\rightarrow\infty\ E(growth(t+j))/D(t) \\ &= p_0 + p_1 D(t+j) + p_2 D^2(t+j) \\ &= 0\ (1-a_1 D)(1-a_2 D) = 0 \qquad (7) \end{aligned}$$

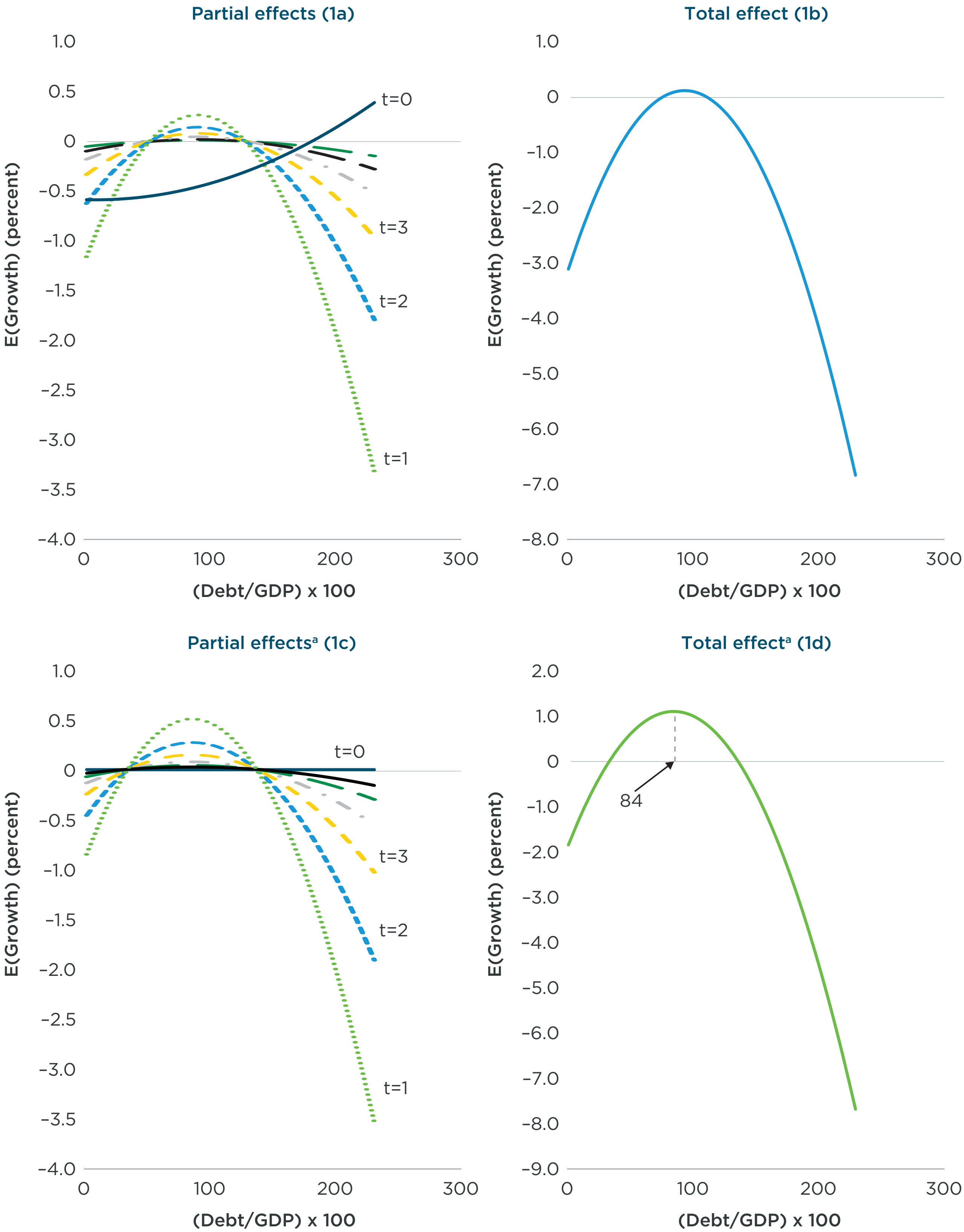
And the optimal debt-to-GDP ratio is derived from the equation:

$$D^* = (-p_1) / 2^*(\ p_2) \qquad (8)$$

Solving Equations (7) and (8) using the coefficients that were statistically significant in the GMM panel ARDL model (with cross and time fixed effects, see Annex), we find that economic growth is expected to be positive between 32 percent and 136 percent of debt-to-GDP ratio, with an optimal debt-to-GDP ratio for economic growth at 84.3 percent.[12] The results from the non-parametric approach confirm these findings using a regression discontinuity design. In that respect, the following set of graphs in Figure 2 shows the estimated threshold between economic growth and debt-to-GDP ratio for the complete sample of countries (130 economies) and the results after splitting the sample to derive estimates for LAC and OECD countries using a

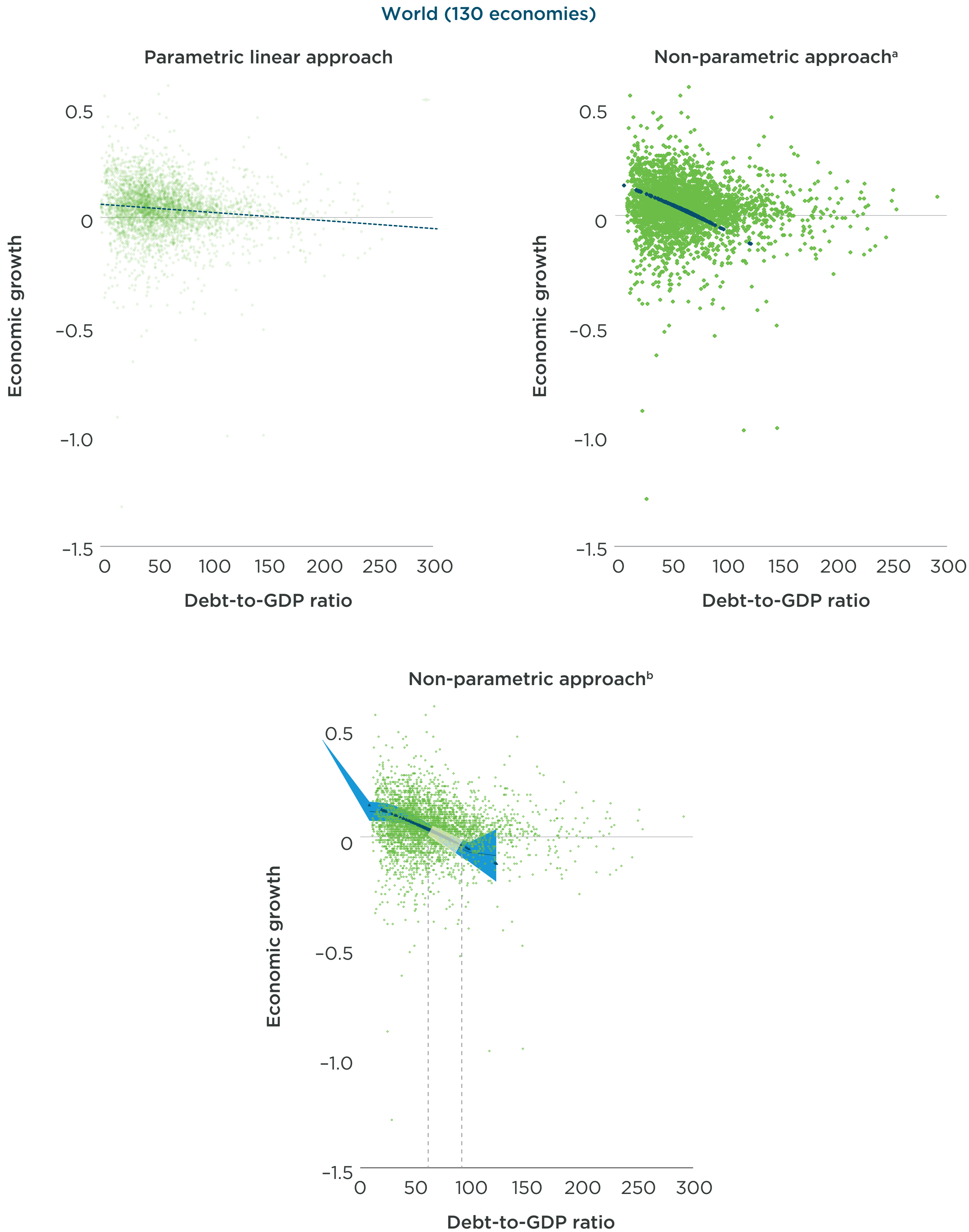
[12] When based on the raw estimates, this range is narrower (75 percent, 111 percent) with an optimal debt-to-GDP ratio for economic growth at 93 percent.

