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## What Are the Channels Through Which External Debt Affects Growth?

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Luca Ricci*

## IMF Working Paper

African and Asia and Pacific Departments

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#### Abstract

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This paper investigates the channels through which debt affects growth, specifically whether debt affects growth through factor accumulation or total factor productivity growth. It also tests for the presence of nonlinearities in the effects of debt on the different sources of growth. We use a large panel dataset of 61 developing countries over the period 1969–98. Results indicate that the negative impact of high debt on growth operates both through a strong negative effect on physical capital accumulation and on total factor productivity growth. On average, for high-debt countries, doubling debt will reduce output growth by about 1 percentage point and reduce both per capita physical capital and total factor productivity growth by somewhat less than that. In terms of the contributions to growth, approximately one-third of the effect of debt on growth occurs via physical capital accumulation and two-thirds via total factor productivity growth. The results are generally robust to the use of alternative estimators to control (to different extents) for biases associated with unobserved country-specific effects and the endogeneity of several regressors, particularly the debt variables. In particular, the results are shown to be compatible with a simultaneous significant effect of growth on debt ratios, as suggested by Easterly (2001).

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## I. INTRODUCTION

In the second half of the 1990s, policymakers and citizens around the world have been increasingly concerned that high external indebtedness in many developing countries is limiting growth and development. In Pattillo, Poirson, and Ricci (2002) (hereinafter referred to as PPR), we found empirical support for a nonlinear impact of debt on growth: at low levels, debt has positive effects on growth; but above particular thresholds or turning points, additional debt begins to have a negative impact on growth. This type of analysis appears very relevant for current policy debates on assessing, for example, external debt sustainability in developing countries.

But there are many unanswered questions that relate to this issue. In this paper, the main questions we ask are what are the channels through which debt affects growth and whether nonlinear effects are also present in the relationship of debt with the different sources of growth. Specifically, we investigate whether debt affects growth mostly through an effect on factor accumulation or an effect on total factor productivity growth, and whether these effects are nonlinear.

Both theory and policy discussions indicate that the effect of debt on growth could occur through all the main sources of growth. The capital-accumulation channel is supported, in particular, by two arguments. First, the debt-overhang concept implies that when external debt grows large, investors lower their expectations of returns in anticipation of higher and progressively more distortionary taxes needed to repay debt, so that new domestic and foreign investment is discouraged, which, in turn, slows capital-stock accumulation. Another strand of literature reaches similar conclusions by stressing that in heavily indebted countries, investors hold back, given the uncertainties about what portion of the debt will actually be serviced with the countries' own resources. Both arguments suggest that nonlinear effects of debt on growth are likely to occur through lower capital accumulation.

Other considerations imply that high debt levels may also constrain growth by lowering total factor productivity growth. For example, governments may be less willing to undertake difficult and costly policy reforms if it is perceived that the future benefit in terms of higher output will accrue partly to foreign creditors. The poorer policy environment, in turn, is likely to affect the efficiency of investment and productivity. In addition, high levels of uncertainties and instabilities related to the debt overhang are likely to hinder incentives to improve technology or to use resources efficiently. For example, as in other high-uncertainty environments, investment may be misallocated to activities with quick returns, rather than long-term, higher-risk irreversible investment which would be more conducive to long-run productivity growth. Misallocated resources and less efficient investment projects could thus contribute to slower productivity growth.

Finally, debt-relief advocates have argued that high debt severely constrains low-income countries' abilities to provide social services, such as education. The decision to acquire human capital is also an investment decision, which might be affected by the expectation of high marginal taxes. This would imply that high debt levels could lower growth by slowing

human capital accumulation. This effect may be very difficult to detect, however, as it would affect human-capital stocks only with long lags.

Our approach combines growth regressions with regressions on the sources of growth derived from a consistent growth-accounting exercise. We augment a standard growth specification based on conditional convergence by adding several debt indicators, and we estimate the same models for the different components of growth—physical-capital accumulation, human-capital accumulation, and total factor productivity growth—similar to the approach of Fischer (1993) and Bosworth and Collins (2003). We use a number of traditional Ordinary Least Squares (OLS), instrumental variables, fixed effects) and more recent estimators (differenced generalized method of moments (diff-GMM, system GMM, and identification through heteroskedasticity) to control (to different extents) for biases associated with unobserved country-specific effects and the endogeneity of several regressors, particularly the debt variables. This ensures that our conclusions are, on average, robust to the use of alternative estimators.

Since in PPR we found support for a nonlinear relationship between total external debt and growth, the approach here also utilizes nonlinear models. Specifically, we employ a spline (inverted V) function approach, allowing the impact of debt to have a structural break. We estimate the same nonlinear model for growth and its different components: capital accumulation, human-capital accumulation, and total factor productivity growth.

Previewing our results, we find that the negative impact of high debt on growth appears to operate both through a strong negative effect on physical-capital accumulation and on total factor productivity growth. The size of the effects are similar to the one on output growth: on average, for countries with high debt levels (in PPR, we identify the debt threshold for a negative marginal impact of debt on growth at around 65 percent of exports), doubling debt will reduce output growth by about 1 percentage point and reduce growth in both per capita physical capital and total factor productivity by almost as much. In terms of the contributions to growth, approximately one-third of the effect of debt on growth occurs via physical-capital accumulation and two-thirds via total factor productivity growth. We also find evidence of nonlinearities in the relationship between debt and the sources of growth, with debt having, on average, a positive impact on growth and total factor productivity growth at low debt levels, and a negative impact at high debt levels. For physical capital, the average impact of debt at low debt levels is negative, but only about half its average impact at high debt levels. Although the impact of debt on growth and its components at *low* debt levels is generally not significant (in part owing to the relatively small number of observations for moderately indebted countries), for *highly indebted* countries the impact of high debt on growth is nearly always significant, even after controlling for the endogeneity bias. Comparing the results with those obtained from a linear model confirms that the negative impact of high debt on growth tends to be underestimated when using a linear specification (that is, when constraining the coefficient of debt to be the same for both moderately and highly indebted countries). Finally, the results suggest that the dynamic aspects of debt accumulation may matter, since the time-series dimension of the panel appears crucial in helping to identify the negative impact of high debt on growth.

One of the key issues in ensuring the robustness of our results is to make certain that we have identified an effect of debt on growth, and not the reverse causality. Does high debt actually lower growth (and its components), or does low growth increase debt? Both directions of causality have been argued in the theoretical literature. We use recently developed panel estimators that, in addition to controlling for other biases, also control for endogeneity by using an optimal instrument set based on lagged values of potentially endogenous variables. Results are further strengthened by employing a state-of-the art estimator that uses the heteroskedasticity in the data to address endogeneity. We find that results summarized above are strongly robust to controlling for endogeneity.

The remainder of the paper is organized in five sections: Section II briefly summarizes related literature on debt and growth and the determinants of total factor productivity growth; Section III describes the data; Section IV describes the estimation methods; Section V discusses the results, and Section VI concludes.

## **II. THEORY AND RELATED LITERATURE**

This paper is related to several strands of literature, on the nonlinear effects of debt on the sources of growth; utilization of growth accounting to explore the channels through which various determinants are related to growth; and empirical analysis of the determinants of total factor productivity growth.

### **A. Nonlinear Effects of Debt on Sources of Growth**

Theory suggests that “reasonable” levels of borrowing by a developing country are likely to enhance its economic growth, both through capital accumulation and productivity growth. Countries at early stages of development have small stocks of capital and are likely to have investment opportunities with rates of return higher than in advanced economies. As long as they use the borrowed funds for productive investment and they do not suffer from macroeconomic instability, policies that distort economic incentives, or sizable adverse shocks, growth should increase and allow for timely debt repayments.

But why would large levels of accumulated debt lead to lower growth, and through which channels is this likely to occur? The most well known explanation comes from “debt overhang” theories, which show that if there is some likelihood that in the future debt will be larger than the country’s repayment ability, expected debt-service costs will discourage further domestic and foreign investment (Krugman, 1988; Sachs, 1989). Potential investors will fear that the more is produced, the more will be “taxed” by creditors to service the external debt, and thus they will be less willing to incur investment costs today for the sake of increased output in the future. This argument is represented in the “debt Laffer curve”, which posits that larger debt stocks tend to be associated with lower probabilities of debt repayment. On the upward-sloping or “good” section of the curve, increases in the face value of debt are associated with increases in expected debt repayment, while increases in debt reduce expected debt repayment on the downward-sloping or “bad” section of the curve. The expectation that some portion of the debt will have to be forgiven can also at some point

discourage private foreign investors from providing new financing, thus lowering capital accumulation.

The channel for the debt overhang's effect on growth may not only be through the volume of investment, but also be through lower productivity growth. Many authors have argued for a broader interpretation of debt overhang theory since any activity that requires incurring costs today for the sake of increased output in the future will be discouraged, as part of the proceeds will be taxed away by creditors (Corden, 1989). Thus, governments may have less incentive to undertake difficult policy reforms with initially high political and economic costs, and the poorer policy environment could contribute to lower productivity growth. The anticipation of future debt relief needed to resolve the debt overhang problem may also reduce governments' incentive to pursue policy reforms that strengthen their capacity to repay, with a similar negative impact on productivity growth.

Similarly, the literature stressing the uncertainties created by high debt stocks could imply that debt constrains growth through either the capital accumulation or productivity channel. Particularly in low-income countries with debt servicing difficulties, there are uncertainties about what portion of the debt will actually be serviced with the countries' own resources. The investment under uncertainty literature stresses that in highly uncertain and unstable environments, even if the fundamentals are improving, investors continue to exercise their option of waiting when considering whether to invest in costly, irreversible projects (Serven, 1997). The highly uncertain environment may also lead to misallocated and poorer quality investment projects that slow productivity growth.

