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The Empirical Economic Growth Literature

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THE EMPIRICAL ECONOMIC GROWTH LITERATURE: ROBUSTNESS, SIGNIFICANCE AND SIZE

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Abstract
The empirical economic growth literature is criticized for its lack of robustness. For different definitions of robustness, conclusions vary from "almost every correlation is fragile" to "a substantial number of explanatory variables are robust." We re-analyze the empirical results of the economic growth literature for various alternative definitions of robustness using quasi-experiments. The analysis pertains to sign, size and significance of the effects. Response surface analyses of the quasi-experiments reveal that the number of robust variables is limited and that the effects crucially depend on the specification of the set of conditioning variables.

Key words: economic growth, sensitivity analysis, robustness, response surface
JEL code: C52, C90, O11, O40

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1. Introduction

The introduction of endogenous growth theory in the 1980s and the improved availability of datasets covering broad cross-sections of countries with relatively long time series has had an unequivocal impact on the empirical literature dealing with single-equation macroeconomic models for cross-sections of countries or regions. The empirics are geared towards determining the significance of institutions, knowledge accumulation, and catch-up and convergence for explaining economic growth differentials. With virtually no theoretical guidance as to the precise nature of the hypothesized relationships, a plethora of specifications exists. Durlauf and Quah (1999) stress that empirical economists are inclined to follow theory rather loosely, and simply 'try' variables to establish the factors determining economic growth (Sala-i-Martin, 1997). In these specification searches, econometric problems such as endogeneity of the regressors, nonlinearity, nonstationarity and multicollinearity, are largely ignored (Durlauf, 2001).

Because the literature reveals more than fifty variables significantly correlated with growth in at least one study, the question arises as to how sensitive results of cross-country growth regressions are to slight alterations in the empirical setup. Levine and Renelt (1992) instigated the discussion by investigating the robustness of explanatory variables in cross-country growth regressions using Leamer's Extreme Bounds Analysis (EBA; see Leamer, 1983, 1985). The EBA approach boils down to an assessment of the sign and significance of a variable's estimated coefficient relative to a varying set of conditioning variables. Levine and Renelt conclude that almost all results are fragile, except for the correlations between the share of investment in GDP and growth, and between the investment share and the ratio of international trade to output. Sala-i-Martin (1997) refutes EBA maintaining that the test is 'too strong'. He moves away from the 'extreme test' and its binary outcome of a variable being either robust or fragile, and investigates the distribution of coefficient estimates, concluding that for a substantial number of variables the relation to economic growth is robust.

The occurrence of differing, and sometimes conflicting, results of individual studies or experiments evokes a legitimate quest for an assessment of the robustness of research findings. In his Nobel Prize lecture, Heckman (2001) points to the availability of micro survey data and the development of econometrics as the main causes for creating a formidable “flood of numbers”. The flood of numbers is difficult to interpret, and complicates testing theories and attaining an informed policy consensus. A similar problem exists in the empirical growth literature. This paper aims to take the conflicting robustness analyses of this literature one step further by explicitly recognizing the multi-dimensionality of the robustness concept. More specifically, we analyze the variability in sign, significance and size of coefficient estimates in the empirical growth literature. In line with the earlier studies by Levine and Renelt (1992) and Sala-i-Martin (1997), we generate study results by means of quasi-experimentation using a well-known dataset under varying conditions. We subsequently perform regression analysis on these datasets and analyze the obtained e stimation results. Specifically, we analyze the parameter estimates obtained from a wide range of possible regressions specifications aimed at explaining growth in order to establish the robustness of the relationship between growth and its proposed determinants. We use a technique developed and frequently used in econometrics that is know as response surface analysis (Hendry, 1984).[1]

The paper proceeds as follows. Section 2 concisely reviews the discussion on the robustness of empirical economic growth studies. In Section 3, we elaborate on response surface analysis as a tool to analyze variation in research results, and we explain the setup for the quasi -experimentation. Section 4 provides known as well as new results regarding robustness in terms of sign and significance. In Section 5, we extend the robustness criterion to include the magnitude of the estimated effects and we analyze the sensitivity of the results for multicollinearity among the explanatory variables. Conclusions are presented in Section 6.

