Some million thresholds: Nonlinearity and cross-country growth regressions*

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Abstract

This paper examines the robustness of the determinants of economic growth in cross-country regressions allowing for nonlinearity in the specification of the data generating process. The nonlinearity is modelled as regime-dependent parameter heterogeneity, where the regime is determined by the level of the explanatory variable whose robustness we aim to measure. Using a generalization of the procedure in Sala-i-Martin (*American Economic Review, 1997*), strong evidence of nonlinearity is found for practically all of the variables that are robustly correlated to growth in the linear setting, including those variables which are usually included in most cross-county growth regressions.

Keywords: Growth regressions, robustness, nonlinearity, threshold models.

JEL Classification: C52, O50

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1 Introduction

Since the influential contributions of Kormendi and Meguire (1985) and Barro (1991), the use of cross-country regressions in order to identify variables that are robustly (partially) correlated to growth of GDP per-capita has become a fundamental part of the empirical agenda in economic growth theory.[1]

The fairly general setting provided by the Solow-Swan model of economic growth leaves the empirical researcher with a great deal of freedom in modelling the relatively abstract concept of *technological progress*.The ever-growing literature on empirics of economic growth has used an incredibly vast amount of economic, social and political variables with the aim of finding robust determinants of GDP per-capita growth. Durlauf and Quah (1999), for instance, name more than eighty variables that have been included at least once in a cross-country growth regression.

The discussion on robustness and model selection on cross-country growth regressions gained momentum after the seminal contribution of Levine and Renelt (1992).[2] Levine and Renelt (1992) applied Leamer (1983)'s extreme bounds analysis to check the robustness of the determinants of long-run growth to changes in the information set that the researcher conditions upon when obtaining estimates of the partial correlation. The analysis concluded that practically no variable among those used by Kormendi and Meguire (1985) and Barro (1991) is robustly correlated with average GDP per capita growth.

Sala-i-Martin (1997a, 1997b), however, considers that the robustness test implied by extreme bounds analysis is too strong for any variable to pass it in the framework of empirical growth research, and proposes analyzing the entire distribution of estimates of the partial correlation of a given variable and long-run growth. Adopting such an approach, Sala-i-Martin (1997a, 1997b) attaches a "confidence level" (in terms of the probability mass lying on one side of zero in the empirical distribution of the estimate of the partial correlation) to each variable, and interprets those variables with a confidence

[1] See Durlauf and Quah (1999) and Temple (1999) for extensive surveys on the empirics of economic growth.

[2] For an excelent survey and literature review on the subject of model uncertainty in cross-country growth regressions, see Temple (2000).

level of 95% or more as robustly correlated with long-run growth. Using this method, the conclusion is that there exists a considerable number of economic, political and demographic variables that are actually (partially) correlated to growth in a robust fashion.

Alternatively, Bayesian methods have been used by Doppelhofer, Miller and Sala-i-Martin (2000) and Fernández, Ley and Steel (2001) to assess the robustness of explanatory variables in cross-country growth regressions. While Fernández, Ley and Steel (2001) use Bayesian Model Averaging techniques to assess model uncertainty in cross-country regressions, Doppelhofer, Miller and Sala-i-Martin (2000) introduce an alternative approach, Bayesian Averaging of Classical Estimates, that builds upon Bayesian Model Averaging without needing to specify prior distributions for all parameters in the econometric specification. In both cases the results are in line with Sala-i-Martin (1997a, 1997b), indicating that there are some variables which are robust explanatory factors for economic growth.

This paper studies the robustness of explanatory variables in cross-country growth regressions allowing for level-dependent parameter heterogeneity, which implies that the partial correlation between economic growth and the variable of interest could be different for low and high values of the explanatory variable. Using a methodology based on the threshold estimation and testing methodology (see e.g. Hansen (1996), or Hansen (2000)), this framework allows to draw conclusions on two different issues. On the one hand, given that the nonlinearity can be tested using the method put forward by Hansen (1996), it sheds a light on the evidence of nonlinearities in cross-country growth regressions. On the other hand, it offers a generalization of the results in Sala-i-Martin (1997a, 1997b), as the econometric exercise allows for testing the robustness of the determinants of growth in subsamples of the data once that the linearity hypothesis has been rejected. The results provide overwhelming evidence for nonlinearity in the relationship between the explanatory variables that have usually been found robust in cross-country studies and economic growth. Furthermore, the set of robust determinants of long-run growth is enhanced by identifying variables that appear robustly correlated with GDP per capita growth in a subsample of the original dataset for nonlinear specifications that are supported by the data.

Several studies have provided evidence on parameter heterogeneity and

multiple regimes in cross country growth regressions (see e.g. Durlauf and Johnson (1995), Durlauf, Kourtellos and Minkin (2001), Masanjala and Papageorgiou (2002) or Papageorgiou (2002)), and different theoretical interpretations have been given to the finding. Although this paper will abstract from systematically interpreting the results under the light of economic theory, there exist theoretical models that deliver multiple steady states (e.g. Azariadis and Drazen (1990)) and explicitly model nonlinearities in the aggregate production function (e.g. Masanjala and Papageorgiou (2002)). This streams of literature can convincingly explain the existence of nonlinearities (in the form of parameter heterogeneity) in cross-country regressions.

The paper is organized as follows. Section two presents the robustness exercise, which is a generalization of the approach in Sala-i-Martin (1997a, 1997b) allowing for piecewise-linearity in the specification of the growth equation. Section three reports the results of the robustness analysis, and these are commented in section four. Section five concludes.