FIGURE 1. EXPECTED GROWTH DUE TO CHANGES IN DEBT-TO-GDP RATIO (COMPLETE SAMPLE OF COUNTRIES)



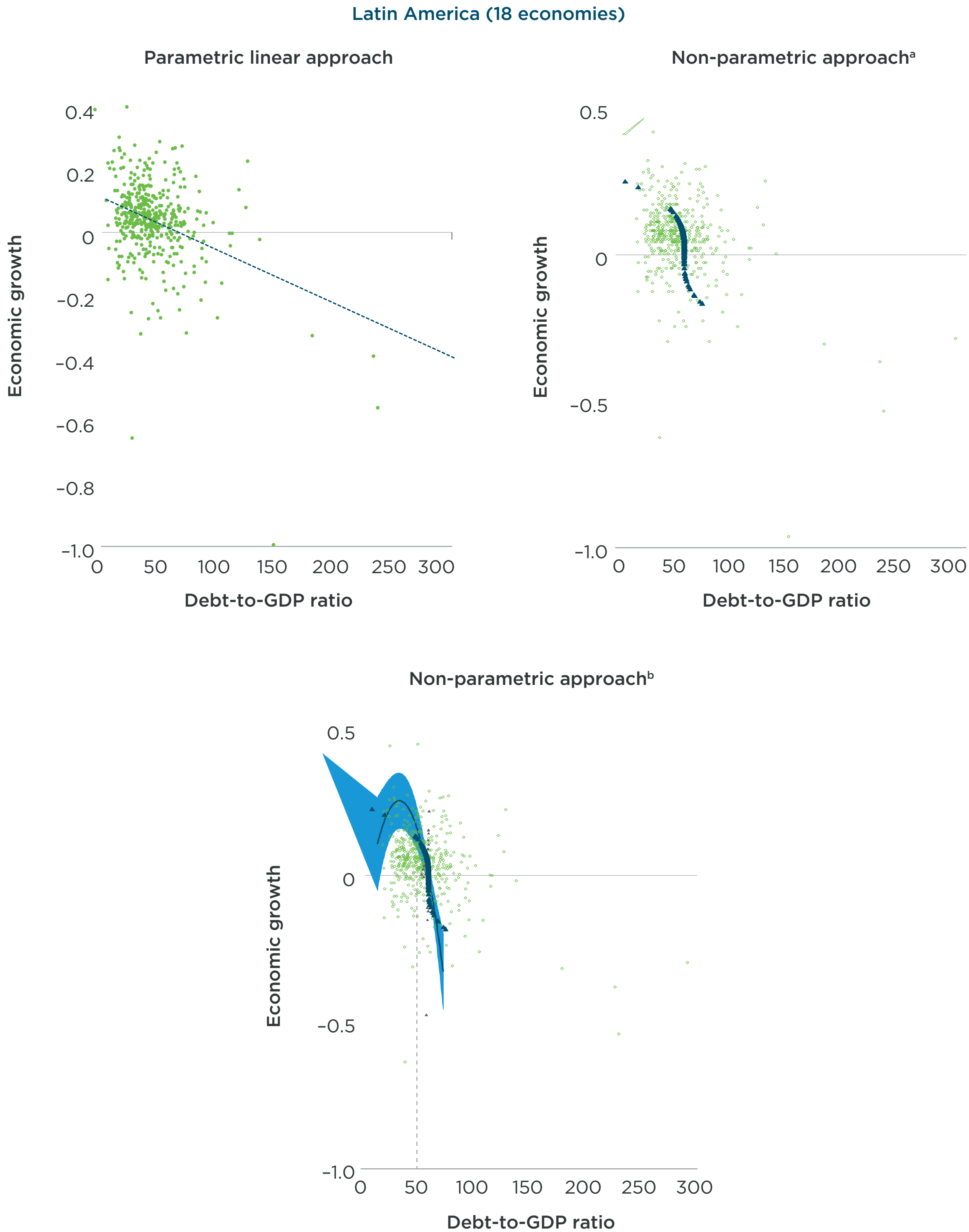
[a] Responses calculated taking from the panel ARDL the significant coefficients at 93 percent and above.