Theory thus suggests that debt may have nonlinear effects on growth, either through capital accumulation or productivity growth. In PPR (2002) we found support for this inverted-U or inverted-V relationship of debt with growth. We employed various nonlinear specifications to identify the levels of debt at which the average and the marginal impact of debt on growth becomes negative. The nonlinear relationship between debt and growth (controlling for all other growth determinants) is stylized in Figure 1: the average impact of debt becomes negative at the intercept of the function on the horizontal axis (see point B in Figure 1), while the marginal impact of debt becomes negative at the turning point of the function (see point A in Figure 1). Our findings suggest that the average impact of debt becomes negative at about 160–170 percent of exports or 35–40 percent of GDP. Results indicate that the marginal impact of debt starts being negative at about half of these values on average. The quantitative effects of high debt were found to be quite substantial: for a country with average indebtedness, doubling the debt ratio would reduce annual per capita growth by between half and a full percentage point, while for countries that are to benefit from debt reduction under the current Heavily Indebted Poor Country (HIPC) initiative, per capita growth might increase by 1 percentage point, unless constrained by other macroeconomic and structural distortions.

Only a few other studies investigate empirically the nonlinear effects of debt on growth. Cohen (1997) finds that the probability of debt rescheduling—which depends positively on external indebtedness—significantly lowers growth. He find that debt becomes excessive

when it reaches levels of the order of 50 percent of GDP or 200 percent of exports. Elbadawi et al. (1997) directly considers nonlinear effects of debt on growth, using a quadratic specification and controlling for country effects. Their results imply a growth maximizing debt to GDP ratio of 97 percent, which is quite high considering that the average debt to GDP ratio in our sample is around 70 percent. They do not however correct for biases arising from the endogeneity of several regressors—particularly the debt variables—and from the presence of unobserved country-specific effects in a dynamic panel model. Based on a history of credit events going back to the 1820s, a more recent study by Reinhart, Rogoff, and Savastano (2003) finds much lower thresholds for the probability of a debt crisis. Although Reinhart, Rogoff, and Savastano do not directly investigate the relationship between debt and growth, their results suggest that risks of a debt crisis (with expected negative consequences for growth) increase significantly at debt levels as low as 15 percent of GNP, for countries with a weak default and inflation history.

It should be noted that while we have argued that the evidence supports a negative and significant effect of debt on growth (even after accounting for possible endogeneity of debt to the growth process), Easterly (2001), for example, contends that the causality runs in the opposite direction. That is, he maintains that the worldwide slowdown in growth after 1975 contributed to the debt crises of the middle-income countries in the 1980s and the HIPCs in the 1980s and 1990s. In this view, lower growth lowers tax revenues and primary surpluses, and without adjustment, debt ratios explode. Although we are not aware of any study that has investigated the issue of causality between debt and growth based on a nonlinear model, in a linear setting, Chowdhury (2001) provides some supporting evidence that the causality runs from debt to growth. Using panel causality tests (based on a dynamic linear model of the relationship between debt and growth), he finds a significant and negative causal impact of debt on growth, both in HIPC and non-HIPC developing countries. We will also find evidence of causality running from debt to growth.

## **B. Use of Growth Accounting to Analyze the Channels Through Which Determinants Affect Growth**

Growth accounting decomposes output growth into the contribution of changes in factor inputs—capital and human capital accumulation—and a residual, total factor productivity (TFP). There are relatively few studies that use growth accounting decompositions to explore how various determinants affect growth, as we do in this paper. An important paper by Fischer (1993) found support for causal relationships between macroeconomic policy and growth, and showed high budget deficits and inflation-reduced growth both by lowering capital accumulation and productivity growth. Bosworth and Collins (2003) find that, in accordance with expectations, life expectancy (proxying health status of the population), changes in the terms of trade (external volatility) and the quality of institutions have greater effects through TFP growth, while budget deficits (an alternative source of national savings) primarily affect capital growth. In contrast to theoretical predictions and other empirical studies, trade openness is found to affect growth through capital accumulation, rather than



TFP<sup>2</sup> (see also Collins and Bosworth, 1996). Beck et al. (2000), focus, as we do, on one growth determinant, and find that financial development has a positive effect on growth by improving TFP. As for debt, we are not aware of any studies to date that have examined the channels through which it might affect growth. Thus, at this stage, relatively little is known about the channels through which various determinants—and particularly debt—affect growth.

### **C. Empirical Analyses of Determinants of TFP Growth**

This paper also contributes to a small literature on the determinants of TFP growth across countries. Easterly and Levine (2001) argue strongly that TFP and not capital accumulation drives growth, implying that research on theoretically and empirically defining TFP and identifying policies and institutions most conducive to its growth should be a priority. However, the fundamental issue of whether factor accumulation or TFP accounts for cross-country differences in growth rates is not resolved in the literature.<sup>3</sup> Without taking a position on this debate, we note that the empirical literature on determinants of TFP growth across broad samples of countries is quite limited, with the exception of those focusing on the role of openness.<sup>4</sup> For example, Edwards (1998) uses alternative openness indicators to demonstrate that more open countries experience faster TFP growth, Coe et al. (1997) show that developing countries that trade with R&D intensive industrial countries have higher productivity growth, and Miller and Upadhyay (2000) find that in low-income countries human capital boosts TFP only when countries achieve certain levels of openness. The present paper provides some insight on the effect of debt on TFP.

## **III. DATA DESCRIPTION**

The analysis uses panel regressions for 61 developing countries spanning Sub-Saharan Africa, Asia, Latin America, and the Middle East over the period 1969–98.<sup>5</sup> The data are from various sources. Real Purchasing Power Parity (PPP) GDP is from the WEO database of the IMF, as data for several countries and for the latter half of the last decade are not

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<sup>2</sup> This finding may be related to the specific openness measure used, the Sachs-Warner measure.

<sup>3</sup> See for example Bosworth and Collins (2003) for evidence of an equal role of factor accumulation and TFP growth in accounting for growth differences (across countries and over time).

<sup>4</sup> There is however, a substantial literature on the determinants of productivity differences across industrial countries, as well as national studies on the sources of inter-industry productivity differences.

<sup>5</sup> The sample is reduced to 60 countries when net present value of debt indicators are used.

available in the Penn World Tables (PWT) dataset. Several basic control variables included in the growth regressions are also from the WEO database: terms of trade, fiscal balance to GDP (central government), and openness as a ratio of GDP. Other control variables, including population growth, secondary education, and investment to GDP are from the *World Development Indicators* (WDI) dataset (World Bank).

To capture the debt overhang effect, we used total external debt stock variables to represent the burden of future debt service. We used both the face value of debt stocks, the indicator that was most frequently used in previous studies and can therefore generate directly comparable results, and the net present value (NPV) of debt. The latter reflects the degree of concessionality of loans and thus more accurately measures the expected burden of future debt service across countries. Nominal debt to exports and to GDP are from the *Global Development Finance* dataset (World Bank), complemented with WEO data. Net present values of debt data were kindly provided by William Easterly (see Easterly, 2002). To isolate a potential crowding out effect, we also control for the contemporaneous debt service to exports ratio, from the *Global Development Finance* (GDF) dataset (World Bank).

In constructing the growth accounts used to examine the channels through which debt and other independent variables affect growth, we assume a constant returns to scale production function of the form:

$$Y = AK^{\alpha}H^{\beta}L^{1-\alpha-\beta} \quad (1)$$

where K measures physical capital, H measures human capital (educational attainment), and L is the labor force. This specification is consistent with the “augmented” neoclassical Solow growth model used in Mankiw, Romer, and Weil (1992) (thereafter MRW) and in more recent studies by Klenow and Rodriguez-Clare (1997) and Cohen (1997). We assume that the physical and human capital income shares  $\alpha$  and  $\beta$  are both equal to 0.33 for the entire sample, based on the coefficients implied by the MRW study.<sup>6</sup> In per capita form and taking logs, equation (1) can be rewritten, after first differencing:

$$\ln(y_t) - \ln(y_{t-1}) = \alpha[\ln(k_t) - \ln(k_{t-1})] + \beta[\ln(h_t) - \ln(h_{t-1})] + [\ln(A_t) - \ln(A_{t-1})] \quad (2)$$

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<sup>6</sup> Shares of physical and human capital of one-third each are also consistent with the data on income shares available for a few (mostly advanced) countries. The similarity of income shares in countries where they can be measured appropriately suggests that assuming them to be the same for all countries is not a serious simplification. The assumption that income shares weights are fixed over time is also consistent with the available data for the OECD countries. Given the lack of data on weights for developing countries, we avoid arbitrary choices by assuming that industrial countries weights also apply to developing countries, which is likely to be a rough approximation.

Equation (2) decomposes the growth in output per capita,  $y$ , into the contributions of growth in capital per capita,  $k$ , increases in human capital per capita,  $h$ , and the contribution of improvements in TFP,  $A$ .