2 The econometric setting

The robustness experiment will be carried out using a similar setting and similar data as Sala-i-Martin (1997a, 1997b). The dataset used in this study contains information on average GDP per capita growth and economic, political and demographic variables for 138 countries in the period 1960-1990.[3] A typical, linear specification of a cross-country growth regression in the robustness exercise is given by

$$\Delta y_i = \beta_0 + \sum_{j=1}^{f} \beta_j x_{j,i} + \gamma z_i + \sum_{j=1}^{m} \phi_j v_{j,i} + \epsilon_i, \tag{1}$$

where Δy is the average growth rate of GDP per-capita in the period 1960-90, $x_1, \ldots, x_f$ are fixed variables that appear in all regressions in the experiment, z is the variable of interest, whose robustness we are interested in measuring, $v_1, \ldots, v_m$ are variables chosen from the pool of remaining variables, $X \backslash \{x_1, \ldots, x_f, z\}$, and ϵ_i is assumed to be white noise with constant variance σ_ϵ^2.

[3]For the original source and information on the variables, see the appendix.

The alternative, nonlinear specification is given by

$$\Delta y_i = \beta_0^k + \sum_{j=1}^{f} \beta_j^k x_{j,i} + \gamma^k z_i + \sum_{j=1}^{m} \phi_j^k v_{j,i} + \epsilon_i^k, \tag{2}$$

that is, the specification is piecewise-linear, and the regime k is postulated to depend upon the level of the variable whose robustness we are testing,[4]

$$k = \begin{cases} 1 & \text{if } z_i \leq \mu, \\ 2 & \text{if } z_i > \mu. \end{cases} \tag{3}$$

In a given replication of the experiment, when evaluating the robustness and potential nonlinearity of variable z, equation (1) and its nonlinear counterpart, (2)-(3) are estimated for a given combination of variables $\{v_1, \ldots, v_m\}$. The estimator of μ in (2)-(3) is given by

$$\hat{\mu} = \text{argmin}_z \{\sum \hat{\epsilon}(z)^2\},$$

that is, the value of z that minimizes the sum of squared residuals in the nonlinear regression (2)-(3). The estimator $\hat{\mu}$ is sought among the actually realized values of z, after trimming the extremes of the distribution for obvious identification reasons.[5] Once an estimator for μ has been found, (2)-(3) can be estimated by OLS in a straightforward manner.

The problem of testing for threshold-nonlinearity of the type presented above has been widely discussed recently in the econometric literature. The intuition of the test for linearity is extremely simple: just test the null hypothesis of parameter equality across regimes against the alternative that at least one of the parameters differs between regime 1 and regime 2. The technical difficulty is posed by the fact that, given that the parameter μ is only identified under the alternative hypothesis of nonlinearity, standard

[4]The analysis carried out will limit the number of regimes to two. Allowing for more regimes implies repeating the exercise for the subsamples in which the threshold divides the full sample. Given the number of observations in the dataset used and the fact that finding a single significant threshold - in the sense of rejection of the null hypothesis of linearity - already implies evidence of nonlinearity, the analysis concentrates on piecewise linear models with a single kink.

[5]For the properties of this estimator, see e.g. Chan (1993).

probability distributions cannot be used in order to evaluate the corresponding likelihood ratio test statistic. Hansen (1996, 2000) proposes a bootstrap procedure for testing the null of linearity against piecewise-linearity of the threshold type. The procedure can be summarized as follows: using the estimated linear relationship (1), artificial data on the dependent variable (real GDP per-capita growth) is simulated and both a linear and a piecewise linear model with the estimated threshold are fitted to the simulated sample. The corresponding likelihood ratio test statistic for the test of parameter equality across regimes is computed and the procedure is repeated a large number of times, leading to an approximate distribution of the test statistic under the null of linearity. The percentage of replicated test statistics that exceed the original value of the test statistic computed with real data is thus the p-value of the linearity test.

The threshold estimation and linearity testing procedure described above will be used in the modelling exercise in order to quantify the significance of the potential deviation from linearity of the data given the postulated linear relationship (1). The exercise is carried out in the following steps: For a given variable of interest, z, and a set $\{v_1, \ldots, v_m\}$ from the pool of remaining variables, specification (1) is estimated, as well as the nonlinear specification (2)-(3). The estimated parameters corresponding to variable z in the linear specification ($\hat{\gamma}$) and in the nonlinear specification ($\hat{\gamma}^i, i = 1, 2$) are stored, together with their estimated variances ($\hat{\sigma}^2_\gamma, \hat{\sigma}^2_{\gamma^1}$ and $\hat{\sigma}^2_{\gamma^2}$, respectively). For this specification of the cross-country growth regression the bootstrap testing procedure for linearity is carried out, and the resulting p-value is stored. The procedure is then repeated for another combination of $\{v_1, \ldots, v_m\}$ variables, until all possible combinations are tried out. The resulting (average) estimate of γ is the average value of $\hat{\gamma}$ across all replications of the experiment, and the (average) estimate of σ^2_γ is the average value of $\hat{\sigma}^2_\gamma$.

As in Sala-i-Martin (1997a, 1997b), if we assume that the average estimator of γ is normally distributed, the significance level attached to variable z is then the probability mass to the right (left) of zero in a normal distribution centered around the average estimate of γ with variance equal to the average variance computed. The same applies for the regime-dependent estimates.[6]

[6]There are no significant qualitative differences in the conclusions if the empirical distribution of parameter estimates is used instead of the normal distribution, so the results

3 Nonlinearity and cross-country regressions

In order to make the results comparable to those of Sala-i-Martin (1997a, 1997b), the same fixed variables as in that study were used in each specification, namely "Life expectancy in 1960", "Primary school enrollment rate in 1960" and "Initial GDP per-capita in 1960".[7] Due to the computational load involved in the threshold estimation and testing procedure of the experiment, the number of additional variables in the cross-country regressions (the vs in the specifications above) was set to two, and 500 replications were used in order to compute the bootstrap p-value for each specification.[8] For the estimation of the threshold parameter, μ, 25% of the empirical distribution of z was trimmed in each extreme, so that the search was done in the central 50% mass of the distribution of z in each round. Dummy variables and variables whose values are not spread enough across countries as to lead to statistically meaningful results were excluded from the pool of z variables, but all were included as additional variables in all regressions. The total number of tested variables is 48, including the three fixed variables. When a fixed variable was analyzed, the other two were kept as fixed in all regressions.