FIGURE 2. STATIC APPROACHES (PANEL 1 OF SAMPLES)



(continued on next page)

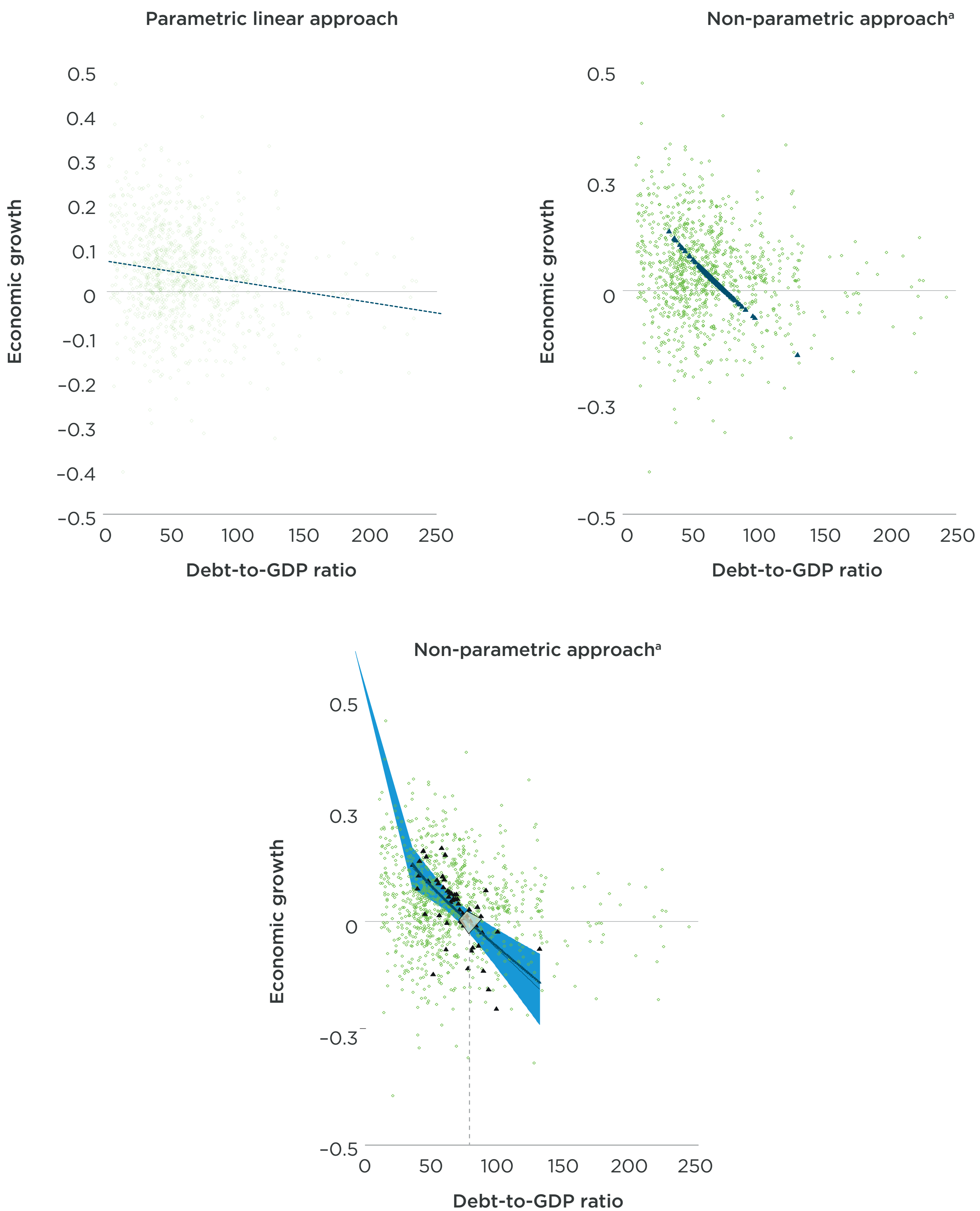
FIGURE 2. STATIC APPROACHES (PANEL 1 OF SAMPLES) *(continued)*



(continued on next page)

FIGURE 2. STATIC APPROACHES (PANEL 1 OF SAMPLES) *(continued)*

World (130 economies)



[a] Based on growth and debt figures regressed by primary balances (red line).
[b] Based on growth and debt figures regressed by primary balances (red line) and based on growth and debt pooled mean data (triangles).

simple linear regression between both variables (left graphs) and non-parametric approaches (middle and right set of graphs).

As can be seen, the relationship between economic growth and the debt-to-GDP ratio seems to be negative in all cases with both parametric and non-parametric static approaches; however, the slope of this relationship is steeper with the non-parametric approaches, which explains reaching a threshold between 54 percent and 96 percent for the whole sample of countries instead of the 150 percent threshold reached with the simple linear regression. This means that above a 96 percent debt-to-GDP ratio economic growth seems to turn negative. Similar results are found for the OECD and LAC economies. For the developed economies the threshold is reached at a higher level (75 percent) compared to the Latin American countries (50 percent).

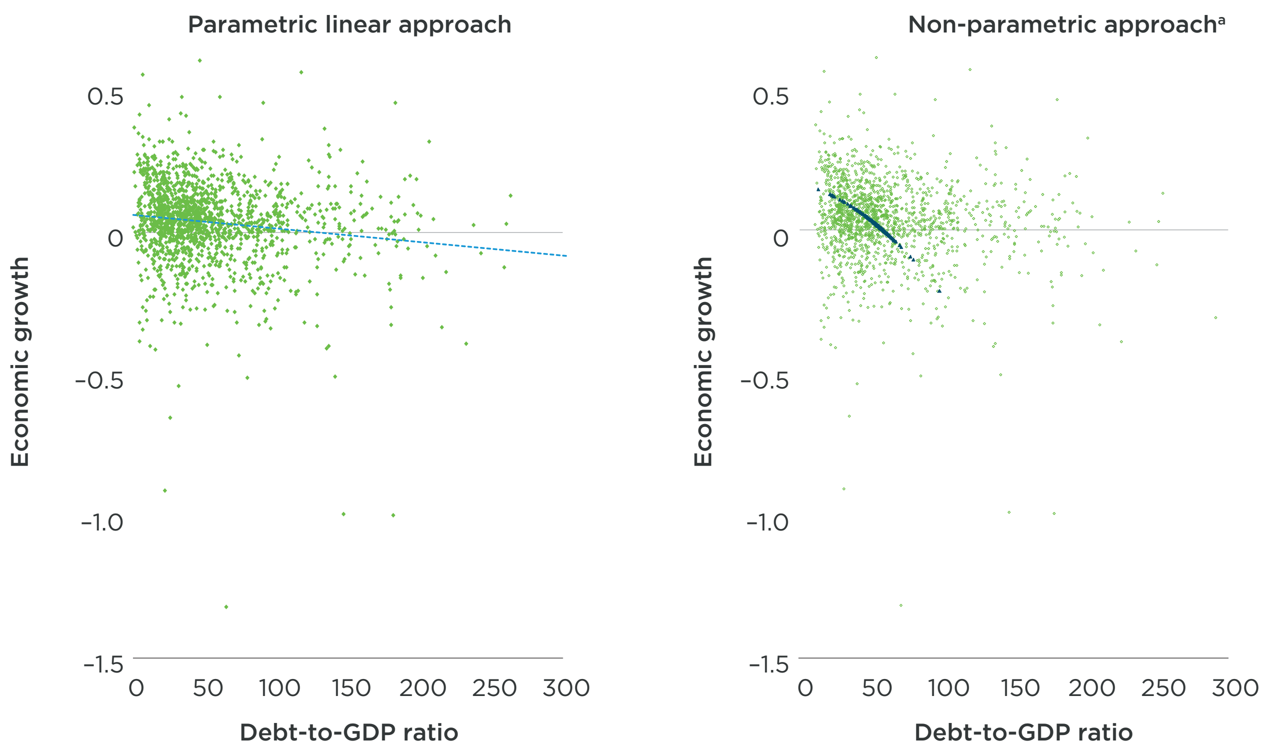
We then proceed to split the sample into commodity-driven and non-commodity-driven economies, so as to find out if different economic structures manifest divergent patterns in the relationship between debt threshold and economic growth. According to Hamann, Mendoza, and Restrepo-Echavarria (2018), there is a relationship between the international oil price and sovereign risk in oil-exporting economies. The authors show that being a larger oil producer decreases sovereign risk while having more oil reserves increases it. These results suggest that default and debt dynamics for oil-exporting economies may actually depend on oil prices.