The measures of physical and human capital used to compute increases in factor input stocks in the growth accounting equation (3) were kindly provided by Susan Collins (see Collins and Bosworth, 2003). Capital stock series in national currency values, at constant prices, were estimated by Bosworth and Collins based on a perpetual inventory method.<sup>7</sup> The investment series employed in the calculation are from Nehru and Dhareshwar (1993), updated with WDI data. Bosworth and Collins' preferred measure of human capital,  $H$ , is obtained by adjusting the workforce for improvements in education, assuming a 7 percent return to an additional year of schooling – a value near the lower boundary of the results from microeconomic studies:

$$H = (1.07)^s L, \quad \text{or in per capita terms: } h = (1.07)^s \quad (3)$$

where  $s$  measures average years of schooling (from Barro and Lee, 2000). In a country with an average educational attainment of 10 years for example, the effective labor supply – or human capital – will be almost twice the labor force according to this formula. TFP growth can then be calculated as a residual, rewriting equation (2) as follows:<sup>8 9</sup>

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<sup>7</sup> Alternative measures of capital stocks using international price measures of investment (PWT; Easterly and Levine, 2001) were not available for several countries and for the latter half of the past decade. See Bosworth and Collins (2003) for a discussion of the advantages of using national price measures of investment in a growth accounting context. Of course, any such calculation can provide only a rough estimation of the capital stock data.

<sup>8</sup> We prefer a specification where human capital has a separate role as a factor of production (following MRW and subsequent studies) rather than exclusively augmenting the labor force as in Bosworth and Collins (2003). The problem with the latter specification is that it constrains the income share of human capital to be equal to the labor share (i.e.,  $1-\alpha$ ), thus giving a larger weight (0.6-0.7) to human capital contribution than suggested by previous studies (0.3-0.4). The residual TFP growth is systematically lower in Bosworth and Collins' growth accounts as a result of the larger share assumed for human capital contribution.

<sup>9</sup> In the Diff-GMM regressions for physical and human capital and TFP growth, we control for initial conditions using initial levels of physical and human capital stocks per capita and TFP (other estimators use initial income per capita). Human capital levels were taken directly from Bosworth and Collins. For physical capital, to obtain estimates of real PPP capital stocks comparable across countries, we multiplied the ratio of capital to GDP in local currency (from Bosworth and Collins) by real PPP GDP (from the WEO):

$$K^{PPP} = (K / Y) Y^{PPP}$$

(continued...)

$$\ln(A_t) - \ln(A_{t-1}) = [\ln(y_t) - \ln(y_{t-1})] + \alpha[\ln(k_t) - \ln(k_{t-1})] - \beta[\ln(h_t) - \ln(h_{t-1})] \quad (4)$$

We calculate three-year averages of all the variables, to net out the effects of short run fluctuations, while maintaining the ability to utilize the time series dimension of the data. The latter feature of the data compilation is quite important, given that understanding how debt affects growth over time (the within-country variability of the panel data) is at least as important as understanding how countries with different levels of debt experienced different growth patterns (the between-country variability of the panel data). Our complete data set consists of 455 observations for 61 countries over the period 1969–98 (446 observations and 60 countries when using the net present value indicator of debt).<sup>10</sup>

Descriptive statistics for all variables are provided in Table 1. The last two columns of Table 1 (within and between standard deviations) show that the time-series variation in the data is substantial for all variables, in some cases (per capita GDP growth, TFP growth, human capital growth, debt service to exports, and openness) even greater than the cross-section variation. For the debt variables, the within- and between- variations in the data are of the same order of magnitude, although somewhat smaller in the within-dimension. The use of estimators that rely on the within-country variability of the data is thus likely to yield more significant results than pure cross-section estimators (in addition to helping address the issues of biases arising from endogeneity of some regressors and unobserved country-specific effects).

#### IV. ESTIMATION METHODOLOGY AND MODEL SPECIFICATION

We augment a standard growth model, based on conditional convergence<sup>11</sup>, by adding several different debt variables, and test for a nonlinear relationship between debt and growth by using a spline function where debt can have a different effect on growth before and after a particular debt threshold. We estimate the same nonlinear (spline) model with the proximate sources of growth as endogenous variables: physical capital growth, human capital growth, and total factor productivity. To the extent that debt has a nonlinear effect on growth, we can explore the extent to which it operates through each of these sources. For comparison purposes, we also estimate the simple linear relationship between debt and growth and each of its sources (i.e. constrain the coefficient of debt to be the same for both low- and high-debt

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The TFP levels were then calculated as a residual, substituting real PPP GDP per capita and real PPP capital stock per capita in equation (2) (a levels version):

$$\ln(A) = \ln(y^{PPP}) - \alpha \ln(k^{PPP}) - \beta \ln(h)$$

<sup>10</sup> However, the presence of lagged income in the estimation reduces the actual estimation sample to 9 periods, or 1972–98.

<sup>11</sup> See Mankiw, Romer and Weil (1992).

observations). In the presence of significant nonlinearity, we expect the impact of high debt to be underestimated (less negative) in the linear specification.

We describe our estimation methodology, model specifications, and results below.

### **A. Estimation Methodology**

Most of the dynamic panel specifications are estimated using a number of different estimators: (a) simple OLS; (b) instrumental variables—henceforth IV—to correct for endogeneity (the estimation method is two-stage least squares, using as instruments the lagged values of the endogenous regressors and the contemporaneous values of the other regressors); (c) fixed effects to allow countries to have different intercepts (that may be correlated with the regressors); and (d) differenced and system GMM to correct for endogeneity of debt and other control variables, and for the bias introduced by the lagged income variable in the presence of fixed effects.

The first two methods do not account for the presence of country effects, and thus results may be affected by an omitted variables bias. Therefore we also estimate regressions with fixed effects (third and fourth methods). In the presence of fixed effects however, the results with traditional panel data estimation (fixed effects) are biased by the presence of the lagged income variable among the regressors.<sup>12</sup> Recently developed methods such as differenced-GMM and system-GMM yield unbiased estimates under certain conditions of validity of the instruments, and simultaneously address the endogeneity issue for some of the explanatory variables (Blundell and Bond, 1998). Differenced-GMM estimates the model in first differences, using lagged levels of the dependent and endogenous variables as instruments. The system-GMM method, unlike fixed effects or differenced-GMM, does not entirely wipe out the cross-country dimension of the data by first-differencing (diff-GMM) or taking differences with respect to country means (fixed effects). Instead, cross-country information is used by jointly estimating the equation in first-difference and in levels, with first-differences instrumented by lagged levels of the dependent and independent variables and levels instrumented by first-differences of the regressors. These additional instruments are valid as long as they are uncorrelated with the fixed effects and exploiting these additional restrictions means that the sys-GMM estimator is more efficient than the diff-GMM one.

A new method to address endogeneity has recently been developed (Rigobon and Sack, 2003, Rigobon, 2003, and Hogan and Rigobon, 2003) which uses the natural heteroscedasticity in the data, rather than lagged values of the explanatory variables as instruments, to solve the identification problem that arises in simultaneous equations models. As an additional check on the robustness of our results, we also employ this methodology

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<sup>12</sup> The presence of the fixed effects introduces a correlation between the lagged income variable and the residual, which biases the results. In particular, the coefficient on the lagged income variable is negatively biased.

(Identification through Heteroskedasticity, hereafter IH.) An instrumental variable interpretation of this methodology is provided by Rigobon (2003) for the case of identifying a demand and supply schedule. “A valid instrument to estimate the demand schedule is one that moves the supply, without affecting the demand. In this example, the rise in the variance of the supply shocks precisely becomes a probabilistic instrument by increasing the likelihood that the supply equation ‘moves’ (pg. 4).”

It can be easily shown that the system of two simultaneous equations is just identified when heteroscedasticity can be described as a two-regime process. Identification under general conditions, such as more than two regimes, is discussed in Rigobon (2003). It would be quite difficult to estimate the full nonlinear dynamic model, with unobserved country-specific effects, and to correct for the endogeneity of all the variables. Nevertheless, the method can still be employed to identify the linear relationship between *high* debt and growth (and its sources) by using the heteroscedasticity of the debt ratios, after netting out the influence of all the other control variables, and restricting the sample to high-debt observations only.<sup>13</sup> In other words, we employ a two-step method. First, using only the sample of high-debt observations, both growth (and its sources) and the debt variables are regressed (using OLS) on all the other control variables (with the potentially endogenous regressors entered as lags to minimize endogeneity problems). Second, we use the IH method to identify the linear relationship between debt and growth (or its sources) in this high-debt sub sample. The estimate of the debt coefficient obtained is expected to be robust to an endogeneity bias, although ignoring country-specific effects may result in some omitted variable bias.

To ensure that our results are not driven by time specific effects or the presence of outliers, we estimate regressions with time dummies and with a sample where outliers are eliminated.<sup>14</sup>

## **B. Model Specification**

The dynamic panel data models we estimate have per capita growth (or physical/human capital growth per capita, total factor productivity) as dependent variables, and include, as control variables, lagged income per capita, the investment rate, the secondary school enrollment rate, the population growth rate<sup>15</sup> (all in logs), a number of other variables to

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<sup>13</sup> For practical estimation purposes, heteroskedasticity is treated as a multiple-regime process, with one regime per time period. To ensure identification, we normalize the data by dividing the residual of each variable by its standard deviation prior to estimation. The estimated coefficients are then renormalized to ensure comparability with the other methods.

<sup>14</sup> For each variable, outliers are defined as observations that deviate from the mean by more than five times the standard deviation.

<sup>15</sup> Augmented by the rate of technical progress (2 percent) and by the rate of depreciation (3 percent), as in Mankiw, Romer, and Weil (1992).

control for differences in total factor productivity (openness—defined as exports plus imports over GDP—and fiscal balance), and exogenous shocks (terms of trade growth).<sup>16</sup>

Turning to debt variables, the theories implying nonlinear relationships between debt and the sources of growth rely on debt overhang effects, which can be captured with a variable representing the burden of future debt service, such as the debt stock. To isolate this effect, it is important to also control for potential crowding out, which we proxy by a contemporaneous debt service ratio, total debt service to exports. We use four debt stock ratios: nominal debt to exports and GDP, and the net present value (NPV) of debt to exports and to GDP, the latter reflecting the degree of concessionality of loans.