In Table 1 the results based on the average (non-weighted) estimators are presented, while Table 2 contains the results for the weighted estimators, where each regression is weighted using the likelihood of the estimated model over the sum of the likelihoods of all estimated cross-country regressions for the variable studied. The weighting scheme, similar to the one used in Sala-i-Martin (1997a, 1997b), aims at giving more importance to those models that fit the data better in terms of sum of squared residuals. Doppelhofer, Miller and Sala-i-Martin (2000) show that this weighting scheme results as a

presented are exclusively those concerning the normal distribution.

[7] In order to avoid the potential endogeneity problem attached to the use of investment as an explanatory variable in cross-country growth regressions, given the fact that the estimation will be carried out using OLS, the specification without investment as a fixed variable was used.

[8] The average number of cross-country regressions estimated for each variable is around 1550. For each one of these cross country regresions 500 bootstrap replications were computed, each one involving the estimation of a linear and a nonlinear specification. This implies that approximately 1,550,000 estimated regressions are hidden behind each row of Table 1 and 2. As 48 variables were analyzed, around 74,400,000 cross-country regressions were actually needed for the results.

limiting case of Bayesian model averaging with diffuse priors

After the name of the variable studied (see the appendix for the description and source of each variable), the first three columns of Table 1 and 2 show the average estimate of the corresponding parameter ($\hat{\gamma}$), the standard deviation (square root of the average estimate of the variance of $\hat{\gamma}$) of the estimate ($\hat{\sigma}_\gamma$) and the corresponding probability mass to the left of zero (right of zero if $\hat{\gamma} < 0$) in a normal distribution centered around $\hat{\gamma}$ with variance $\hat{\sigma}^2_\gamma$. The following six columns report the same statistics for the "low regime" ($z_i \leq \hat{\mu}$) and "high regime" ($z_i > \hat{\mu}$) estimates, $\hat{\gamma}_1$ and $\hat{\gamma}_2$. The average estimated threshold is reported in the tenth column.[9] The average p-value in the linarity test and the proportion of cross country regressions in which linearity was rejected at 5% or less appear in column eleven and twelve, respectively. The variables are ordered according to their significance level in the linear specification, and a horizontal line divides the variables which are significant at a 5% level (in the linear specification) from the rest of the variables.

Despite the fact that this study uses one variable less in the set of explanatory variables for GDP per-capita growth, the variables that appear robustly related to growth in the linear setting are essentially the same as in Sala-i-Martin (1997a, 1997b). The only exceptions are "Revolutions and coups" and "Fraction of GDP in Mining", which are 5%-significant in the weighted results of Sala-i-Martin (1997a, 1997b), but do not achieve such significance level in the analysis performed with two additional variables instead of three. These are precisely the two variables for which Sala-i-Martin (1997a, 1997b) reports substantially different significance levels depending on whether the likelihood-weighting scheme is used or not, which highlights the fact that their robustness could be due to the high weight of some specification for the case with three additional variables as regressors.

The results concerning the average p-value in the linearity tests are considerably striking: for the weighted case 15 out of the 19 variables that appear robust in the linear specification have an average p-value lower than 5%, and all except for one ("Degree of Capitalism") reject the null of linearity at 10%

[9]Note that the threshold estimate is *not* asymptotically normally distributed (see Chan, 1993). Results on the variance of the estimates of μ in the exercise are available from the author upon request.

using the average p-value. Furthermore, 11 out of the 19 variables reject linearity at a 5% significance level in more than 80% of the cross-country regressions estimated. For the non-weighted results, also all robust variables in the linear specification except for "Degree of Capitalism" have an average p-value lower than 10%, and 12 of them have an average p-value smaller than 5%. Of the remaining variables, there are 7 in the non-weighted setting and 15 in the weighted case with an average p-value smaller than 5% in the linearity test.

Apart from the variables that appear robust in the linear exercise there are certain variables which, not being labelled as "robust" in the linear setting, have a p-value smaller than 5% in the linearity test and appear robust in at least one of the two regimes. For the weighted setting there are 5 such variables: "Black market premium", "Free trade openness", "Defense spending share", "Urbanization Rate in 1960" and "Higher education enrollment in 1960". For the unweighted scheme, none of the variables that are not robust in the linear specification show (95%) robustness in the nonlinear setting, although two of them ("Ethnolinguistic fractionalization" and "Governmental education spending share") are 90% robust in at least one of the two regimes.

4 Multiple regimes and the determinants of economic growth

This section reexamines the nature of the relationship between economic growth and the set of robust determinants when allowing for nonlinearity.[10] Table 3 summarizes the results by dividing those variables which cause significant nonlinearity into two broad groups. Table 3 summarizes the variables that reject linearity using the average p-value but whose parameters in the upper and lower regime are either not significantly different from zero (in both regimes), or not significantly different from each other. This type of nonlinearity is labelled "conditioning nonlinearity", and implies that the level of the variable causing the nonlinearity could be correlated to the parameters corresponding to other variables in the cross-country regression. Table 4 presents the variables presenting level-dependent parameter heterogeneity

[10]In order to allow comparisons in a straightforward manner, the grouping resembles that of Sala-i-Martin (1997a, 1997b).