[1] This approach is akin to a technique known as meta-analysis. Meta-analysis is suited to come to grips with abundant research output on a specific topic (Smith and Pattanayak, 2002). It constitutes an array of statistical techniques for a rigorous quantitative analysis of empirical results of previous studies, and is increasingly used as a tool to evaluate and synthesize findings reported in the literature (Hedges and Olkin, 1985). In medicine, education, psychology and the sciences, meta-analysis is commonly used. Economists still largely rely on narrative literature reviews and simple counts of significant results of a specific sign (Stanley, 2001), although meta-analysis is increasingly being applied (see, e.g., Smith and Huang, 1995; Card and Krueger, 1995; Smith and Osborne, 1996; Ashenfelter et al., 1999; Görg and Strobl, 2001; Dalhuisen et al., 2003). The quasi-experimental approach used in this paper samples repeatedly from the same dataset and uses variation in specifications to generate variation in outcomes. In meta-analysis, study results are sampled from primary studies frequently employing different datasets as well as different specifications. For an example of meta-analysis in the context of the economic growth literature, see Abreu et al. (2003), who investigate the speed of convergence in empirical growth studies.

2. Robustness of empirical growth explanations

The vast empirical literature determining the empirically observed variation in economic growth has predominantly used simple linear cross-section regression models, known as 'Barro regressions' (after Barro, 1991).[2] The size of the literature is formidable, but Durlauf and Quah (1999), and Temple (1999) provide excellent surveys.

The most intensively studied factors explaining economic growth are the initial level of income, the investment ratio, population growth, political stability, market distortions, and the development of financial markets. The evidence for theoretically plausible correlations is abundant, but insignificant and even unexpected correlations show up as well. The empirical results are therefore at best indecisive. Levine and Renelt (1992) cogently express the problem of lacking robustness. They use the EBA-methodology in which the relationship between economic growth and a particular variable is 'robust' if the coefficient estimate remains statistically significant and of the theoretically expected sign under permutations of the set of conditioning variables.[3] Their main conclusion is that a positive and robust relationship between economic growth and the investment share of GDP is apparent. They also show that the investment share is robustly correlated with the share of trade in GDP, and they find qualified support for the hypothesis of conditional convergence: when a measure of human capital is included, a robust negative correlation between growth and initial income appears.

For some time, the Levine and Renelt critique is considered a 'kiss of death' for the empirical growth literature. Their devastating conclusion holds up until Sala-i-Martin (1997) criticizes the EBA-methodology for being too strict by requiring all correlations to be significant and of the predicted sign. He argues that we should focus on the entire *distribution* of the coefficient estimates and their significance level. Finding a variable that is significant in 95 percent of the cases provides sufficient evidence for a specific variable to be robustly correlated with growth. His relaxation of the robustness

[2] Notable exceptions are studies using panel data, such as Islam (1995), and Caselli et al. (1996).

[3] An intuitively appealing overview of the EBA-methodology is given in Levine and Renelt (1992), and the usefulness of the methodology is discussed in, for instance, McAleer and Veall (1989), and McAleer (1994).

criterion leads to a more optimistic conclusion regarding the empirical growth literature. Over one-third of the variables that matter in at least one Barro-regression, turn out to be robustly correlated with long-term economic growth. Many of these variables are related to investment in (human and physical) capital, cultural and institutional differences, and macroeconomic performance (including trade), or they mimic variations over space and time.[4]

In a similar vein, Fernandez et al. (2001) and Doppelhofer et al. (2000) apply Bayesian techniques to the analysis of determinants of long-term growth, which is 'natural' given the intrinsic model uncertainty. The results of the Bayesian approach are by and large in line with the conclusion drawn by Sala-i-Martin (1997). Once one moves away from the very strict EBA test, the number of robust relationships between growth and a wide range of potential explanatory variables increases substantially.

3. Response surface analysis and quasi-experimental design

Although Sala-i-Martin, and Levine and Renelt type sensitivity analyses provide useful insights, they have serious limitations. First, they focus merely on sign and significance. Second, a number of conditioning variables is 'fixed', implying that they are used in each and every regression model. We take the analysis a step further by investigating a range of definitions of robustness, by explaining the variation in magnitude in addition to the sign and significance of the coefficient estimates, and by relaxing the assumption that some of the conditioning variables are 'fixed'.