The nonlinear relationship between debt and sources of growth is estimated using the spline function:<sup>17</sup>

$$y_{it} = \alpha_{(it)} + \beta X_{it} + \gamma D_{it} + \chi (D_{it} - D_{it}^*)Z + \varepsilon_{it}, \quad (5)$$

where  $y_{it}$  is the logarithmic difference in GDP, physical/human capital per capita or TFP, and  $X_{it}$  are control variables (including lagged GDP per capita).  $D_{it}^*$  represents the debt threshold and  $Z$  is a dummy equal to 1 if debt is above  $D_{it}^*$  (and 0 otherwise). This specification allows the impact of debt on the dependent variable to have a structural break, in the sense that the impact is different below and above the threshold if  $\chi$  is significantly different from zero.

We draw on results from our earlier paper, PPR (2002) to determine the debt threshold  $D_{it}^*$ . Estimating growth models using both quadratic and spline functions, we looked for the best debt threshold  $D_{it}^*$  by varying the threshold and evaluating which regression produced the highest R-squared. We were not, however, able to pinpoint this turning point with accuracy as the results varied across estimation methods. Hence, the average of the significant coefficients, which yield turning points of 65 percent for debt to exports and 18 percent for debt to GDP, was used to identify  $D_{it}^*$  in the present paper.

Tables 2a-2d show illustrative results for the four dependent variables (five estimation methods each) and for the nominal debt to GDP variable. The results for the control variables all appear reasonable in the growth regression, and similar to our earlier results (see PPR, 2002). Focusing on the variables of interest, the debt variables, we show coefficients for the

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<sup>16</sup> The schooling, investment, fiscal balance, openness and debt variables are instrumented in the IV, difference and system GMM estimations.

<sup>17</sup> Equation (4) implies that, for any particular methodology employed, we expect the coefficient in the growth regression to be a weighted average of the coefficients of the regressions for the three growth components. The weights would equal 1, alpha, and beta for the coefficients in the TFP, physical capital, and human capital regressions, respectively.

debt variable, and for the “debt extra” term,  $(D - D^*)Z$ . To get the total effect of debt above the threshold, it is necessary to sum these two terms. We also show the p-value of an F-test for the hypothesis that the sum of these two coefficients equals zero, or that there is no effect of debt above the threshold. For the two GMM estimators, the Sargan test (for the validity of the instruments) in the last two columns indicates that the restrictions imposed are generally accepted in the regressions explaining growth of per capita output, per capita physical capital, and TFP, but not in those explaining growth in human capital.

For the debt to income variable, the results support a nonlinear effect of debt on growth that operates through both capital accumulation and total factor productivity, but not through human capital accumulation. While the coefficient on the  $\log(\text{debt})$  term (measuring the debt impact for the “low debt” case or debt below the threshold) is either positive or small and negative, but generally not significant, the coefficient of the “debt extra” term is negative and significant, confirming the presence of a structural break in the debt coefficient. The total effect of debt for the “high debt,” or debt above the threshold case (obtained by summing the coefficients of debt and the “debt extra” term), is significantly negative. We discuss the magnitudes of the coefficients below, as we consider the results for all four of the debt variables.

## V. RESULTS

This section describes the econometric results addressing the main question of the paper: what are the channels through which debt affects growth, and whether the possible effect on the sources of growth is nonlinear as in the case of the effect on output growth.

### A. How Does Debt Affect Growth?

First, we summarize results on the channels through which debt affects growth. For each specification, the results are presented for the four alternative measures of debt: debt to exports, debt to GDP, NPV of debt to exports, and NPV of debt to GDP.

Tables 3 and 4 presents the results for coefficients estimated from the spline function. Table 3 reports the results for the coefficients of debt at low levels (the term  $\gamma$  in equation (5) above). As we employ five estimation methods (OLS, IV, fixed effects, diff-GMM, and sys-GMM) and four debt indicators, there are twenty regressions for each endogenous variable. We run these regressions for the four endogenous variables, thus obtaining four blocs (of twenty regressions each), one for growth and the next three for the sources of growth. Table 4 reports the results for the coefficients of debt at high levels, i.e. the sum of the coefficients of debt and the debt extra term, (the sum of  $\gamma + \chi$  in equation (5) above). The structure is similar to Table 3 with an extra column for the sixth estimation method (IH) that we apply for robustness only to the high debt sample (see Section IV.A ). In Table 4, therefore, each bloc presents twenty-four regressions for each endogenous variable. Apart from column 6 in



Table 4, cells in the same position in Tables 3 and 4 refer to the same spline regression.<sup>18</sup> Note that in order to derive the impact of doubling debt, all coefficients in Tables 3 and 4 should be multiplied by the natural logarithm of 2. Also, the contribution to growth of the per capita physical and human capital can be calculated by further multiplying by 0.33, i.e. their growth accounting share.

The first horizontal bloc examines the nonlinear relationship between debt and growth. Consistent with our previous study (PPR, 2002), the impact of debt on growth is very different at low levels of debt than at high levels. At low levels (Table 3), the effect is generally positive but often not significant. This may reflect in part the small number of low-debt observations in the sample (arising in turn from the relatively low debt threshold implied by our earlier results), which makes it difficult to identify precisely the relationship between debt and growth at low debt levels. At high levels of debt (Table 4), there is a large negative impact: on average, doubling debt from any initial debt level at or above the threshold will reduce per capita growth by about 1 percentage point (as can be derived by multiplying an average coefficient of about -1.5 times the natural log of 2). The result is strongly robust to endogeneity: the IV estimator, the two GMM estimators, and the IH estimators all yield generally significant coefficients, although the magnitudes of the estimates tend to be smaller for the sys-GMM estimator.<sup>19</sup>

The next three horizontal blocs present the regressions for the sources of growth. Again, the most robust results relate to the “high debt” coefficients (Table 4). High debt seems to have quite a strong negative effect on both physical capital accumulation and on total factor productivity. The size of the effect is similar to the one on output growth: on average, doubling debt will reduce growth in both per capita physical capital and total factor productivity by almost 1 percentage point. The result remains robust after controlling for the endogeneity of debt, although again the estimated coefficient of high debt tends to be smaller on average for the sys-GMM method. As perhaps intuitive, the impact of high debt on human

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<sup>18</sup> Thus, as an example, looking at the top left cells in Tables 3 and 4 (first row) indicates that the OLS growth regression using the debt/export variable yields an insignificant coefficient of 0.73 for low debt (below the threshold) and a significantly (at the 1 percent level) negative coefficient of -1.24 for high debt (above the threshold). For the IH method, only the high debt coefficient, -1.88, (obtained by linear estimation on the sample restricted to high debt observations) is reported.

<sup>19</sup> Note that the direct comparison of IH and OLS results is not feasible here. Normally one would expect IH to deliver smaller estimates of the effect of debt on growth than OLS, because the former method eliminates the endogeneity bias. However, in table 4 the two methods are applied to different specifications: the IH specification is estimated only on the high debt sub-sample, and all the potentially endogenous explanatory variables—apart from debt indicators—are lagged (to control for endogeneity). As expected, OLS estimates of the same specification (only on the high-debt sub-sample) were larger than IH ones.

capital accumulation is very small and generally not significant (one might expect that high debt would only affect human capital with very long lags). The effect of “low debt” (Table 3) tend to be positive for total factor productivity and negative for capital (on average), but is generally not significant.

Overall, our results suggest that doubling debt in a high debt environment would reduce per capita growth by about 1 percentage point, two thirds of which would arise from an effect via total factor productivity and one third via per capita capital accumulation.

### **B. Are Effects Linear or Nonlinear?**

For comparison purposes, we also estimated the linear relationship between debt and growth and its sources (constraining the low- and high-debt coefficient to be the same) with a subset of methodologies (see Table 5). Linear results are qualitatively similar: we find a negative effect of debt on growth, capital growth, and TFP growth, but no significant effect on human capital growth. However, the effect of debt on growth and its components estimated from the linear model is on average smaller than the effect of high debt estimated in the spline model (Table 4): doubling the debt ratio would reduce growth, TFP growth, and physical capital growth by about a quarter less per annum than implied by non-linear specification results, for the high debt case. This type of result would be expected in the presence of significant nonlinearity. Hence, comparing Tables 4 and 5 provides further evidence supporting the non-linear relationship between debt and growth (as well as its components) and warns against the risk that the effect of debt will be underestimated in a linear specification.

### **C. How Do Results Compare Using Decades Panel Data?**

We also estimate the same specifications with data averaged over a decade (hence a panel with three periods and the same number of countries), in order to further smooth the effect of economic fluctuations on growth. However, the limited time dimension of the dataset dictates that it is only possible to estimate the model using OLS, IV and fixed effect methodologies. Although the signs and magnitudes of the debt variable coefficients were similar, significance was generally weaker. There could be three main explanations for this difference between the results derived with the three-year average and the decade-average data. First, the decade-average data results are less reliable because of the limitations of the methodologies employable (as compared to diff-GMM, Sys-GMM and IH). Second, the weaker results with decade-average data could be due the importance of the time dimension of the effect of debt on growth—rather than its cross-sectional explanatory power—as witnessed by the importance of within country variability of the debt ratios (see Table 1).<sup>20</sup> One may wonder, however, whether the effect of debt on growth is long lasting or simply a medium term phenomenon. Note that our previous study (PPR, 2002) finds that in a wider

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<sup>20</sup> The within county variability is even higher than the between variability, when evaluated in a wider sample of about 100 developing countries (the dataset employed by PPR, 2002, which was not constrained by the availability of data for physical and human capital).

sample of about 100 developing countries the non-linear effect of debt on growth is detectable even with decade averages. Third, the three-year average data may simply capture reverse causality from growth to debt (as argued in Easterly, 2002, for example). However, such an interpretation seems inconsistent with the fact that our results are strongly robust to controlling for endogeneity with four different methods. Hence, we maintain that our three-year average data results are representative of the effect of debt on growth.