(those variables where linearity is rejected using the average p-value, and the parameters of the two regimes are significantly different from each other, with at least one of them robust) .[11]

Fixed variables and initial values

There is strong evidence of nonlinearity induced by the "Initial GDP per-capita" variable in the weighted scheme, although the corresponding (robust) parameters are not significantly unequal across regimes. The nonlinearity induced by the initial level of development seems to affect, thus, the parameters corresponding to other variables in the postulated cross-country regressions. A similar result emerges for all human capital variables measured in the initial period ("Primary school enrollment in 1960", "Average years of primary school in 1960", "Secondary school enrollment in 1960", "Average years of secondary school in 1960" "Higher education enrollment in 1960", "Average years of higher education in 1960" "Average years of schooling in 1960" and "Average years of schooling $\times$ Initial GDP per-capita") and for "Life Expectancy in 1960" and "Urban population in 1960". The results for the variable "Higher education enrollment in 1960" in the weighted scheme give an interesting insight to the extent to which results concerning the value of the parameter associated to an exogenous variable in a cross-country growth regression may depend upon the level of the variable in consideration. In the linear setting the average value of the parameter associated to "Higher education enrollment in 1960" is, in absolute value, more than four thousand times smaller than the "low regime" parameter in the nonlinear alternative. Furthermore, this parameter is highly robust in the nonlinear specification (for the low regime), but not robust in the linear setting. Initial conditions seem thus to play a highly important role in determining the appropriate statistical model describing GDP per-capita growth. Evidence concerning nonlinearities in the relationship between initial GDP levels and average growth can be found in Durlauf and Johnson (1995), Masanjala and Papageorgiou (2002) and Hansen (2000). The initial literacy rate (potentially highly correlated with our variable "Primary school enrollment in 1960") also appears as an adequate threshold variable in Hansen (2000).

[11]The results for most of the variables coincide for the weighted and unweighted scheme. Table 3 and 4 present the evidence for the weighted scheme for those variables for the cases where both approaches differ.

Political variables

The variable "Political Rights" (notice that higher values of this variable imply less political rights) appears robustly (negatively) correlated to growth exclusively in the upper regime - that is, for countries with relatively less political rights -, and the absolute value of the estimated parameter in this case is more than twice the value of the estimate in the linear setting.[12] On the other hand, the "Rule of Law" variable appears robust only for the lower regime when the weighting scheme is used, while the non-weighted scheme renders the parameters in both regimes not significantly different. Given the strong evidence of nonlinearity for this variable, the result concerning the unweighted setting seems to point towards the fact that the level-dependent parameter heterogeneity caused by this political variable could have an effect in the interaction of other variables with economic growth.[13] A similar result emerges in the case of "Civil liberties". While the extent of development of political rights seems to be able to partly explain (robustly) cross-country differences in growth rates of GDP per-capita only for the subgroup of countries with lower levels of democracy, the overall level of political development seems to play a fundamental role in the effect that other variables have in economic growth.

Religious variables

The positive partial correlation often found between rates of economic growth and the fraction of population of muslim religion appears robust only for countries with a relatively high proportion of muslim population (the average estimated threshold is around 10%), while the level of catholic population seems to have an effect on the effect of other variables on growth (linearity is strongly rejected, but the corresponding parameter is not robust in any of the two regimes). The proportion of protestants, however, appears robustly and linearly correlated to growth performance.

[12] Barro (1996, 1997) reports also evidence of this type of nonlinearity.

[13] Temple (2000) comments on the potential correlation between measures of political instability and other parameters in cross-country growth regressions. This result seems to show evidence in this direction.

Market distortion variables

The negative partial correlation between the standard deviation of the black market premium and economic growth appears robust only for the upper regime. Low levels of variation in the black market premium do not present a robust correlation with growth. Exchange rate distorsions, however, seem to induce parameter heterogeneity in the relationship of other variables with growth. The (weighted) results using the nonlinear specification find also a robust, level-dependent relationship between the black market premium level and economic growth: while for low levels of black market premium there is a positive partial correlation, it reverts its effect in the upper regime. The average weighted threshold estimate divides the sample in two samples with remarkable different sizes, with only 29 countries in the upper regime.

Investment variables

The evidence of nonlinearity when using both equipment and non-equipment investment as a threshold variable is overwhelming: practically all regressions performed rejected the null of linearity at a 5% significance level. The nonlinearity induced by equipment investment levels, however, seems to affect other parameters in the specification, while the robust positive partial correlation between growth and non-equipment investment found for the lower regime turns negative (and 90% robust) in the upper regime in the weighted scheme. For the unweighted results, the parameter corresponding to the upper regime is not significantly different from zero.

Primary sector variables

The negative parameter corresponding to the variable "Fraction of primary products in total exports" is substantially higher in absolute value in the upper regime, giving evidence of an overproportionally worse average growth performance, ceteris paribus, of countries with a higher proportion of primary exports.

Trade-related variables

The results concerning the relationship between openness and growth indicate that the positive effects of trade on growth are only visible after a

certain level of openness is reached. Both for the variables "Number of years open economy" and "Free trade openness", the positive robust correlation is only present in the upper regime. The variable "Tariff restrictions" seems to induce nonlinearity as well in other parameters of the cross-country regressions. Recently Papageorgiou (2002), using similar methods to the ones in this study, finds evidence concerning the fact that sets of countries with different openness levels tend to differ in the statistical model relating economic growth to other economic variables.

Ethnolinguistic variables

There is evidence of parameter heterogeneity induced by the level of ethnolinguistic fractionalization, although the variable itself does not appear robustly related to economic growth in any of the two estimated regimes.

Inflation-related variables

The fact that the partial correlation between economic growth and inflation level could be of a nonlinear nature in the sense that it depends on the level of inflation has been already suggested by Barro (1995) and Khan and Senhadji (2001). There is no evidence in the data used in this study concerning such a form of nonlinearity, but the standard deviation of the inflation rate does seem to induce different statistical models as a threshold variable.

Public spending variables

The results present evidence concerning the fact that the level of government consumption, as measured by the variable "Public consumption share" induces parameter heterogeneity through its interaction with other variables. A similar conclusion can be drawn from the variable "Government education spending share". The results for the variable "Defense spending as % of GDP" are relatively striking: in the unweighted setting, the linear specification cannot be rejected at the 5% significance level using the average p-value, and the variable is very close to (95%) robustness. The (average) parameter of "Defense spending as % of GDP" in the linear, unweighted framework is positive, indicating that higher levels of defense expenditure tend to be associated to better growth performance. However, in the unweighted setting

the results are very different: linearity can be rejected and a robust negative relationship with growth appears for low levels of defense expenditure (with respect to the threshold). The absolute value of the parameter is more than eighty times higher than the average estimate in the linear setting.