Implicit in the Levine and Renelt sensitivity analyses is the use of vote-counting, referring to simple counts of significantly positive and negative, and insignificant results. Subsequently, the results are tallied, and it is assumed that the category representing the majority of cases represents the true underlying relationship (Light and Smith, 1971). In the case of EBA, the interpretation is very strict, because results are labeled 'robust' if and only if the coefficient estimates are always significant

[4] An alternative method to relax the strictness of EBA is to construct *reasonable* extreme bounds, as proposed by Granger and Uhlig (1990). This method uses estimates derived from "sufficiently reliable" regressions only. The assessment of reliability is made on the basis of the goodness of fit of a specific regression relative to all other estimated regressions (see Doppelhofer, 2000, for an application).

and conform to the theoretically expected sign. Sala-i-Martin (1997) is slightly more lenient, but essentially his procedure does not go beyond vote-counting either.

Hedges and Olkin (1980, 1985) show that the vote-counting methodology is inadequate, because it tends to lead to the wrong conclusion more often as the number of studies increases, because the Type-II errors of the underlying studies do not cancel one another. The rather crude vote-counting analysis is also unsatisfactory because a classification based on sign and significance level alone, is insufficient to determine whether the results of different growth regressions are the same (Hedges, 1997). Consequently, an appropriate analysis of the results of the empirical long-term growth literature should go beyond counting results of a specific sign and significance, and an appropriate analysis should account for differences in magnitude of the effects. In this paper, the effect size measure is the estimated regression coefficient for different specifications of Barro growth equations. Essentially, we will model the effect size as a function of fixed effects representing differences in the specification of the underlying growth equations.[5]

This approach of quasi-experimentation resembles the response surface technique developed in econometrics (Hendry, 1979, 1984). Response surface analysis is based on an auxiliary regression in which each observation corresponds to the result of one experiment. The independent variables reflect the dimensions that have been changed over the experiments by the experimenter (Davidson and MacKinnon, 1993). Response surface analysis is particularly useful because it reduces what Hendry calls 'specificity'.[6] Strictly speaking, each experiment only extends to the data-generating process that has been used for that experiment, and a series of experiments extends merely to a finite set of data-generating processes. The results of a correctly estimated response surface, however, also

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[5] Although this approach is similar to performing a meta-analysis, on should note that the Levine and Renelt (1992) and Sala-i-Martin (1997) as well as the current sensitivity analyses depart from the traditional meta-analysis setup in the sense that they do not sample from the population of studies making up the empirical economic growth literature. Instead, they sample from the literature in terms of variables used in earlier studies, and subsequently apply this selection of variables to one specific data set. This has two important consequences in terms of avoiding some of the well-known methodological pitfalls of meta-analysis (see also Glass et al., 1981). First, it limits the potential biases introduced by non-representative sampling, if the number of quasi-experiments covers a sufficient number of cases. Second, because the empirical results are generated using an identical theoretical and modeling framework, the same data set, and the same estimation technique, the potential bias resulting from heterogeneity in underlying 'studies' is limited.

[6] See Maasoumi and Philips (1982) for a critical discussion, along with Hendry's (1982) reply.

extend to cases that have not been included in the experimental setup (for instance, regressions with a larger number of explanatory variables).

Our quasi-experiments are based on the estimation of Barro-regressions with a varying set of conditioning variables, essentially following the approach in earlier sensitivity analyses. Formally, we estimate a series of regressions:

$$\mathbf{y} = \mathbf{F}\boldsymbol{\theta}_\mathbf{j} + \beta_{ij}\mathbf{x}_\mathbf{i} + \mathbf{C}_\mathbf{j}\boldsymbol{\gamma}_\mathbf{j} + \boldsymbol{\varepsilon}_\mathbf{j}, \quad \forall i, j, \tag{1}$$

where $\mathbf{y}$ is a vector of per capita GDP growth observations, $\mathbf{F}$ a matrix of variables that are "fixed" between the regressions with the associated parameter vector $\boldsymbol{\theta}_\mathbf{j}$, $\mathbf{x}_\mathbf{i}$ the variable of interest with parameter β_{ij}, and $\mathbf{C}_\mathbf{j}$ a matrix of a subset of conditioning variables taken from the full set of potentially important explanatory variables for economic growth, with $\gamma_\mathbf{j}$ for the corresponding vector of parameter estimates. The set of fixed variables includes the usual constant term, and $\varepsilon_\mathbf{j}$ is a well-behaved vector of errors. The subscript i (= 1, 2, …, I) indexes the variables of interest, and j (= 1, 2, …, J) the different combinations of conditioning variables. Including a fixed number, say c, conditioning variables in each regression equation (in addition to the variable of interest) implies that the number of equations to be estimated, J, equals $(I–1)!/(c!\cdot(I – c–1)!)$.