#### **D. Reverse Causality**

The IH estimation method allows us also to shed light on the compatibility of our results (which show a robust effect of debt ratios on growth) with Easterly (2001) ones (which refer to an effect of growth on the debt ratios, mainly via a change in the denominator of the ratios). In fact, the Rigobon method allows to derive estimates for both effects simultaneously, correcting for the reverse causality of their interaction. It turns out that both effects are significant. Table 6 reports the IH results for the impact of growth on debt that are derived from the same IH estimations reported in the last column of first panel of Table 4 (hence for the high debt sample only). Such results suggest that an increase in growth by 1 percentage point would reduce the debt ratios by about 2-4 percent (the effect is somewhat larger for nominal debt ratios than net present value ratios and for ratios to exports than ratios to income). The normalized effects are somewhat similar in the two directions: an increase in debt ratios by one standard deviation reduces growth by 0.13-0.26 standard deviations; conversely, an increase in output growth by one standard deviation reduces debt ratios by 0.11-0.32 standard deviations.<sup>21</sup>

Such results are quite interesting as they confirm the existence of the reverse causality that can be expected to occur between output growth and debt ratios. This suggests that the effect we focused on (indebtedness on growth) is compatible and coexists with the one Easterly highlighted (growth on indebtedness).

#### **VI. CONCLUSION**

Consistent with our previous study (PPR), the impact of debt on growth is very different at low levels of debt and at high levels. At high levels of debt, there is a large negative impact: on average, the results imply that doubling debt from any initial debt level at or above the threshold will reduce per capita growth by about 1 percentage point. At low levels, the effect is generally positive but often not significant. The difficulty in identifying the relationship between debt and growth at low debt levels may, in part, be due to the small number of low-

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<sup>21</sup> These estimates should be considered as indicative. Our model was designed to investigate growth and the set of control variable necessary to explain debt might be different from ours. Further research would be necessary to properly estimate the effect of growth on indebtedness controlling for endogeneity. Such an analysis is beyond the scope of the paper.

debt observations in the sample, given the relatively low debt turning point implied by our earlier results (PPR).

In terms of the channels through which debt affects growth, the negative impact of high debt on growth appears to operate through both a strong negative effect on physical-capital accumulation and on TFP growth. The size of the effects are similar to that of the effect on output growth: on average, for countries with high debt levels, doubling debt will reduce output growth by about 1 percentage point and reduce growth in both per capita physical capital and total factor productivity by almost as much. In terms of the contributions to growth, approximately one-third of effect of debt at high levels of indebtedness occurs via physical-capital accumulation and two-thirds via total factor productivity growth. In contrast, the impact of high debt on human capital accumulation is very small and generally not significant. At low debt levels, the effect of debt tends to be positive for TFP growth and negative for capital (on average), but is generally not significant.

All the results are strongly robust to endogeneity bias: in particular, the impact of high debt on growth, physical capital growth, and TFP growth remains significant and negative even with estimators that control for endogeneity of debt. It is also interesting to note that a deeper analysis of the reverse causality between debt and growth (allowed by the IH estimation methodology put forward by Rigobon) suggests that both the effect of indebtedness on growth (the one we focus on) and the effect of growth on indebtedness (the one Easterly focuses on) are significant when controlling for endogeneity. Hence, our results are not incompatible with those of Easterly (2001 and 2002).

On the one hand, these results are consistent with the speculation that high debt reduces the incentive to invest and to undertake good policies, since the return on such actions can be expected to accrue partly to lenders rather than to citizens and politicians of a highly indebted country. On the other hand, the impact of debt on human-capital accumulation could not be detected, perhaps because it operates with very long lags.

In terms of policy implications, the findings suggest that for the average country in the sample, reducing debt levels would contribute to growth by boosting both capital accumulation and productivity growth. But reducing debt may not have the desired effect on capital or productivity growth (and therefore output growth) if other macroeconomic and structural distortions or political constraints bind. It is also important to note that although the findings are relevant for current policy debates on the potential impact of the Heavily Indebted Poor Countries (HIPC) Initiative and forward-looking assessments of debt sustainability in low-income countries, the economic and political situations of these countries makes them a nontypical subsample. In addition to worse macroeconomic and institutional conditions than the average country in the sample, HIPCs have continued to receive a positive net transfer of resources throughout the 1980s and 1990s (as have many other low-income countries), given that aid flows exceeded debt service. Nonetheless, the debt-overhang effect would still apply if higher debt had an adverse incentive effect at the margin. Thus, further research would be necessary to determine the extent to which these findings hold specifically for HIPCs.

The paper's findings suggest a number of further questions. For example, does high debt constrain capital accumulation through reducing public investment, private investment, or foreign direct investment? What are the mechanisms through which high debt levels lower total factor productivity growth? Does the negative impact of high debt on growth and its sources vary across countries, depending, for example, on the overall quality of policies? In that case, which types of policies are most important in supporting growth even when a country is highly indebted? To what extent would the results hold specifically for low-income countries? Does the flow (and not only the stock) of debt matter? In other words, would a high past debt stock with no new borrowing have different implications for growth than a low past debt with high new borrowing? We leave these interesting issues for further research.

Table 1. Summary Statistics and List of Countries

| Variables                            | Number of<br>Observations | Mean    | Std. Dev. | Between <sup>1/</sup><br>Std. Dev | Within <sup>1/</sup><br>Std. Dev. |
|--------------------------------------|---------------------------|---------|-----------|-----------------------------------|-----------------------------------|
| Per capita GDP growth                | 455                       | 1.1     | 3.8       | 2.31                              | 3.06                              |
| Lagged income per capita             | 455                       | 3,562.8 | 2,588.6   | 0.80                              | 0.18                              |
| Terms of trade growth                | 455                       | -0.1    | 9.5       | 2.22                              | 9.27                              |
| Population growth                    | 455                       | 1.9     | 0.1       | 0.13                              | 0.04                              |
| Debt service to exports              | 455                       | 23.2    | 15.2      | 10.33                             | 11.35                             |
| Schooling                            | 455                       | 38.6    | 22.3      | 0.72                              | 0.27                              |
| Investment/GDP                       | 455                       | 19.9    | 6.8       | 0.32                              | 0.21                              |
| Fiscal balance/GDP                   | 455                       | -4.6    | 4.6       | 3.38                              | 3.11                              |
| Openness                             | 455                       | 25.0    | 15.0      | 13.27                             | 7.17                              |
| Debt to exports                      | 455                       | 283.1   | 330.5     | 0.74                              | 0.53                              |
| NPV of debt to exports               | 446                       | 234.9   | 218.3     | 0.67                              | 0.51                              |
| Debt to GDP                          | 455                       | 67.4    | 89.8      | 0.69                              | 0.55                              |
| NPV of debt to GDP                   | 446                       | 47.2    | 40.8      | 0.65                              | 0.53                              |
| Capital stock growth<br>(per capita) | 455                       | 2.1     | 3.6       | 2.60                              | 2.52                              |
| Human capital growth<br>(per capita) | 445                       | 0.6     | 0.5       | 0.27                              | 0.43                              |
| Total factor productivity<br>growth  | 446                       | 0.2     | 3.2       | 1.77                              | 2.76                              |

Source: Authors' calculations.

Note: NPV denotes net present value.

<sup>1/</sup>Consistent with usage in our regressions, for some variables the between/within standard deviations are calculated using the log of the variable: lagged income per capita, population growth, schooling, investment/GDP, all debt to income and debt to export indicators.

#### LIST OF COUNTRIES IN THE SAMPLE

Algeria, Argentina, Bangladesh, Bolivia, Brazil, Cameroon, Chile, China, Colombia, Congo Democratic Republic, Costa Rica, Cote d'Ivoire, Cyprus, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Ghana, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Iran, Jamaica, Kenya, Korea, Madagascar, Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Mozambique, Myanmar, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela, Zambia, and Zimbabwe.