5 Conclusions

This paper performed a robustness analysis of the determinants of long-run economic growth allowing for nonlinearity in the relationship between the explanatory variables and the average growth rate of GDP per capita. Using threshold modelling techniques, the results present evidence of nonlinearity in most of the variables that appear robustly correlated to economic growth in a linear setting. The results enhance and complement previous studies which, using a more theory-driven modelling strategy, also find evidence of parameter heterogeneity in cross-country regressions (Durlauf and Johnson (1995), Papageorgiou (2002) or Masanjala and Papageorgiou (2002), just to name a few). The overwhelming evidence concerning parameter heterogeneity in cross-country growth regressions presented in this paper suggests that theoretical models that incorporate a source of nonlinearity will be able to replicate better the empirical facts of the process of economic growth in the last decades.

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Appendix: Data sources

ABSLATIT: Absolute Lattitude. Barro (1996).
AREA: Total area of the country. Barro and Lee (1993).
BMP1: Black Market Premium [log (1+Black Market Premium)].Barro and Lee (1993).
BMS6087: Standard Deviation of the Black Market Premium, 1960-87. Levine and Renelt (1992).
CATH Fraction of Catholic population. Barro (1996).
CIVLIBB: Civil Liberties Index. Knack and Keefer (1995).
DEMOC65: Index of Democracy (democratic freedom), 1965. Knack and Keefer (1995).
DPOP6090: Growth Rate of Population 1960-90. Barro and Lee (1993).
ECORG: Degree of Capitalism. Hall and Jones (1996).
EQINV: Equipment Investment (% GDP). Delong and Summers (1991).
FRAC: Ethnolinguistic Fractionalization (probability that two randomly chosen people in a country do not speak the same language). Easterly and Levine (1997).
FREEOP: Free Trade Openness. Barro and Lee (1993).
FREETAR: Degree of tariff barriers. Barro and Lee (1993).
GDC6089: Growth of Domestic Credit 1960-89. Levine and Renelt (1992).
GDE1: Defense Spending (% GDP). Barro and Lee (1993).
GDPSH60: log(GDP per capita 1960). Barro and Lee (1993).
GEEREC1: Government Education Spending (% GDP). Barro and Lee (1993).
GGCFD3: Public Investment Share (% of GDP). Barro and Lee (1993).
GVXDXE52: Public Consumption Share (% GDP). Barro and Lee (1993).
H60: Higher education enrollment, 1960. Barro and Lee (1993).
HYR60: Average number of years in higher education for total population, 1960. Barro and Lee (1993) .
HUMAN60: Average Years of Schooling, 1960. Barro and Lee (1993).
HUMANYL:Product of average years of schooling and GDP per capita in 1960. Barro and Lee (1993).
LFORCE60: Size of the labor force, 1960. Barro and Lee (1993)
LIFEEO60: Life Expectancy, 1960. Barro and Lee (1993).
LLY1: Liquid Liabilities to GDP. King and Levine (1993).
MINING: Fraction of GDP in Mining. Hall and Jones (1996).
MUSLIM: Fraction of Muslim population. Barro (1996).

NONEQINV: Non-Equipment Investment (% GDP). Delong and Summers (1991).
OTHFRAC: Fraction of population able to speak a foreign language. Sala-i-Martin (1997a).
P60: Primary School Enrollment, 1960. Barro and Lee (1993).
PI6089: Average Inflation Rate, 1960-89. Levine and Renelt (1992).
PINSTAB2: Political Instability index. Knack and Keefer (1995).
PRIEXP70: Primary Exports (% total exports), 1970. Sachs and Warner (1996).
PRIGHTSB: Political Rights index. Barro (1996).
PROT: Fraction of Protestant population. Barro (1996).
PYR60: Average years of primary school, 1960. Barro and Lee (1993).
RERD: Exchange Rate Distortions. Levine and Renelt (1992).
REVCOUP: Number of revolutions and coups. Barro and Lee (1993).
RULELAW: Rule of Law. Barro (1996).
S60: Secondary School Enrollment, 1960. Barro and Lee (1993).
STDC6089: Standard Deviation of Domestic Credit, 1960-89. King and Levine (1993).
STPI6089: Standard Deviation of Inflation, 1960-89. Levine and Renelt (1992).
SYR60: Average Years of Secondary School, 1960. Barro and Lee (1993).
TOT1: Terms of Trade growth, 1960-89. Barro and Lee (1993).
URB60: Fraction of population living in cities. Barro and Lee (1993).
WORK60L: Ratio of workers to total population. Barro and Lee (1993).
YRSOPEN: Number of Years Open Economy. Sachs and Warner (1996).