We define commodity-driven economies by their exports profile. Those whose exports are primarily fuel, agricultural, or mining[13] are included

[13] We employed the UNCTAD commodity dependence code.

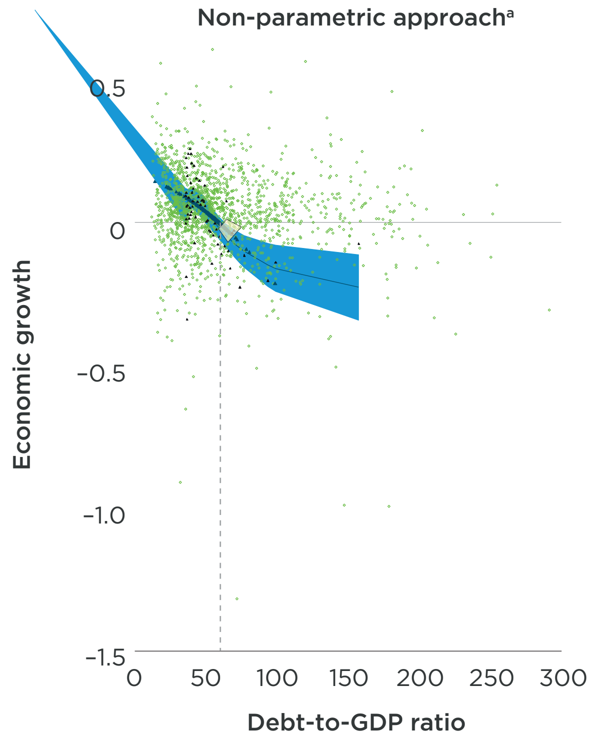
FIGURE 3. STATIC APPROACHES (PANEL 2 OF SAMPLES)

Commodity-driven economies (63 economies)

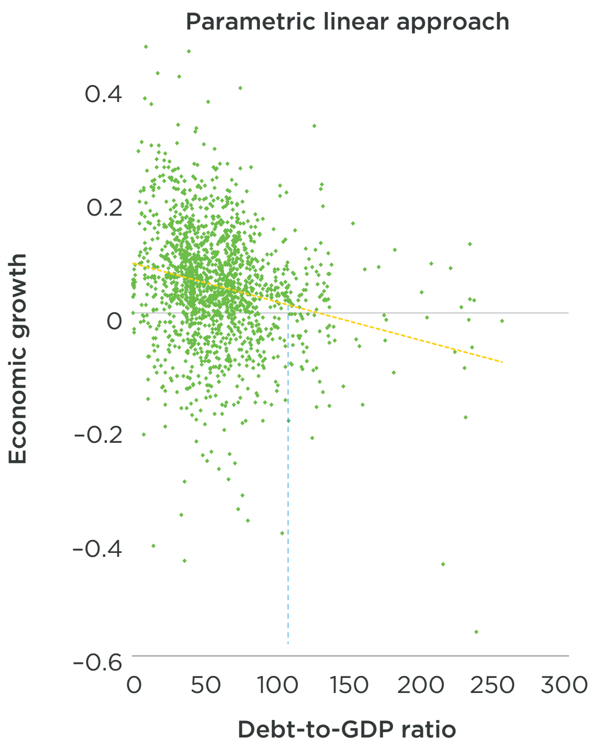


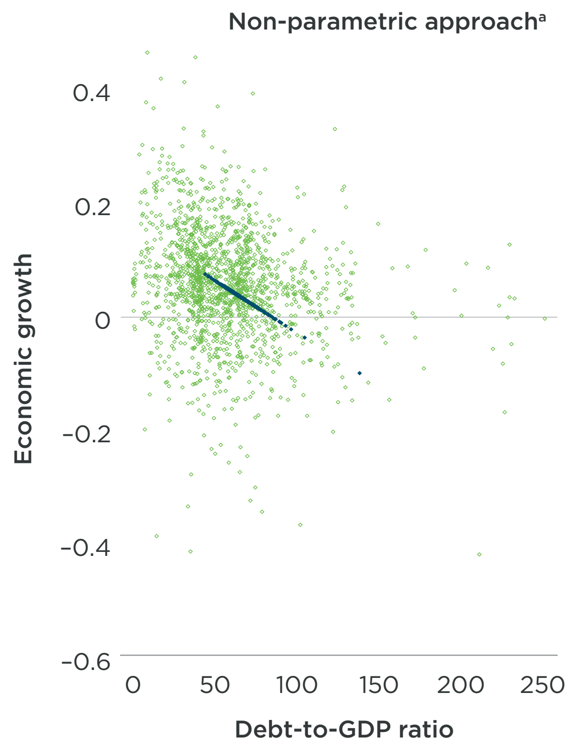
(continued on next page)

FIGURE 3. STATIC APPROACHES (PANEL 2 OF SAMPLES) *(continued)*



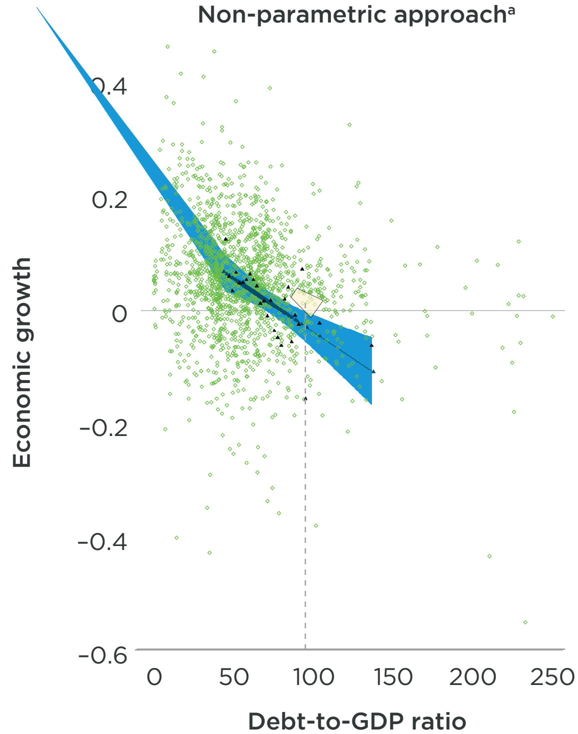
Non-Commodity driven economies (60 economies)