Table 2a. Nonlinear Effects of Debt/GDP on Growth: Spline Regression

|                                      | OLS                 | IV                  | FE                  | Diff-GMM 1/          | SYS-GMM              |
|--------------------------------------|---------------------|---------------------|---------------------|----------------------|----------------------|
| Log (Income) <sub>t-1</sub>          | -1.982<br>(6.54)*** | -1.645<br>(4.70)*** | -8.223<br>(7.74)*** | -7.300<br>(32.29)*** | -3.098<br>(-5.27)*** |
| Terms of Trade Growth                | 0.018<br>(0.94)     | 0.015<br>(0.66)     | 0.015<br>(0.89)     | -0.008<br>(0.76)     | -0.002<br>(-0.11)    |
| Log (Population Growth)              | -3.919<br>(2.78)*** | -4.023<br>(2.45)**  | -3.989<br>(0.99)    | -0.948<br>(0.33)     | -2.731<br>(-1.27)    |
| Debt Service/Exports                 | 0.005<br>(0.35)     | -0.007<br>(0.41)    | 0.013<br>(0.84)     | 0.001<br>(0.08)      | -0.023<br>(-1.06)    |
| Log (Schooling)                      | 1.038<br>(3.59)***  | 1.457<br>(4.05)***  | -1.293<br>(1.88)*   | 0.166<br>(0.22)      | 2.326<br>(2.04)**    |
| Log (Investment)                     | 3.800<br>(7.93)***  | 1.832<br>(2.81)***  | 4.472<br>(5.88)***  | 6.170<br>(10.82)***  | 3.399<br>(2.97)***   |
| Fiscal Balance                       | 0.171<br>(3.93)***  | 0.076<br>(1.16)     | 0.217<br>(4.26)***  | 0.188<br>(4.99)***   | 0.448<br>(4.21)***   |
| Openness                             | 0.025<br>(1.88)*    | 0.003<br>(0.19)     | 0.065<br>(2.34)**   | 0.064<br>(2.56)**    | 0.015<br>(0.62)      |
| Log (Debt/GDP) (LDEBTY)              | 0.588<br>(0.84)     | 1.081<br>(0.67)     | 1.368<br>(1.76)*    | 1.005<br>(1.45)      | 2.271<br>(1.80)*     |
| Log (Debt/GDP) Extra (LDEBTYx) 2/    | -1.964<br>(2.46)**  | -2.291<br>(1.33)    | -3.684<br>(4.25)*** | -3.401<br>(4.18)***  | -2.688<br>(-1.75)*   |
| Constant                             | 10.525<br>(2.71)*** | 10.142<br>(1.65)    | 66.331<br>(5.10)*** | 0.273<br>(2.65)***   | 11.124<br>(2.23)**   |
| Observations                         | 449                 | 381                 | 449                 | 318                  | 449                  |
| R-squared 3/                         | 0.38                | 0.32                | 0.59                |                      | 0.27                 |
| p-value for F-test: LDEBTY+LDEBTYx=0 | 0.00                | 0.00                | 0.00                | 0.00                 |                      |
| p-value for Sargan test              |                     |                     |                     | 0.69                 | 0.89                 |

Source: Authors' calculations.

Notes:

Robust t statistics in parentheses

\* significant at 10 percent; \*\* significant at 5 percent; \*\*\* significant at 1 percent

1/ The model estimated by Diff-GMM is  $y_t = \alpha + \beta y_{t-1} + \dots$  rather than  $y_t - y_{t-1} = \alpha + \beta y_{t-1} + \dots$  (where y is the log of income per worker, and  $\beta$  is estimated by the other methods. We transform the  $\beta$  to be comparable to the other methods, and a test of  $\beta=0$  is rejected at 1 percent significance levels.

2/ Coefficient on extra term,  $(D-\hat{D})Z$ , where  $Z=1$  if  $D>\hat{D}$ , 0 otherwise

3/ 1-RSS/TSS reported for SYS-GMM.

Table 2b. Nonlinear Effects of Debt/GDP on Capital Accumulation: Spline Regression

|                                      | OLS                 | IV                  | FE                  | Diff-GMM 2/          | SYS-GMM              |
|--------------------------------------|---------------------|---------------------|---------------------|----------------------|----------------------|
| Log (Income) <sub>t-1</sub> /1       | -0.856<br>(3.79)*** | -0.898<br>(3.42)*** | -1.095<br>(1.67)*   | -2.800<br>(58.75)*** | -1.230<br>(-2.49)*** |
| Terms of Trade Growth                | 0.014<br>(1.07)     | 0.008<br>(0.59)     | 0.014<br>(1.42)     | 0.004<br>(0.41)      | 0.000<br>(-0.06)     |
| Log (Population Growth)              | -3.569<br>(3.55)*** | -3.768<br>(3.51)*** | -5.276<br>(2.35)**  | -3.164<br>(1.34)     | -3.416<br>(-1.66)*   |
| Debt Service/Exports                 | -0.034<br>(4.18)*** | -0.050<br>(4.66)*** | 0.004<br>(0.48)     | 0.012<br>(1.23)      | -0.021<br>(-2.13)**  |
| Log (Schooling)                      | 0.083<br>(0.32)     | 0.425<br>(1.25)     | -1.252<br>(2.13)**  | 0.786<br>(1.27)      | 0.163<br>(0.26)      |
| Log (Investment)                     | 5.745<br>(15.06)*** | 4.721<br>(9.64)***  | 6.912<br>(13.13)*** | 6.435<br>(13.29)***  | 6.963<br>(8.29)***   |
| Fiscal Balance                       | 0.068<br>(2.10)**   | 0.134<br>(2.32)**   | 0.031<br>(0.98)     | -0.098<br>(3.04)***  | 0.068<br>(1.63)*     |
| Openness                             | -0.004<br>(0.44)    | -0.007<br>(0.50)    | 0.042<br>(2.83)***  | 0.077<br>(3.90)***   | 0.009<br>(0.75)      |
| Log (Debt/GDP) (LDEBTY)              | 0.416<br>(0.61)     | 2.162<br>(2.44)**   | 0.259<br>(0.44)     | -1.069<br>(1.83)*    | -0.130<br>(-0.11)    |
| Log (Debt/GDP) Extra (LDEBTYx) 3/    | -1.932<br>(2.54)**  | -3.709<br>(3.76)*** | -2.040<br>(3.04)*** | -1.061<br>(1.58)     | -1.488<br>(-1.09)    |
| Constant                             | 0.450<br>(0.14)     | -2.369<br>(0.61)    | 7.574<br>(1.01)     | 0.571<br>(1.67)*     | 0.449<br>(0.07)      |
| Observations                         | 449                 | 381                 | 449                 | 318                  | 441                  |
| R-squared 4/                         | 0.59                | 0.60                | 0.81                |                      | 0.56                 |
| p-value for F-test: LDEBTY+LDEBTYx=0 | 0.00                | 0.00                | 0.00                | 0.00                 |                      |
| p-value for Sargan test              |                     |                     |                     | 0.01                 | 0.15                 |

Source: Authors' calculations.

Notes:

Robust t statistics in parentheses

\* significant at 10 percent; \*\* significant at 5 percent; \*\*\* significant at 1 percent

1/ For Diff-GMM, variable is lagged capital accumulation.

2/ The model estimated by Diff-GMM is  $y_t = \alpha + \beta y_{t-1} + \dots$  rather than  $y_t - y_{t-1} = \alpha + \beta y_{t-1} + \dots$  (where y is the log of capital accumulation per worker, and  $\beta$  is estimated by the other methods. We transform the  $\beta$  to be comparable to the other methods, and a test of  $\beta=0$  is rejected at 1 percent significance levels.

3/ Coefficient on extra term,  $(D-\hat{D})Z$ , where  $Z=1$  if  $D>\hat{D}$ , 0 otherwise

4/ 1-RSS/TSS reported for SYS-GMM.



Table 2c. Nonlinear Effects of Debt/GDP on Human Capital Accumulation: Spline Regression

|                                      | OLS                 | IV                  | FE                 | Diff-GMM 2/          | SYS-GMM              |
|--------------------------------------|---------------------|---------------------|--------------------|----------------------|----------------------|
| Log (Income) <sub>t-1</sub> /1       | 0.021<br>(0.41)     | 0.035<br>(0.60)     | -0.184<br>(1.34)   | -6.367<br>(26.00)*** | 0.009<br>(0.09)      |
| Terms of Trade Growth                | 0.004<br>(1.98)**   | 0.005<br>(1.91)*    | 0.003<br>(1.36)    | 0.000<br>(0.12)      | 0.001<br>(0.89)      |
| Log (Population Growth)              | 0.738<br>(3.64)***  | 0.803<br>(3.60)***  | 0.608<br>(1.16)    | 0.730<br>(1.29)      | 0.773<br>(2.30)**    |
| Debt Service/Exports                 | 0.000<br>(0.06)     | 0.003<br>(1.28)     | 0.001<br>(0.31)    | 0.005<br>(2.11)**    | 0.002<br>(0.59)      |
| Log (Schooling)                      | 0.239<br>(5.13)***  | 0.211<br>(4.06)***  | 0.393<br>(3.11)*** | 0.484<br>(3.51)***   | 0.210<br>(1.19)      |
| Log (Investment)                     | 0.170<br>(2.65)***  | 0.241<br>(2.40)**   | 0.047<br>(0.42)    | -0.236<br>(2.09)**   | 0.036<br>(0.24)      |
| Fiscal Balance                       | -0.001<br>(0.10)    | -0.011<br>(1.08)    | 0.004<br>(0.53)    | 0.004<br>(0.51)      | 0.006<br>(0.74)      |
| Openness                             | -0.003<br>(1.66)*   | -0.004<br>(1.41)    | 0.000<br>(0.04)    | 0.003<br>(0.63)      | 0.000<br>(0.11)      |
| Log (Debt/GDP) (LDEBTY)              | 0.020<br>(0.26)     | -0.152<br>(1.25)    | 0.101<br>(0.91)    | 0.162<br>(1.24)      | 0.205<br>(1.65)*     |
| Log (Debt/GDP) Extra (LDEBTYx) 3/    | -0.011<br>(0.12)    | 0.138<br>(0.95)     | -0.089<br>(0.66)   | -0.245<br>(1.62)     | -0.327<br>(-2.20)**  |
| Constant                             | -2.346<br>(3.58)*** | -2.424<br>(2.71)*** | -0.715<br>(0.41)   | 0.216<br>(2.73)***   | -2.382<br>(-2.69)*** |
| Observations                         | 440                 | 376                 | 440                | 313                  | 440                  |
| R-squared 4/                         | 0.17                | 0.19                | 0.35               |                      | 0.14                 |
| p-value for F-test: LDEBTY+LDEBTYx=0 | 0.84                | 0.80                | 0.89               | 0.26                 |                      |
| p-value for Sargan test              |                     |                     |                    | 0.01                 | 0.09                 |

Source: Authors' calculations.