	Var Name	$\hat{\gamma}$	$\hat{\sigma}_\gamma$	$P(\hat{\gamma})$	$\hat{\gamma}^1$	$\hat{\sigma}_{\gamma 1}$	$P(\hat{\gamma}^1)$	$\hat{\gamma}^2$	$\hat{\sigma}_{\gamma 2}$	$P(\hat{\gamma}^2)$	$\hat{\mu}$	p-value	% nonlinear
1	YrsOpen	0.024400	0.004980	1.000000	0.005400	0.044322	0.548486	0.023026	0.012625	0.965907	0.368680	0.009717	0.982318
2	GDPSH60	-0.014815	0.003044	0.999999	-0.011866	0.007940	0.932474	-0.017416	0.004305	0.999974	7.038771	0.060643	0.643827
3	EQINV	0.264567	0.054780	0.999999	0.542330	0.428298	0.897287	0.153767	0.071077	0.984744	0.032157	0.006119	0.993485
4	LIFEE060	0.001215	0.000308	0.999960	0.000469	0.001179	0.654455	0.001628	0.000553	0.998372	47.841396	0.038849	0.747910
5	RULELAW	0.022783	0.006063	0.999914	0.068626	0.042732	0.945859	0.029358	0.018663	0.942151	0.447039	0.026194	0.862581
6	MUSLIM	0.015603	0.004734	0.999510	-0.156632	0.113318	0.916550	0.025333	0.006969	0.999861	0.099980	0.029649	0.873531
7	PRIEXP70	-0.020326	0.006359	0.999304	-0.019598	0.008316	0.990779	-0.087928	0.059626	0.929847	0.865271	0.012912	0.944236
8	CATH	-0.011627	0.004002	0.998164	-0.085755	0.098044	0.809120	0.008386	0.009458	0.812366	0.215366	0.019123	0.883934
9	NONEQINV	0.079971	0.031348	0.994630	0.210632	0.065987	0.999294	-0.062864	0.057785	0.861680	0.152326	0.001156	0.999373
10	lly1	0.026187	0.010770	0.992479	-0.037831	0.063493	0.724359	0.016304	0.012865	0.897477	0.229474	0.059255	0.611039
11	ABSLATIT	0.000284	0.000120	0.991084	-0.000289	0.000423	0.753006	0.000067	0.000241	0.608877	20.456723	0.010636	0.950681
12	RERD	-0.000087	0.000040	0.985588	-0.000057	0.000104	0.708269	0.000015	0.000084	0.571793	130.037940	0.060738	0.628839
13	PROT	-0.013333	0.006654	0.977457	-0.074952	0.265630	0.611092	0.000998	0.013004	0.530572	0.181206	0.066938	0.584433
14	EcOrg	0.001980	0.001061	0.969019	0.002456	0.002090	0.880021	-0.001451	0.004600	0.623784	3.040000	0.532084	0.049624
15	P60	0.016931	0.009251	0.966378	-0.024299	0.055014	0.670640	0.031738	0.082882	0.649113	0.689734	0.080679	0.573155
16	BMS6087	-0.000029	0.000016	0.964035	-0.000081	0.000484	0.566431	-0.000017	0.000018	0.833133	26.777134	0.005831	0.981818
17	gvxdxe52	-0.044139	0.024625	0.963469	-0.090259	0.092474	0.835478	-0.005921	0.045183	0.552127	0.089077	0.024157	0.865493
18	prightsb	-0.002163	0.001281	0.954264	-0.001719	0.002123	0.790883	-0.006157	0.004552	0.911904	4.789143	0.010629	0.960448
19	gde1	0.091517	0.058842	0.940062	-0.514397	0.455693	0.870514	0.063221	0.077856	0.791612	0.021556	0.079225	0.442417
20	OthFrac	0.005052	0.003813	0.907388	0.368404	3.248481	0.545147	0.012436	0.016598	0.773134	0.392026	0.123283	0.366224
21	DEMOC65	-0.008609	0.006836	0.896050	-0.015890	0.020010	0.786428	-0.023249	0.028252	0.794716	0.590661	0.193354	0.159248
22	freeop	0.031082	0.026306	0.881308	0.086773	0.089583	0.833637	0.033691	0.053916	0.733977	0.213125	0.280037	0.122642
23	civlibb	-0.001690	0.001450	0.878123	-0.002439	0.002251	0.860717	-0.003343	0.005519	0.727625	4.861718	0.023833	0.854363
24	syr60	0.003534	0.003523	0.842080	0.007232	0.064899	0.544362	0.004811	0.004723	0.845788	0.425151	0.093423	0.443014
25	work60l	-0.006511	0.006859	0.828757	0.007152	0.025857	0.608959	0.017127	0.024300	0.759534	-0.950557	0.064899	0.616071
26	pyr60	-0.001838	0.001943	0.827899	0.000344	0.010296	0.513339	-0.000770	0.002277	0.632352	2.003353	0.107384	0.399619
27	PI6089	-0.000027	0.000032	0.804046	0.000240	0.001771	0.554000	-0.000022	0.000035	0.734303	9.136752	0.061530	0.609079
28	STDC6089	-0.000022	0.000027	0.795452	-0.000221	0.000680	0.627158	-0.000010	0.000037	0.609682	21.493569	0.154310	0.288945
29	s60	0.010918	0.013646	0.788178	-0.045425	0.244916	0.573571	0.011074	0.013921	0.786836	0.103319	0.041316	0.773196
30	Mining	0.016699	0.021321	0.783251	0.359393	0.918924	0.652139	0.034295	0.028374	0.886605	0.030898	0.268168	0.111529
31	lforce60	0.000000	0.000000	0.778313	-0.000017	0.000013	0.910086	0.000000	0.000000	0.689430	1386.097000	0.135344	0.243719
32	URB60	0.007622	0.010574	0.764507	-0.025234	0.050806	0.690293	0.010102	0.013334	0.775656	0.277590	0.050282	0.643275
33	FRAC	-0.003449	0.005771	0.724951	-0.029074	0.033679	0.806002	-0.047050	0.029917	0.942106	0.550996	0.043651	0.723377
34	freetar	-0.047253	0.080920	0.720371	-0.550251	0.490072	0.869238	0.080054	0.108565	0.769555	0.022299	0.014102	0.932127
35	bmp1	-0.002977	0.005158	0.718070	0.218108	0.696938	0.622841	-0.007864	0.006945	0.871253	0.091704	0.116099	0.333960
36	ggcfd3	0.021771	0.038385	0.714702	0.018624	0.197065	0.537647	-0.086735	0.062697	0.916729	0.048798	0.057110	0.572146
37	geerec1	0.085193	0.161783	0.700760	-0.433350	0.303208	0.923529	-0.763580	0.519299	0.929274	0.028537	0.025266	0.865747
38	revcoup	-0.003567	0.006877	0.698006	0.016557	0.089240	0.573594	-0.005657	0.013012	0.668143	0.215280	0.213264	0.157252
39	humanyl	-0.000112	0.000263	0.664463	0.000086	0.001079	0.531727	-0.000159	0.000556	0.612229	20.499262	0.064997	0.582569
40	hyr60	0.007723	0.018754	0.659752	-0.255192	0.496187	0.696481	0.005839	0.019235	0.619263	0.024140	0.091812	0.470514
41	pinstab2	0.003198	0.014265	0.588678	-0.237139	0.845914	0.610390	-0.005624	0.024700	0.590049	0.080618	0.202148	0.134027
42	GDC6089	0.000014	0.000078	0.570486	0.000322	0.000390	0.795351	-0.000092	0.000119	0.780192	19.353722	0.166970	0.289607
43	h60	0.007277	0.043817	0.565949	-2.098229	2.706799	0.780880	0.009375	0.043175	0.585950	0.008861	0.010321	0.949028
44	STPI6089	-0.000001	0.000008	0.551987	0.000083	0.001405	0.523537	-0.000001	0.000009	0.531683	8.474981	0.009453	0.964924
45	tot1	0.005885	0.051237	0.545722	0.080948	0.109234	0.770667	-0.080806	0.127306	0.737202	-0.003464	0.198821	0.139185
46	area	0.000000	0.000001	0.541606	-0.000077	0.000090	0.802030	0.000000	0.000001	0.576331	281.254670	0.301354	0.068096
47	dpop6090	-0.017855	0.242260	0.529376	0.113372	0.529629	0.584749	-0.754569	0.670930	0.869634	0.022652	0.061384	0.580442
48	human60	-0.000152	0.002389	0.525300	0.003841	0.008647	0.671556	0.001345	0.005119	0.603635	2.784964	0.069309	0.546649