Subsequently, we estimate response surfaces for $\widetilde{\boldsymbol{\beta}}_\mathbf{i}$, which are ($J \times 1$) vectors comprising elements:

$$\widetilde{\beta}_{ij} = \frac{\hat{\beta}_{ij} - \overline{\hat{\beta}}_i}{\overline{\hat{\beta}}_i}, \quad \forall j. \tag{2}$$

The transformation in equation (2) is introduced to facilitate comparison among different explanatory variables. A total of I response surfaces is given by the auxiliary regression:

$$\widetilde{\boldsymbol{\beta}}_\mathbf{i} = \mathbf{D}_\mathbf{i}\boldsymbol{\alpha}_\mathbf{i} + \boldsymbol{\mu}_\mathbf{i}, \quad \forall i, \tag{3}$$

where $\mathbf{D_i}$ is a $(J \times (I-1))$ matrix of fixed effects representing the explanatory variables included in $\mathbf{C_j}$ in equation (2) by means of dummy variables. The resulting estimates contained in $\hat{\boldsymbol{\alpha}}_i$ represent the change of $\hat{\beta}_{ij}$ as a proportion of $\overline{\hat{\beta}_i}$, due to the inclusion of a specific explanatory variable contained in $\mathbf{C_j}$. These estimates are related to the conditional means of the variable of interest, that is, conditional upon inclusion of a particular conditioning variable, in the following way (see Appendix A):

$$\overline{\hat{\beta}_i}\Big|_{D_{kj}=1} = \hat{\beta}_i\left(1+\left(1-\frac{R-2}{I-2}\right)\hat{\alpha}_k\right), \tag{4}$$

where R is the number of regressors. Hence, the mean effect size of a variable of interest, conditional upon a particular conditioning variable being included, $\overline{\hat{\beta}_i}\Big|_{D_{kj}=1}$, relative to the overall mean estimated effect size, $\hat{\beta}_i$, is proportional to the estimated coefficients of equation (3).

The dataset and the setup for the regressions are based on earlier sensitivity analyses, partly for reasons of comparison. We use the same database as Sala-i-Martin (1997), which is available on the web (http://www.columbia.edu/~xs23/data/millions.htm). The database comprises growth of GDP per capita between 1960 and 1992, used as the dependent variable, and 61 explanatory variables chosen as closely as possible to the beginning of the sample period. Following Sala-i-Martin (1997), three variables are initially chosen as fixed variables, because they have been widely used in the empirical growth literature and found to be reasonably robust: the level of income in 1960, life expectancy in 1960, and the primary school enrolment rate in 1960, although the significance of the latter is rather mixed. Following the earlier sensitivity experiments, the set of conditioning variables is restricted to three (out of a total of 61 minus one variable of interest), so that for each variable of interest 57!/(3!·54!) = 29,260 regressions need to be estimated.

4. Robustness results

Table 1 gives the results of the estimation of the Barro growth regressions, containing the mean estimated β, its standard deviation, the left and right-hand sided 95% confidence interval, the percentage of regressions in which the estimated effect has a significant positive or negative sign, and the results of the different sensitivity tests. Six different sensitivity tests are used: the strong and weak sign test, the strong and weak EBA test, the weighted weak EBA test, and the fraction of estimates that fall within the cumulative density function (CDF) of the weighted average of the estimated βs. The adjectives 'strong' and 'weak' refer to all effects, or at least 95% of the effects passing the test, respectively. The weights are defined as the value of the likelihood of the regression equation, as in Sala-i-Martin (1997), giving more weight to regressions that are more likely to represent the true model. The sign tests merely refer to the sign of the effect, the EBA test to sign and significance of the effect, and the CDF approach to the significance of the effects, taking into account the distribution of coefficient estimates.