Notes:

Robust t statistics in parentheses

\* significant at 10 percent; \*\* significant at 5 percent; \*\*\* significant at 1 percent

1/ For Diff-GMM, variable is lagged human capital accumulation.

2/ The model estimated by Diff-GMM is  $y_t = \alpha + \beta y_{t-1} + \dots$  rather than  $y_t - y_{t-1} = \alpha + \beta y_{t-1} + \dots$  (where y is the log of human capital accumulation per worker, and  $\beta$  is estimated by the other methods. We transform the  $\beta$  to be comparable to the other methods, and a test of  $\beta = 0$  is rejected at 1 percent significance levels.

3/ Coefficient on extra term,  $(D - \hat{D})Z$ , where  $Z=1$  if  $D > \hat{D}$ , 0 otherwise

4/ 1-RSS/TSS reported for SYS-GMM.

Table 2d. Nonlinear Effects of Debt/GDP on Total Factor Productivity Growth: Spline Regression

|                                      | OLS                 | IV                  | FE                  | Diff-GMM 2/           | SYS-GMM              |
|--------------------------------------|---------------------|---------------------|---------------------|-----------------------|----------------------|
| Log (Income) <sub>t-1</sub> /1       | -1.706<br>(5.76)*** | -1.348<br>(3.92)*** | -7.921<br>(7.73)*** | -10.767<br>(22.44)*** | -2.750<br>(-3.20)*** |
| Terms of Trade Growth                | 0.013<br>(0.71)     | 0.013<br>(0.59)     | 0.013<br>(0.81)     | -0.004<br>(0.39)      | 0.003<br>(0.20)      |
| Log (Population Growth)              | -2.739<br>(2.06)**  | -2.686<br>(1.74)*   | -2.253<br>(0.57)    | 2.836<br>(1.05)       | -0.906<br>(-0.36)    |
| Debt Service/Exports                 | 0.017<br>(1.42)     | 0.009<br>(0.59)     | 0.013<br>(0.79)     | -0.000<br>(0.04)      | -0.014<br>(-0.64)    |
| Log (Schooling)                      | 1.030<br>(3.71)***  | 1.319<br>(3.77)***  | -0.948<br>(1.34)    | 0.159<br>(0.24)       | 2.695<br>(1.66)*     |
| Log (Investment)                     | 1.736<br>(3.81)***  | 0.185<br>(0.29)     | 2.007<br>(2.59)***  | 4.230<br>(8.03)***    | 0.638<br>(0.59)      |
| Fiscal Balance                       | 0.141<br>(3.38)***  | 0.040<br>(0.65)     | 0.194<br>(3.93)***  | 0.209<br>(6.24)***    | 0.406<br>(3.88)***   |
| Openness                             | 0.029<br>(2.29)**   | 0.009<br>(0.51)     | 0.054<br>(2.15)**   | 0.061<br>(2.73)***    | 0.002<br>(0.08)      |
| Log (Debt/GDP) (LDEBTY)              | 0.473<br>(0.67)     | 0.453<br>(0.28)     | 1.226<br>(1.76)*    | 1.108<br>(1.78)*      | 1.145<br>(1.06)      |
| Log (Debt/GDP) Extra (LDEBTYx) 3/    | -1.445<br>(1.85)*   | -1.197<br>(0.70)    | -3.107<br>(3.93)*** | -3.485<br>(4.75)***   | -1.180<br>(-0.88)    |
| Constant                             | 10.597<br>(2.83)*** | 10.586<br>(1.78)*   | 64.913<br>(5.15)*** | -0.027<br>(0.07)      | 13.192<br>(2.64)***  |
| Observations                         | 441                 | 377                 | 441                 | 313                   | 441                  |
| R-squared 4/                         | 0.26                | 0.20                | 0.51                |                       | 0.12                 |
| p-value for F-test: LDEBTY+LDEBTYx=0 | 0.00                | 0.05                | 0.00                | 0.00                  |                      |
| p-value for Sargan test              |                     |                     |                     | 0.37                  | 0.58                 |

Source: Authors' calculations.

Notes:

Robust t statistics in parentheses

\* significant at 10 percent; \*\* significant at 5 percent; \*\*\* significant at 1 percent

1/ For Diff-GMM, variable is lagged total factor productivity (TFP) growth.

2/ The model estimated by Diff-GMM is  $y_t = \alpha + \beta y_{t-1} + \dots$  rather than  $y_t = \alpha + \beta y_{t-1} + \dots$  (where y is the log of TFP per worker, and  $\beta$  is estimated by the other methods. We transform the  $\beta$  to be comparable to the other methods, and a test of  $\beta=0$  is rejected at 1 percent significance levels.

3/ Coefficient on extra term,  $(D-1)Z$ , where  $Z=1$  if  $D>0$  otherwise

4/ 1-RSS/TSS reported for SYS-GMM.

Table 3. Debt Coefficients for Spline Function: Low Debt

|                      |     | Low Debt |          |        |           |         |       |
|----------------------|-----|----------|----------|--------|-----------|---------|-------|
|                      |     | OLS      | IV       | FE     | Diff-GMM  | SGMM    | Avg   |
| Growth               | DE  | 0.73     | 4.69     | 0.35   | -0.21     | 0.79    | ...   |
|                      | DY  | 0.59     | 1.08     | 1.37 * | 1.01      | 2.27 *  | 1.82  |
|                      | NE  | 0.40     | 3.31     | 0.03   | -0.21     | 0.57    | ...   |
|                      | NY  | 0.36     | 0.68     | 0.59   | 0.24      | 1.09    | ...   |
|                      | Avg | ...      | ...      | 1.37   | ...       | 2.27    | 1.82  |
| Capital growth       | DE  | -1.74 *  | -0.16    | -1.20  | -2.83 *** | -1.16   | -2.29 |
|                      | DY  | 0.42     | 2.16 **  | 0.26   | -1.07     | -0.13   | 0.55  |
|                      | NE  | -0.89    | 1.62     | -0.99  | -2.17 *** | -1.73 * | -1.95 |
|                      | NY  | 0.40     | 1.76 *** | 0.14   | -0.60     | -0.25   | 1.76  |
|                      | Avg | -1.74    | 1.96     | ...    | -2.02     | -1.73   | -0.76 |
| Human capital growth | DE  | 0.03     | 0.00     | 0.00   | -0.01     | -0.03   | ...   |
|                      | DY  | 0.02     | -0.15    | 0.10   | 0.16      | 0.21 *  | 0.21  |
|                      | NE  | -0.01    | -0.18    | -0.01  | -0.03     | -0.02   | ...   |
|                      | NY  | -0.01    | -0.11    | 0.07   | 0.10      | 0.05    | ...   |
|                      | Avg | ...      | ...      | ...    | ...       | 0.21    | 0.21  |
| TFP growth           | DE  | 1.36     | 5.00 *   | 0.75   | 0.05      | 0.38    | 5.00  |
|                      | DY  | 0.47     | 0.45     | 1.23 * | 1.11      | 1.15    | 1.17  |
|                      | NE  | 0.90     | 3.21     | 0.45   | -0.03     | 1.61 ** | 1.61  |
|                      | NY  | 0.39     | 0.21     | 0.67   | 0.24      | 0.98 *  | 0.98  |
|                      | Avg | ...      | 5.00     | 1.23   | 1.11      | 1.29    | 2.20  |

Source: Authors' calculations.

Notes:

- 1) \*: significant at 10 percent; \*\*: significant at 5 percent; \*\*\*: significant at 1 percent.
- 2) "Avg" is simple averages of the significant coefficients only (at 10 percent level).

For SGMM stars indicate significance of debt extra term only.