(continued on next page)

FIGURE 3. STATIC APPROACHES (PANEL 2 OF SAMPLES) *(continued)*



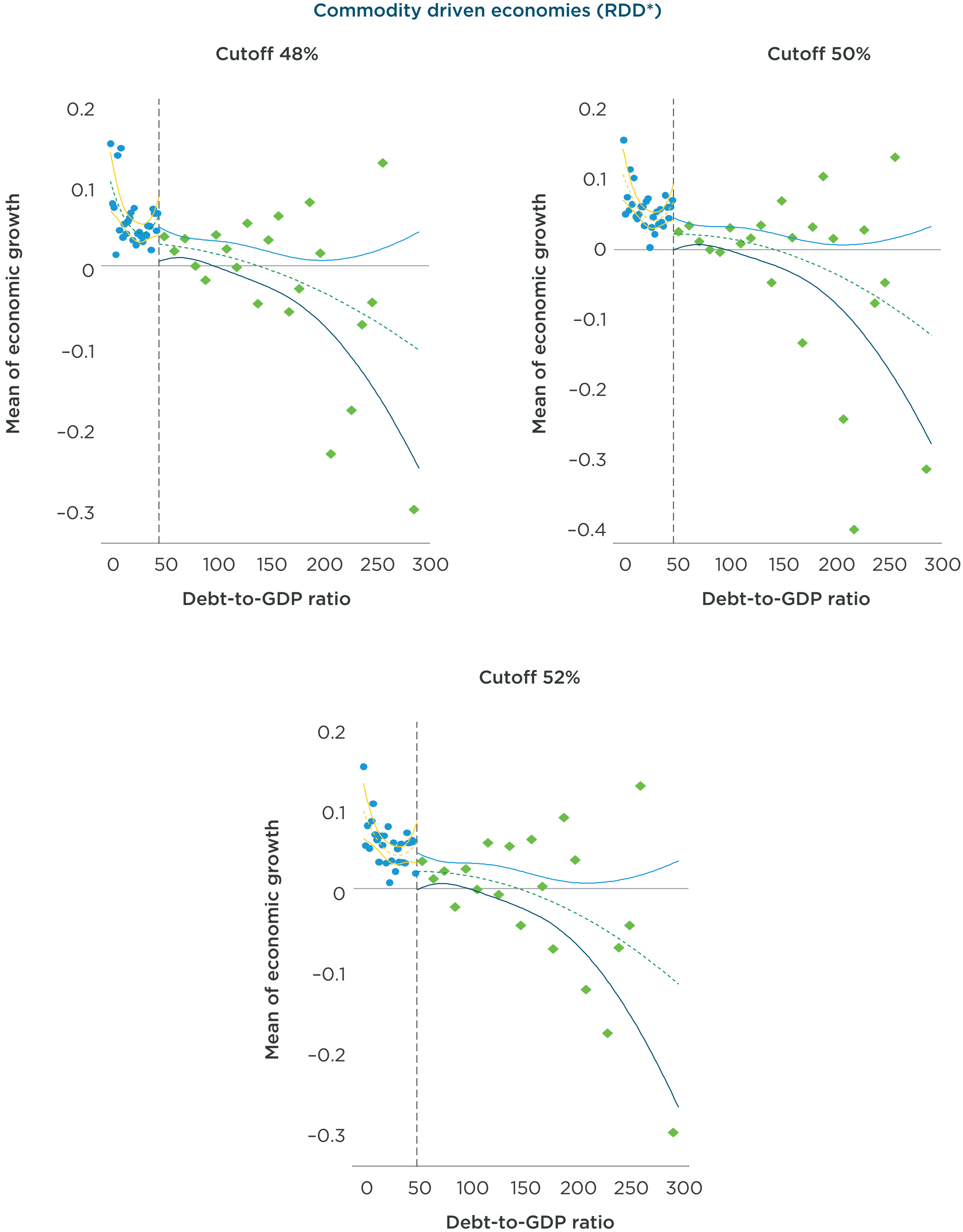
[a] Based on growth and debt figures regressed by primary balances (red line).
[b] Based on growth and debt figures regressed by primary balances (red line) and based on growth and debt pooled mean data (triangles).

in this group. Results show an interesting pattern, as commodity-driven economies face a lower debt threshold (49 percent) compared to non-commodity-driven economies (84 percent), which means that the structure of the economy matters in explaining the differences in the economic growth due to debt surges. One possible explanation to this pattern may be related to liquidity restrictions mixed with risk perceptions.

In the international financial market, investors may associate a high debt-to-GDP ratio with a higher risk environment, which may get exacerbated if investors perceive that government revenues depend mainly on commodity prices. This is because volatility in commodity prices is transmitted to government revenues but also to the current account, which in turn increases the perception of a potential balance of payment crisis. Countries in this scenario tend to pay higher interests for the outstanding debt and also face a tightened fiscal space in which to boost economic growth. Risky perceptions are reflected in credit and investment ratings. For instance, while countries with the highest debt-to-GDP ratio such as Japan (254 percent), Italy (156 percent), and the United States (134 percent) are non-commodity-driven economies, they have high investment grade ratings (A, BBB, and AAA, respectively, according to Fitch ratings); however, other countries with lower debt-to-GDP ratios such as Cameroon (46 percent), Guatemala (32 percent), and Nigeria (35 percent) are commodity-driven economies and face speculative grade ratings (B, BB-, and B, respectively).