< Insert Table 1 around here >

Table 1 clearly shows the divergence between the Levine and Renelt, and the Sala-i-Martin results. The strong EBA-test is only passed by one variable, the fraction Confucian, whereas the weighted CDF approach of Sala-i-Martin identifies 13 variables that are robust at the 95% confidence level. The weighted EBA-test does not have sufficient power, because all but approximately ten variables are identified as being robust. Interestingly, no less than 15 conditioning variables are found to be both positively and negatively significant in at least one regression equation. Among these are population growth, average years of schooling, the public investment share, the number of revolutions and coups, the ratio of workers to population, and the terms of trade growth. This illustrates to some extent the skeptical assertion that almost any relationship can be shown to be either significantly positive or negative, providing the 'correct' set of conditioning variables is used.

Finally, Table 1 also shows that the results of Sala-i-Martin's rather complicated approach are virtually identical to the results of the much more straightforward weak sign test approach. The rank order of the different sensitivity test approaches, defined in terms of increasing numbers of variables identified as being robust, is: STRONG EBA < WEAK EBA < STRONG SIGN < WEIGHTED CDF < WEAK SIGN < WEIGHTED WEAK EBA. This ranking satisfies the requirement of increasing inclusiveness: approaches identifying a larger number of robust variables identify the *same* variables as 'weaker' approaches, plus additional ones. Although the ranking is strictly speaking not the result of experiments, the weighted CDF approach and the weak sign approach appear to have favorable properties in terms of discriminatory power. The strong and weighted weak EBA approaches constitute extremes, identifying almost none or virtually all variables as being robust.

The above results are dependent on the number and the type of 'fixed' variables. Dropping this fixation makes it necessary to introduce further changes, in order to keep the analysis computationally feasible. We therefore reduce the dataset to the 21 robust variables as identified in Sala-i-Martin's CDF approach. Tables 2a and 2b show the results of the re-analysis using these 21 key variables, with three variables fixed for reasons of comparison with the prior analysis in Table 2a, and with none of the variables fixed in Table 2b. Throughout the analysis, we restrict the total number of conditioning variables to seven, excluding the constant term. The results in Tables 1 and 2a are very similar. The ranking of the sensitivity tests is exactly as above, and the inferences regarding the robustness of variables are virtually identical.

< Insert Tables 2a,b around here >

The results are, however, affected when no 'fixed' variables are included in the analysis, as in Table 2b. Substantially fewer robust variables are identified, although it is easily verified that increasing the critical cut-off point to 10 percent would lead to virtually identical results for the weighted CDF approach with and without fixed variables. The ranking of the sensitivity test approaches is also close to the same as before. The weak sign test approach and the weighted CDF approach change rank, and they no longer satisfy the criterion of increasing inclusiveness, but these changes are marginal.

< Insert Table 3 around here >

A detailed variable-by-variable analysis of robustness in terms of significance reveals, however, that Sala-i-Martin's choice to 'fix' three variables has a major impact on the resulting findings. Table 3 presents the proportion of significant results for the variable of interest (by column), in relation to a specific conditioning variable being included (by row). From Table 2b, it is already obvious that the result for initial income is far less robust than it appears in Tables 1 and 2a. Table 3 shows that the insignificant results for initial income only occur in models in which life expectancy is *not* included among the regressors. To a slightly lesser extent, this holds for conditioning on primary school enrollment as well. Apparently, the robust relationship between growth and initial income depends on conditioning for life expectancy, and to a lesser extent on primary school enroll ment.

The analysis based on the Sala-i-Martin approach *without* 'fixed' variables, also shows that the predominant finding of the approach *with* 'fixed' variables, the Fraction Confucian being the most robust variable, is apparent in this case as well. In fact, the variable Fraction Confucian is the only uniformly robust variable. It is always significant, irrespective of the conditioning variable(s) included in the regression.

The impact of modeling economic growth as a convergence/catch-up process, which given the 'fixed' variables in previous sensitivity analyses is the 'default' model, also has a non-negligible effect on the significance of the conditioning variables. For 10 out of the 20 conditioning variables, the highest proportion of significant results is obtained when the specification is the convergence/catch-up model (see the first row of Table 3).