Table 1: Non-weighted results

	Var Name	$\hat{\gamma}$	$\hat{\sigma}_\gamma$	$P(\hat{\gamma})$	$\hat{\gamma}^1$	$\hat{\sigma}_{\gamma 1}$	$P(\hat{\gamma}^1)$	$\hat{\gamma}^2$	$\hat{\sigma}_{\gamma 2}$	$P(\hat{\gamma}^2)$	$\hat{\mu}$	p-value	% nonlinear
1	GDPSH60	-0.014954	0.002406	1.000000	-0.015752	0.003554	0.999995	-0.018714	0.003805	1.000000	7.407232	0.000054	0.643827
2	EQINV	0.238946	0.044724	1.000000	0.164736	0.100921	0.948694	0.096105	0.066506	0.925780	0.048783	0.000207	0.993485
3	YrsOpen	0.021657	0.004454	0.999999	0.016003	0.016316	0.836656	0.024130	0.010872	0.986771	0.346537	0.001660	0.982318
4	RULELAW	0.023633	0.004960	0.999999	0.019857	0.007233	0.996976	0.029407	0.037976	0.780636	0.783687	0.010838	0.862581
5	LIFEE060	0.000876	0.000245	0.999826	0.000542	0.000519	0.851991	0.001240	0.000974	0.898555	55.732646	0.004986	0.747910
6	PRIEXP70	-0.017981	0.005214	0.999718	-0.017577	0.006867	0.994762	-0.084922	0.035556	0.991540	0.843347	0.000010	0.944236
7	MUSLIM	0.015603	0.004734	0.999510	-0.156632	0.113318	0.916550	0.025333	0.006969	0.999861	0.099980	0.029649	0.873531
8	civlibb	-0.003281	0.001053	0.999081	-0.002512	0.001932	0.903248	-0.002357	0.002589	0.818604	4.590117	0.000483	0.854363
9	CATH	-0.011627	0.004002	0.998164	-0.085755	0.098044	0.809120	0.008386	0.009458	0.812366	0.215366	0.019123	0.883934
10	P60	0.020019	0.007262	0.997082	-0.009583	0.011203	0.803841	0.001398	0.023942	0.523279	0.683125	0.000555	0.573155
11	ABSLATIT	0.000258	0.000094	0.996816	-0.000259	0.000244	0.855861	0.000022	0.000175	0.549092	0.249675	0.000000	0.950681
12	NONEQINV	0.064318	0.025205	0.994641	0.156215	0.047350	0.999515	-0.070594	0.050012	0.920959	0.155201	0.000492	0.999373
13	lly1	0.026187	0.010770	0.992479	-0.037831	0.063493	0.724359	0.016304	0.012865	0.897477	0.229474	0.059255	0.611039
14	BMS6087	-0.000029	0.000013	0.987391	0.000081	0.000337	0.594837	-0.000024	0.000012	0.976728	15.840005	0.000000	0.981818
15	PROT	-0.013333	0.006654	0.977457	-0.074952	0.265630	0.611092	0.000998	0.013004	0.530572	0.181206	0.066938	0.584433
16	ggcfd3	0.053877	0.028587	0.970263	0.094548	0.101635	0.823884	-0.078392	0.047476	0.950649	0.060015	0.070863	0.572146
17	EcOrg	0.001980	0.001061	0.969019	0.002456	0.002090	0.880021	-0.001451	0.004600	0.623784	3.040000	0.532084	0.049624
18	RERD	-0.000060	0.000032	0.966811	-0.000097	0.000072	0.912491	0.000019	0.000068	0.607574	134.822210	0.039587	0.628839
19	prightsb	-0.001723	0.000951	0.965004	-0.001537	0.002232	0.754415	-0.003498	0.002014	0.958792	4.171542	0.000226	0.960448
20	gvxdxe52	-0.027214	0.018251	0.932029	-0.089101	0.067565	0.906374	-0.037373	0.026713	0.919101	0.087373	0.001281	0.865493
21	revcoup	-0.007480	0.005426	0.915991	0.016316	0.045052	0.641385	-0.006513	0.007090	0.820840	0.121060	0.050056	0.157252
22	OthFrac	0.005052	0.003813	0.907388	0.368404	3.248481	0.545147	0.012436	0.016598	0.773134	0.392026	0.123283	0.366224
23	PI6089	-0.000023	0.000020	0.882550	0.001998	0.001447	0.916246	-0.000016	0.000020	0.787627	8.072877	0.070305	0.609079
24	FRAC	-0.004830	0.004663	0.849875	0.001094	0.006303	0.568921	-0.031345	0.029518	0.855856	0.673583	0.020038	0.723377
25	dpop6090	0.196409	0.193346	0.845148	0.173116	0.530418	0.627930	-0.332635	0.408959	0.791997	0.020561	0.061537	0.580442
26	bmp1	-0.003884	0.003857	0.842991	0.083705	0.025884	0.999389	-0.010025	0.005331	0.969976	0.186328	0.000146	0.333960
27	pyr60	-0.001330	0.001324	0.842364	0.008395	0.010540	0.787107	-0.001507	0.001386	0.861516	1.069067	0.006529	0.399619
28	STPI6089	-0.000005	0.000005	0.838270	0.001005	0.001109	0.817579	0.000001	0.000005	0.550458	8.757690	0.012244	0.964924
29	work60l	-0.006511	0.006859	0.828757	0.007152	0.025857	0.608959	0.017127	0.024300	0.759534	-0.950557	0.064899	0.616071
30	Mining	0.016699	0.021321	0.783251	0.359393	0.918924	0.652139	0.034295	0.028374	0.886605	0.030898	0.268168	0.111529
31	lforce60	0.000000	0.000000	0.778313	-0.000017	0.000013	0.910086	0.000000	0.000000	0.689430	1386.097000	0.135344	0.243719
32	syr60	0.002000	0.002819	0.761041	0.085790	0.056925	0.934102	0.003883	0.002654	0.928311	0.160729	0.002391	0.443014
33	humanyl	-0.000098	0.000143	0.754317	0.000725	0.001091	0.746877	-0.000061	0.000121	0.693423	9.787159	0.000213	0.582569
34	tot1	0.027362	0.039805	0.754091	0.113057	0.075730	0.932267	0.010064	0.093735	0.542750	-0.001416	0.066516	0.139185
35	geerec1	0.083728	0.128619	0.742469	-0.344544	0.218269	0.942778	-0.532243	0.423483	0.895591	0.029066	0.000201	0.865747
36	DEMOC65	-0.003027	0.005307	0.715791	0.006043	0.012000	0.692735	-0.013325	0.035993	0.644385	0.709635	0.097330	0.159248
37	STDC6089	-0.000007	0.000015	0.678952	-0.000309	0.000263	0.880212	0.000006	0.000018	0.622496	24.411963	0.055803	0.288945
38	freeop	0.008845	0.021361	0.660581	0.084687	0.070578	0.884910	0.065476	0.032505	0.978011	0.195550	0.040327	0.122642
39	hyr60	-0.006124	0.014957	0.658893	-0.124662	0.282635	0.670419	-0.000108	0.014029	0.503057	0.022753	0.000032	0.470514
40	human60	-0.000465	0.001285	0.641313	0.009500	0.008722	0.861975	-0.000371	0.001035	0.640022	1.378536	0.000132	0.546649
41	s60	-0.003143	0.011580	0.606973	-0.016065	0.176286	0.536306	0.001589	0.011402	0.555429	0.089577	0.003841	0.773196
42	gde1	-0.011452	0.050464	0.589759	-0.845100	0.371793	0.988488	-0.046704	0.064965	0.763899	0.019651	0.020519	0.442417
43	freetar	0.012026	0.063922	0.574614	-0.594010	0.397785	0.932320	0.076333	0.074838	0.846129	0.020619	0.001118	0.932127
44	GDC6089	0.000008	0.000049	0.563749	0.000121	0.000252	0.684119	-0.000026	0.000065	0.651920	21.297630	0.096284	0.289607
45	URB60	0.001367	0.008595	0.563199	-0.042116	0.024507	0.957149	0.010573	0.009999	0.854844	0.276289	0.000710	0.643275
46	area	0.000000	0.000001	0.530553	0.000005	0.000013	0.640235	0.000000	0.000001	0.623461	560.233560	0.080882	0.068096
47	pinstab2	-0.000508	0.010995	0.518418	1.885510	1.234827	0.936612	0.024975	0.017012	0.928958	0.010303	0.149172	0.134027
48	h60	-0.001257	0.035494	0.514124	-5.473600	2.210271	0.993365	-0.007436	0.034315	0.585774	0.003904	0.000104	0.949028