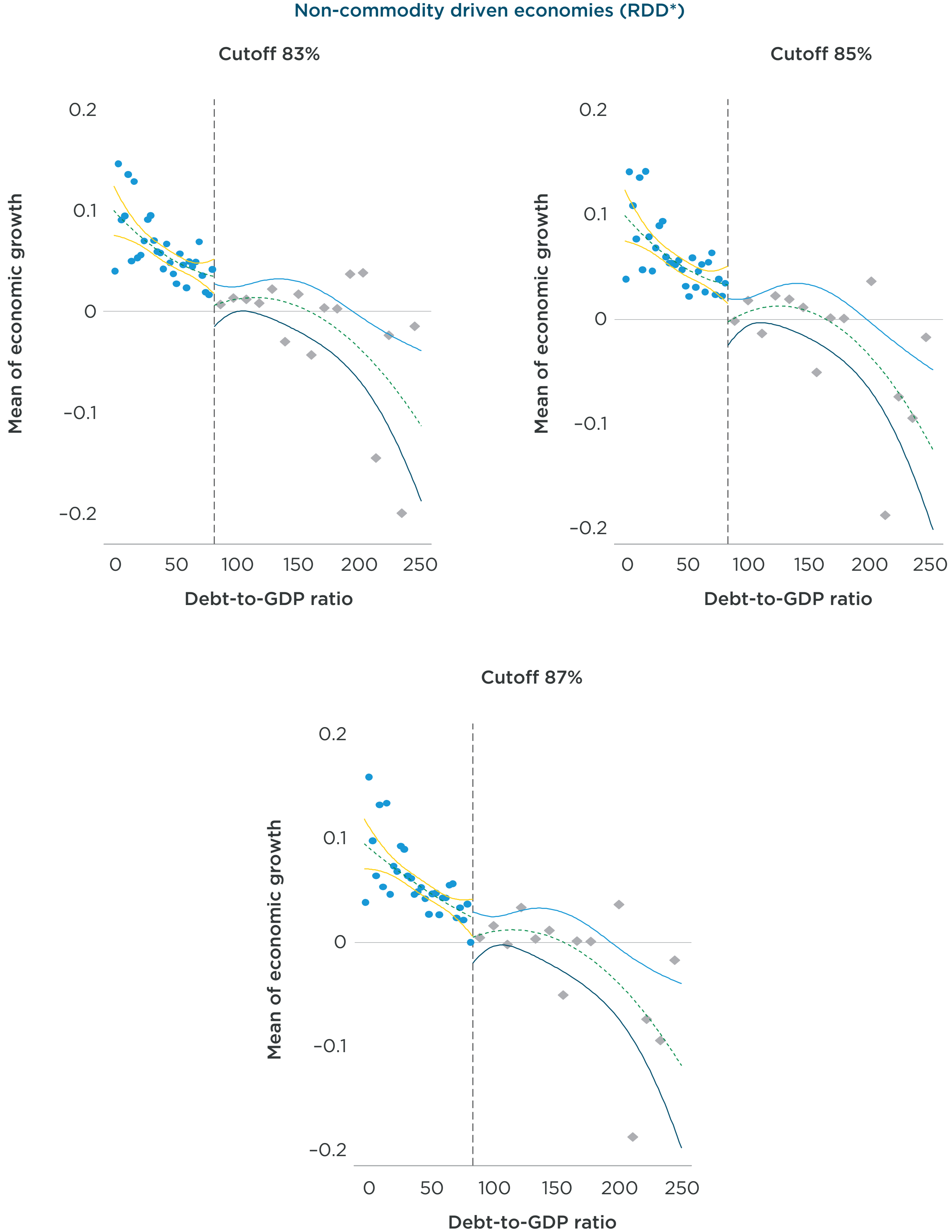
This evidence shows that a lower debt-to-GDP ratio is not necessarily a positive sign, as the rating depends on the structure of the economy and how investors perceive risk of the economy. Commodity-driven economies rely primarily on

FIGURE 4. REGRESSION DISCONTINUITY DESIGNS IN COMMODITY-DRIVEN ECONOMIES



Note: Non-parametric regression discontinuity designs around the threshold of 50 percent. The dotted line represents the predicted values in growth fitted separately for points above and below the 50 percent threshold. The continuous line represents the 95 percent confidence interval.

FIGURE 5. REGRESSION DISCONTINUITY DESIGNS IN NON-COMMODITY-DRIVEN ECONOMIES



Note: Non-parametric regression discontinuity designs around the threshold of 85 percent. The dotted line represents the predicted values in growth fitted separately for points above and below the 85 percent threshold. The continuous line represents the 95 percent confidence interval.

revenues derived from volatile sources of income to finance their growth, which sometimes may be more expensive in terms of their disruptive (stop-start) impacts than would be a steady stream of debt financing. Non-commodity-driven economies have more stable sources of revenue to support their financing and therefore can comfortably handle more debt than the commodity-driven economies. To test if there are two different populations of the economic growth rate around a certain threshold, we opted to test whether there are statistical differences in the economic growth rate around the estimated thresholds using non-parametric regression discontinuity designs (RDD). To obtain a more precise result around the thresholds, we estimated RDDs for ranges both below and above the estimated threshold. As can be seen from the following set of figures, it seems that the threshold for the commodity-driven economies set at 50 percent was statistically significant at a level of 5 percent. Both below and above that threshold, confidence intervals clearly overlap around the cutoff.

Similar results were found for the non-commodity-driven economies, as the threshold around 85 percent was statistically significant at a level of 5 percent. This corroborates the previous finding that these economies can reach a higher threshold in the debt-to-GDP ratio before starting to show negative rates of economic growth compared to the evidence for commodity-driven economies.

5

CONCLUSIONS

The discussion of the long-run effects of debt on economic growth is far from over. There are studies that have shown a negative impact, while others affirm a positive or even nil effect on economic growth. Moreover, while one group of studies has found evidence of a concave relationship between economic growth and the level of debt-to-GDP ratio (i.e., growth initially rises then falls with increasing debt-to-GDP ratios), another group of studies states that the relationship is convex (i.e., growth increases with increasing debt-to-GDP ratios). Amid this discussion, there is still no consensus on whether a threshold exists for the debt-to-GDP ratio after which economic growth is affected in one way or another or, if it does exist and the relationship is concave, what the threshold is above which economic growth starts suffering from the increasing debt-to-GDP ratio.

Amidst this ongoing controversy, we find evidence in favor of the existence of a threshold and the concavity form of the economic growth response after increments in the level of the debt-to-GDP ratio. In addition, we find that this evidence comes in different flavors when considering different time period scenarios: short-run, medium-term, and long-run scenarios. Notwithstanding these differences, the total effect seems to be best represented as a concave relationship between economic growth and the level of debt-to-GDP ratio with a threshold lying at some point between 32 percent and 136 percent, and an optimal debt-to-GDP ratio for economic growth at 84 percent. Furthermore, the dynamics of the relationship between economic growth and the level of the debt-to-GDP ratio can be characterized as taking place in three stages: at the first stage (short run) the relationship is depicted by a convex form, then, at the second stage (medium term), the relationship turns into a concave-like form that governs the characteristic form for the following time periods, until turning it into a flat relationship at the third stage (long run). This pattern is found after controlling for changes in the main macroeconomic rates such as inflation, devaluation, interest and unemployment rates, and population growth.

We also provide evidence for the existence of two different populations of economic growth rates around the estimated thresholds of debt-to-GDP ratio using an RDD approach . Our results are in line with our previous finding that the existence of a threshold lies at some point between 54 percent and 96 percent for the whole sample of countries, while lying around 75 percent and 50 percent for OECD and LAC countries, respectively. We also split the sample of countries between commodity-driven and non-commodity-driven economies and find evidence of different patterns regarding the debt-to-GDP threshold. Those economies whose exports are mainly fuel, agriculture, or mining goods reach the threshold at a lower level (50 percent) compared to countries whose exports do not depend on commodities (85 percent). Our results are in line with those found by Caner, Grennes, and Koehler-Geib (2010) that emerging economies reach a threshold at a lower point (around 64 percent) than developed economies and with the evidence provided by Cecchetti, Mohanty, and Zampolli (2011) pointing out that the threshold is around of 85 percent for OECD countries.