5. Response surface analysis

The vote-counting results reported in the preceding section focus on counting statistically significant results, and shows that the results of the Sala-i-Martin analysis are dependent on the experimental setup using ‘fixed’ variables. The size of the estimated effects is a dimension of robustness that has received considerably less attention, although it is implicitly used in the (weighted) CDF approach. We provide more detail on this aspect in the below subsections.

5.1 Response surface analysis: basic analysis

In Figure 1, we present the results of the response surface analysis for the magnitude of the estimated effect sizes, without ‘fixing’ any of the conditioning variables in the experiments. The 21 key variables are on the horizontal axis, and the conditional mean of the effect size, relative to the mean of the effect size in the full sample of regressions containing this key variable (as reported in Table 2b, and from here on referred to as the ‘grand mean’), on the vertical axis. When this index equals one, the conditional mean is identical to the grand mean, implying that the variable of interest is insensitive in size to the inclusion of a particular conditioning variable. The more the index deviates from one, the more sensitive the key variable is to the inclusion of a particular control variable. The index is negative when the conditional mean has a sign opposite to the sign of the grand mean. The key variables are ranked in declining range of the index. The results reveal that two-thirds of the key variables show deviations going beyond 20-30% of the grand sample means.[7]

As for the proportion of significant results discussed above, the positive outliers causing the range of the index to widen on the left hand side of Figure 1, are brought about by the inclusion of the initial level of GDP. The hypothesis of convergence/catch-up thus causes several conditioning variables to be rather extreme in terms of size. It is unclear to what extent this is the result of endogeneity bias, multicollinearity or potentially another econometric misspecification problem. Table B.1 in Appendix B shows, however, that bivariate correlations with the logarithm of the GDP per capita level in 1960 are almost invariably high for the conditioning variables constituting outliers.

< Insert Figure 1 around here >

[7] The latter are reported in Table 2b. The results for the variable Public consumption share are excluded for reasons of scale. The index values are extreme, ranging from –85.47 to 67.37.

In Figure 2, we show in more detail how this overall result depends on the specification of the set of conditioning variables. The size of the circles in Figure 2 indicates the percentage deviation from the grand mean. Table 4 provides the same results in a numerical format. It is obvious that the variables of interest with large deviations from the grand mean, such as Public consumption share (X_8), Absolute latitude (X_9), and Liquid liabilities to GDP (X_{15}), cannot be labeled robust. This conforms to the re-analysis of the Sala-i-Martin experiments with fixed variables, as reported in Table 2a. Exchange rate distortions (X_{12}) and especially St. dev. Black market premium (X_6) are, however, robust in terms of magnitude. Reading the graph horizontally shows the effect of inclusion of a particular variable recorded on the vertical axis as conditioning variable on the magnitude of the variables recorded on the horizontal axis. It is again evident that the approach with fixed variables has a major impact on the results. In particular, the inclusion of the level of GDP per capita (X_1) substantially inflates the magnitude of the coefficients of Absolute latitude (X_9), Rule of law (X_{11}), and Liquid liabilities to GDP (X_{15}). Figure 2 also reveals that inclusion of the geographical dummy variables for Sub-Saharan Africa and the Latin American continent as well as proportion variables specifying the importance of religious denominations have large impacts on the magnitude of estimated coefficients.

< Insert Figure 2 around here >

In Figure 3, we combine the results for statistical significance and size. We emphasize that in the original Sala-i-Martin analysis all variables considered in Figure 3 are labeled robust. In our re-analysis for 21 key variables, treating three variables as fixed, all except five variables remain robust using Sala-i-Martin's definition. In Figure 3, the size of the circles depicts the proportion of significant results. White circles refer to variables represented on the horizontal axis, conditioned on the variables given on the vertical axis, that are significantly different from zero in at least 43 percent of all relevant regressions. Grey circles represent cases for which the significance criterion is met in addition to the size of the coefficient of the variable of interest being within the 95 percent confidence interval of the grand mean of the variable of interest.[8]