Table 2: Weighted results

Evidence of conditioning nonlinearity	
Group	**Variable**
Initial values	Initial GDP per capita
	Life expectancy in 1960
	Primary school enrollment in 1960
	Average years of primary school in 1960
	Secondary school enrollment in 1960
	Average years of secondary school in 1960
	Average years of higher education in 1960
	Average years of schooling in 1960
	Average years of schooling $\times$ Initial GDP per capita
	Urban population in 1960
Political	Civil liberties
Religious	Fraction of Catholic population
Market distortion	Exchange rate distortions
Investment	Equipment investment
Trade	Tariff restrictions
Ethnolinguistic	Ethnolinguistic fractionalization
Inflation	Standard deviation of inflation
Public spending	Public consumption share

Table 3: Variables that induce conditioning nonlinearity

Evidence of level-dependent parameter heterogeneity			
Group	**Variable**	**Low regime**	**High regime**
Initial values	Higher education enrollment in 1960	(−)	NR
Political	Political rights	NR	(−)
	Rule of law	(+)	NR
Religious	Fraction of Muslim population	NR	(+)
Market distortion	Black market premium volatility	NR	(−)
Investment	Non-equipment investment	(+)	NR
Primary sector	Primary exports, share in total exports	(−)	(− −)
Trade	Years open economy	NR	(+)
	Free trade openness	NR	(+)
Public spending	Defense spending share in GDP	(−)	NR

NR stands for "Not robust", (−) stands for negatively and (at least 95%) robustly related to growth, (+) stands for positively and (at least 95%) robustly related to growth. A double sign indicates higher absolute value than in the alternative regime

Table 4: Variables with level-dependent parameter heterogeneity