Finally, for the purposes of policymaking, the following findings should be stressed: (i) the existence seems irrefutable of a threshold above which increments in debt-to-GDP ratio negatively affect economic growth and (ii) this threshold likely depends on the structure of the economy, as emerging commodity-based economies will tend to reach a threshold at a lower point than non-commodity-driven economies such as the OECD countries. This means that richer, solvent, and more credible economies would have more fiscal space for issuing new debt as their bonds are better rated by investors and consequently traded at lower interest rates. As these economies pay lower interest for new debt issues, the positive effects on economic growth may last for higher levels of the debt-to-GDP ratio compared to emerging commodity-based economies.

Results from this paper lead us to confirm that there exists on average an optimal level of debt-to-GDP ratio around 84 percent, as it is expected that after crossing this point countries start to experience lower rates of growth or even negative growth. This level should be estimated for each country according to its particular context and own available historical data. We recommend using the methodology proposed in this paper via an ARDL and its error correction model for two reasons: (i) the impulse response function from this model can provide information not just on the contemporaneous impact of debt surges on economic growth but also for successive horizons ahead as well as the whole response in the long run and (ii) this methodology can be adjusted for estimating the optimal level of a single country using a uniequational approach and a set of appropriate instruments. Moreover, in terms of policy recommendations, the results from this paper lead us to suggest that countries whose exports are primarily commodity-based should take with certain precaution successive increases in public debt, as we should expect positive returns on growth up to a level of 50 percent of debt-to-GDP ratio and after this level successive increments on debt will put the country in a position that may potentially harm the wealth for future generations. If countries want more fiscal space to take positive yields from surges on public debt, they should transform their productive capacity to depend less on commodity exports, as countries with economies less dependent on commodities reach on average a higher threshold of debt-to-GDP ratio at 85 percent.

REFERENCES

Afonso, A., and J. Alves. 2014. The Role of Government Debt in Economic Growth. Department of Economics, WP16/2014/DE/UECE. Lisbon: Lisboa School of Economics and Management.

Afonso, A., and J. T. Jalles. 2013. Growth and Productivity: The Role of Government Debt. *International Review of Economics and Finance* 25: 384–407.

Alexius, A., and D. Spang. 2018. Stock Prices and GDP in the Long Run. *Journal of Applied Finance and Banking* 8(4): 107–126.

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.

Baglan, D., and E. Yoldas. 2013. Government Debt and Macroeconomic Activity: A Predictive Analysis for Advanced Economies. Finance and Economics Discussion Series. Divisions of Research & Statistics and Monetary Affairs. Washington, DC: Federal Reserve Board.

Barro, R. J. 1974. Are Government Bonds Net Wealth? *Journal of Political Economy* 82(6): 1095–1117.

———. 1979. On the Determination of the Public Debt. *Journal of Political Economy* 87(5, 1): 940–971.

———. 1999. Notes on Optimal Debt Management. *Journal of Applied Economics* II(2): 281–289.

Baum, A., C. Checherita-Westphal, and P. Rother. 2013. Debt and Growth: New Evidence for the Euro Area. Working Paper No. 1450. Frankfurt: European Central Bank.

Baum, C., M. Schaffer, and S. Stillman. 2003. Instrumental Variables and GMM: Estimation and Testing. *The Stata Journal* 3(1): 1–31.

Bilan, I., and I. Ihnatov. 2015. Public Debt and Economic Growth: A Two-Sided Story. *International Journal of Economic Sciences* IV(2): 24–39. Available at https://doi.org/10.20472/ES.2015.4.2.003.

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

Boga, S. 2020. Investigating the Asymmetry between Economic Growth and Unemployment in Turkey: A Hidden Cointegration Approach. *Journal of Economics, Finance and Accounting* 7(1): 22–33.

Bond, S. 2002. Dynamic Panel Data Models: A Guide to Micro Data Methods and Practice. *Portuguese Economic Journal* 1: 141–162.

Bowen, W. G., R. G. Davis, and D. H. Kopf. 1960. The Public Debt: A Burden on Future Generations? *American Economic Review* 50(4): 701–6.

Buchanan, J. M. 1958. *Public Principles of Public Debt: A Defense and Restatement*. Homewood, IL: Richard D. Irwin.

Caner, M., T. Grennes, and F. Koehler-Geib. 2010. Finding the Tipping Point: When Sovereign Debt Turns Bad. Paper submitted to Conference Volume: World Bank Conference on Debt Management.

Caporale, G. M., G. Claudio-Quiroga, and L. Alberiko Gil-Alana. 2021. The Relationship between Prices and Output in the UK and the US. Economics and Finance Working Paper Series, Working Paper No. 2108. London: Brunel University London.

Carlsson, A., and J. Holm. 2020. Is There a Long-Run Relationship between Stock Prices and Economic Activity and Are Stock Returns a Leading Indicator for Economic Growth? Evidence for Scandinavian Countries. Master Thesis, Advanced Level. Örebro, Sweden: Örebro University, School of Business.

Cecchetti S., M. S. Mohanty, and F. Zampolli. 2011. The Real Effects of Debt. BIS Working Papers No. 352. Basel: Bank for International Settlements.

Checherita, C., A. H. Hallett, and P. Rother. 2012. Fiscal Sustainability Using Growth-Maximizing Debt Targets. Working Paper No. 1472. Frankfurt: European Central Bank.

Chisti, K. A., and S. Shakeel. 2018. Co-integration and Causal Relationship between Stock Prices and Macroeconomic Variables. *International Journal of Economics and Management Sciences* 7:1–6.

Churchman, N. 2001. *David Ricardo on Public Debt.* New York: Palgrave.

Clements, B., R. Bhattacharya, and T. Q. Nguyen. 2003. External Debt, Public Investment, and Growth in Low-Income Countries. IMF Working Paper WP/03/249. Washington, DC: International Monetary Fund.

Diamond, P. A. 1965. National Debt in a Neoclassical Growth Model. *American Economic Review* 55(5): 1126–1150.

Durlauf, S. N., P. A. Johnson, and J. Temple. 2005. Growth Econometrics. In P. Aghion and S. N. Durlauf, eds, *Handbook of Economic Growth* (Vol. 1A). Amsterdam: Elsevier.

Federal Reserve Bank of San Francisco. 2002. What Are Business Cycles and How Do They Affect the Economy? Available at https://www.frbsf.org/education/publications/doctor-econ/2002/may/business-cycles-economy/.

Franses, P. H., and R. van Oest. 2004. On the Econometrics of the Koyck Model. Econometric Institute Report 2004–07. Rotterdam: Econometric Institute, Erasmus University Rotterdam.

Hamann, F., E. Mendoza, and P. Restrepo-Echavarria. 2018. Resource Curse or Blessing? Sovereign Risk in Resource-Rich Emerging Economies. Working Paper 2018-032D. St. Louis, MO: Federal Reserve Bank of St. Louis. Available at https://doi.org/10.20955/wp.2018.032.