3) DE is Debt/exports, DY: Debt/GDP, NE: NPV of Debt/Exports, NY: NPV of Debt/GDP

4) Low debt is coefficient on debt term, D,

Table 4. Debt Coefficients for Spline Function: High Debt

|                      |     | High Debt |          |          |          |         |          | Avg   |
|----------------------|-----|-----------|----------|----------|----------|---------|----------|-------|
|                      |     | OLS       | IV       | FE       | Diff-GMM | SGMM    | IH       |       |
| Growth               | DE  | -1.24***  | -1.02**  | -1.92*** | -1.98*** | -0.36   | -1.88*** | -1.61 |
|                      | DY  | -1.38***  | -1.21*** | -2.32*** | -2.40*** | -0.42*  | -1.54*** | -1.54 |
|                      | NE  | -1.04***  | -1.23**  | -1.31**  | -1.40**  | -0.92   | -1.63*** | -1.32 |
|                      | NY  | -1.51***  | -1.06**  | -2.28*** | -2.33*** | -0.41   | -1.16*** | -1.67 |
|                      | Avg | -1.29     | -1.13    | -1.96    | -2.03    | -0.42   | -1.55    | -1.54 |
| Capital growth       | DE  | -0.85***  | -0.91*** | -0.78**  | -0.94*   | -0.77   | -0.62*** | -0.82 |
|                      | DY  | -1.52***  | -1.55*** | -1.78*** | -2.13*** | -1.62   | -1.02*** | -1.60 |
|                      | NE  | -0.82***  | -1.61*** | -0.76**  | 0.00     | -0.34   | -0.97*** | -1.04 |
|                      | NY  | -1.99***  | -2.19*** | -1.91*** | -2.29*** | -1.90*  | -1.07*** | -1.89 |
|                      | Avg | -1.29     | -1.56    | -1.31    | -1.79    | -1.90   | -0.92    | -1.38 |
| Human capital growth | DE  | -0.04     | -0.12**  | -0.05    | -0.06    | -0.10   | -0.21*** | -0.16 |
|                      | DY  | 0.01      | -0.01    | 0.01     | -0.08    | -0.12** | -0.14*** | -0.13 |
|                      | NE  | -0.05     | -0.09    | -0.09    | -0.30*** | -0.16   | -0.24*** | -0.27 |
|                      | NY  | -0.02     | -0.03    | -0.07    | -0.14*   | -0.21*  | -0.22*** | -0.19 |
|                      | Avg | ...       | -0.12    | ...      | -0.22    | -0.17   | -0.20    | -0.19 |
| TFP growth           | DE  | -1.11***  | -0.83*   | -1.70*** | -1.99*** | -0.23   | -1.76*** | -1.48 |
|                      | DY  | -0.97***  | -0.74**  | -1.88*** | -2.38*** | -0.03   | -1.39*** | -1.47 |
|                      | NE  | -0.84**   | -0.98*   | -1.04*   | -1.81*** | -0.65** | -1.59*** | -1.15 |
|                      | NY  | -0.99***  | -0.48    | -1.72*** | -2.15*** | 0.27    | -1.33*** | -1.55 |
|                      | Avg | -0.98     | -0.85    | -1.59    | -2.08    | -0.65   | -1.52    | -1.39 |

Source: Authors' calculations.

Notes:

- 1) \*: significant at 10 percent; \*\*: significant at 5 percent; \*\*\*: significant at 1 percent.
- 2) "Avg" is simple averages of the significant coefficients only (at 10 percent level). For SGMM stars indicate significance of debt extra term only.
- 3) DE is Debt/exports, DY: Debt/GDP, NE: NPV of Debt/Exports, NY: NPV of Debt/GDP.
- 4) High debt is sum of coefficient on D plus on extra term,  $(D-D^*)Z$ , where  $Z=1$  if  $D>D^*$ , 0 otherwise. Threshold  $D^*$  is 65 percent for debt to export variables (DE, NE) and 18 percent for debt to GDP (DY,NY).

Table 5. Debt Coefficients for Linear Model

|                      |     | Debt      |           |           |           | Avg   |
|----------------------|-----|-----------|-----------|-----------|-----------|-------|
|                      |     | OLS       | IV        | FE        | Diff-GMM  |       |
| Growth               | DE  | -0.91 **  | -0.43     | -1.44 *** | -1.65 *** | -1.33 |
|                      | DY  | -0.89 *** | -0.74 *   | -1.25 **  | -1.38 **  | -1.06 |
|                      | NE  | -0.71 *   | -0.28     | -1.00 **  | -1.14 **  | -0.95 |
|                      | NY  | -0.73 **  | -0.43     | -1.04 **  | -1.15 **  | -0.97 |
|                      | Avg | -0.81     | -0.74     | -1.18     | -1.33     | -1.08 |
| Capital growth       | DE  | -1.00 *** | -0.83 **  | -0.87 *** | -1.25 **  | -0.99 |
|                      | DY  | -1.03 *** | -0.79 *** | -1.19 *** | -1.82 *** | -1.21 |
|                      | NE  | -0.84 *** | -0.94 *** | -0.81 *** | -0.75     | -0.86 |
|                      | NY  | -1.00 *** | -0.76 **  | -1.02 *** | -1.70 *** | -1.12 |
|                      | Avg | -0.96     | -0.83     | -0.97     | -1.59     | -1.06 |
| Human capital growth | DE  | -0.03     | -0.11 *   | -0.04     | -0.08     | -0.11 |
|                      | DY  | 0.01      | -0.04     | 0.04      | 0.00      | ...   |
|                      | NE  | -0.05     | -0.11 *   | -0.07     | -0.17 *   | -0.14 |
|                      | NY  | -0.01     | -0.06     | -0.01     | -0.01     | ...   |
|                      | Avg | ...       | -0.11     | ...       | -0.17     | -0.13 |
| TFP growth           | DE  | -0.67 *   | -0.19     | -1.14 **  | -1.65 *** | -1.15 |
|                      | DY  | -0.60 **  | -0.49     | -0.92 *   | -1.39 **  | -0.97 |
|                      | NE  | -0.42     | -0.07     | -0.70     | -1.35 *** | -1.35 |
|                      | NY  | -0.41     | -0.22     | -0.69     | -1.09 **  | -1.09 |
|                      | Avg | -0.63     | ...       | -1.03     | -1.37     | -1.10 |

Source: Authors' calculations.

Notes:

- 1) \*: significant at 10 percent; \*\*: significant at 5 percent; \*\*\*: significant at 1 percent.
- 2) "Avg" is simple averages of the significant coefficients only (at 10 percent level).

Table 6. Reverse Causality: Simultaneous Effect of Growth on Debt

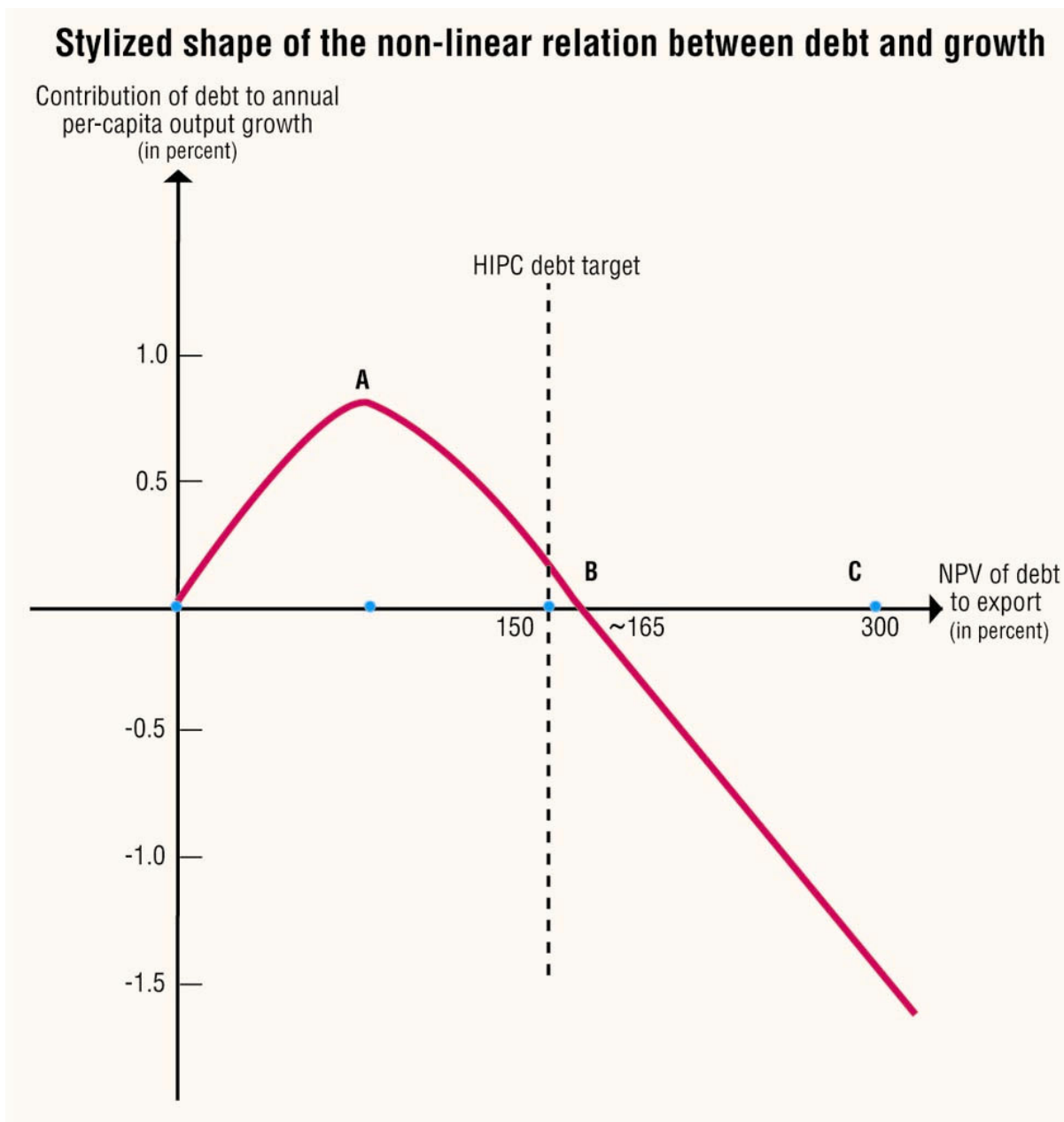
| IH Estimates of Effect of Output Growth on Debt |            |            |            |            |
|---|------------|------------|------------|------------|
|   | DE         | DY         | NE         | NY         |
| Growth  | -0.044 *** | -0.032 *** | -0.024 *** | -0.014 *** |

Source: Authors' calculations.

Notes:

1) \*\*\* corresponds to significance at 1 percent.

Figure 1.



Source: Authors' calculations.

Notes: HIPC denote highly indebted poor countries; NPV denotes net present value.

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