Idris, M., B. A. Ashemi, and M. Musa. 2019. Relationship between Exchange Rate and Gross Domestic Product in Nigeria ARDL Approach. *Journal of Economics and Development Studies* 7(3): 66–76.

Im, K. S., H. Pesaran, and Y. Shin. 2003. Testing for Unit Roots in Heterogenous Panels. *Journal of Econometrics* 115(1): 53–74.

Islam, N. 1995. Growth Empirics: A Panel Data Approach. *Quarterly Journal of Economics* 110(4): 1127–1170.

Kelly, R., K. McQuinn, and R. Stuart. 2013. Exploring the Steady-State Relationship between Credit and GDP for a Small Open Economy: The Case of Ireland. Working Paper No. 1531. Frankfurt: European Central Bank.

Kriss, P., H. Miki-Imoto, H. Nishimaki, and T. Riku. 2021. Evolution of Quality Infrastructure Investment in Japan. Washington, DC: World Bank.

Kumar, M. S., and J. Woo. 2010. Public Debt and Growth. IMF Working Paper WP/10/174. Washington, DC: International Monetary Fund.

Linacre, S. 2006. Australian Labour Market Statistics, 6105, January. Canberra: Australian Bureau of Statistics.

Liu, W.-C. 2020. The Relationship between Primary Energy Consumption and Real Gross Domestic Product: Evidence from Major Asian Countries. *Sustainability* 12(6): 2568. Available at http://doi.org/10.3390/su12062568.

Meade, J. E. 1958. Is the National Debt a Burden? *Oxford Economic Papers* 10(2): 163–183.

Mirovic, V., B. Kalas, and N. Milenkovic. 2021. Panel Cointegration Analysis of Total Environmental Taxes and Economic Growth in EU Countries. *Economic Analysis* 54(1): 92–103.

Modigliani, F. 1961. Long-Run Implications of Alternative Fiscal Policies and the Burden of the National Debt. *Economic Journal* 71(284): 730–755.

Musgrave, R. A. 1959. *The Theory of Public Finance.* New York: McGraw Hill.

Naser, H. 2017. On the Cointegration and Causality between Oil Market, Nuclear Energy Consumption, and Economic Growth: Evidence from Developed Countries. *Energy Ecology and Environment* 2(3): 182–197.

OECD. 2021. Government at a Glance 2021. Country Fact Sheet, Japan.

Padoan, P., U. Sila, and P. van den Noord. 2012. Avoiding Debt Traps: Fiscal Consolidation, Financial Backstops and Structural Reforms. *OECD Journal: Economic Studies* 2012(1). Available at https://doi.org/10.1787/eco_studies-2012-5k8xbnjbn9hl.

Panizza, U., and A. F. Presbitero. 2013. Public Debt and Economic Growth in Advanced Economies: A Survey. *Swiss Journal of Economics and Statistics* 149(2): 175–204. Available at https://sjes.springeropen.com/counter/pdf/10.1007/BF03399388.pdf.

Patillo, C., H. Poirson, and L. Ricci. 2002. External Debt and Growth. IMF Working Paper WP/02. Washington, DC: International Monetary Fund.

Pescatori, A., D. Sandri, and J. Simon. 2014. Debt and Growth: Is There a Magic Threshold? IMF Working Paper WP/14/34. Washington, DC: International Monetary Fund.

Pesaran, M. H. 2007. A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence. *Journal of Applied Econometrics* 22(2): 265–312.

Reinhart, C. M., V. R. Reinhart, and K. S. Rogoff. 2012. Debt Overhangs: Past and Present. NBER Working Paper Series. Working Paper No. 18015. Cambridge, MA: National Bureau of Economic Research.

Reinhart, C. M., and K. S. Rogoff. 2010. Growth in a Time of Debt. *American Economic Review* 100(2): 573–78.

Roodman, D. 2009. How to do Xtabond2: An Introduction to Difference and System GMM in Stata. *The Stata Journal* 9(1): 86–136.

Swaray, R. 2005. Primary Commodity Dependence and Debt Problem in Less Developed Countries. *Applied Econometrics and International Development* 5(4): 131–142.

Smyth, D., and Y. Hsing. 1995. In Search of an Optimal Debt Ratio for Economic Growth.

Contemporary Economic Policy 13 (1995): 51–59.

Vespignani, J., M. Kumar, and M. Raghavan. 2021. Impact of Commodity Price Volatility on External Debt: The Role of Exchange Rate Regimes. HAL Open Science. Available at https://hal.archives-ouvertes.fr/hal-03106698.

Zou, X. 2018. VECM Model Analysis of Carbon Emissions, GDP, and International Crude Oil Prices. *Discrete Dynamics in Nature and Society* Vol. 2018, Article ID 5350308. Available at https://doi.org/10.1155/2018/5350308.

ANNEX. PANEL ARDL COEFFICIENTS: EQUATION (5)

Dependent variable: log(y)						
Variable	**POLS**	**FEM**	**FEM**	**GMM**	**GMM**	**GMM**
D	-1.19***	-1.13***	-0.81***	-3.32***	-1.46***	-0.59*
D^2	0.44***	0.50	0.28*	2.28***	0.59*	-0.01
D^3	-0.06	-0.10**	-0.05	-0.51***	-0.06	0.07
lag(D)	1.23***	0.98***	0.72***	3.62***	0.55	-0.85*
lag(D2)	-0.54***	-0.45***	-0.29**	-2.75***	0.02	1.61***
lag(D3)	0.09**	0.03*	0.05	0.66***	-0.10	-0.64***
log(cpi)	0.00	0.31***	0.25***	-0.00	0.61***	0.61***
log(exr)	0.001*	-0.29***	-0.23***	-0.00	-0.43***	-0.52***
irate	0.02	-0.8	-0.05	-0.01	-0.89***	-0.43**
D(dpir)	-0.00	-0.002***	-0.00	0.01	-0.00	-0.00
D[log(pop)]	-0.40***	0.01	-0.15	-0.11	-1.30	-0.25
cons	–	1.06***	0.83***	–	2.42***	2.87***
lag[log(y)]	1.00***	0.81***	0.85***	1.00***	0.57***	0.54***
Cross-fixed	No	Yes	Yes	No	Yes	Yes
Time-fixed	No	No	Yes	No	No	Yes
Hansen J	–	–	–	104.91	113.97	65.44
Prob(J-stat)	–	–	–	0.00	0.00	0.18
R2	0.00	0.00	0.99	0.99	0.99	0.99
Cross-sections	120	120	120	105	105	105
Obs	2922	2922	2922	1013	1013	1013

*(**)[***]: 90% (95%) [99%].
y: GDP per capita (USD); D: Debt-to-GDP ratio; u: Unemployment rate; cpi: Consumer price index; pop: Population; exr: Exchange rate; dpir: Debt payment interest rate; irate: short-term interest rate.

IDB

Improving lives