< Insert Figure 3 around here >

The results deviate remarkably from both Levine and Renelt's, and Sala-i-Martin's conclusions. First, no single variable shows uniform significance in at least 43 percent of the cases and relative stability in size (i.e., the coefficient is within the 95% confidence interval of the grand mean), regardless of the conditioning variables. Second, depending on the conditioning variables the criterion of robustness in size and significance is met in 50 percent or more of all cases by the Level of GDP per capita, and Non-equipment investment only. The results for the variables Fraction Protestant and Fraction Buddhist are close to 50 percent as well. There are only four more variables showing more than occasional robustness in size and significance, the variables Number of years open economy, Equipment investment, Fraction Confucian, and Primary school enrollment. This clearly indicates that the "nothing is robust" conclusion (Levine and Renelt, 1992), and the conclusion that a substantial number of variables is strongly related to growth (Sala-i-Martin, 1997), are both overstatements.[9]

< Insert Table 4 around here >

In the literature, too much emphasis is put on statistical significance, implicitly assuming a statistically significant effect is economically meaningful in terms of size. McCloskey (1985), and McCloskey and Ziliak (1996) cogently argue that ultimately the *economic* significance in terms of the size of the estimated effects is of overriding importance. This is particularly relevant for the

[8] The significance criterion corresponds to the result of Sala-i-Martin's CDF approach, as can be seen in Table 2B. The information to construct confidence intervals is also taken from Table 2B.

[9] This result does not depend on our using an unbalanced sample (different number of observations per regression, depending on data availability). The use of a balanced sample with 53 observations hardly changes the results.

development of growth-inducing policies. In Table 4, we present the mean estimated effect sizes (in addition to the percentage deviations of the grand means, already graphically presented in Figure 2). In combination with the minimum, maximum, and standard deviation of the variables given in the column headings, we estimate the impact ranges on the growth rate of a one standard deviation change in the minimum and maximum of the effect sizes. First, the results show that, with the exception of changes in the initial level of GDP, none of the changes results in an impact on the growth rate exceeding one percentage point. Second, not all of the variables can be viewed as policy variables, because they refer to geographical location, the initial level of GDP, or relatively constant proportions of religious factions. Of the policy variables that are robust in terms of significance and size, only Primary school enrollment and Equipment and Non-equipment investment are economically significant, implying that growth-inducing policies targeted at schooling and stimulating investments may be expected to have the greatest impact on the size of an economy's growth rate.

5.2 Multicollinearity

An important econometric problem in the analyses reported in the preceding sections – or actually, in empirical growth studies in general – is the potential of multicollinearity driving the results. The bivariate correlations in Table A.1 give a first indication of the potential relevance of multicollinearity. In this section, we investigate the implications of the occurrence of multicollinearity for three exhaustively analyzed explanatory variables for growth differentials; specifically, initial income, the investment rate, and absolute latitude. We investigate the relevance of multicollinearity by restricting the set of conditioning variables in the robustness analysis to variables with a bivariate correlation to the variable of interest of less than 0.10. In contrast to the analysis in Section 5.1, we use the entire dataset of 61 potential control variables for this analysis.[10] The results provide a reliable assessment of the extent to which the sign, significance and size of the effect sizes are driven by

[10] Results for other variables of interest and for other values of the cut-off point for the bivariate correlation as well as the correlation table for the complete set of variables are available upon request.

multicollinearity, although it should be acknowledged that leaving out relevant variables may eventually cause omitted variable bias.

< Insert Figures 4a, b, and c around here >

The results for initial income are depicted in Figure 4a. The Figure shows results for 13 variables (out of 61) having a correlation smaller than 0.10 with initial income. The overall average effect size for initial income that results from adding 6 variables from the set of 13 variables to the specification in all possible combinations equals 0.0057. The coefficient i s statistically significant at the 5% level in 99.8 percent of the cases, and the coefficient is positive in all cases. The Figure shows the conditional average effect size (i.e., conditional on the variable being included) relative to the overall average effect size, with the associated confidence interval. Comparing the results to Figure 1 and Table 4 reveals that the estimated coefficient is much more stable.[11] This result clearly demonstrates the effect of omitting variables that are correlated with init ial income: initial income then serves as a proxy for omitted variables that are positively correlated with initial income and have a positive effect on economic growth.

Figure 4b depicts the results for investment in equipment. Of the 61 conditioning var iables, only 8 variables are correlated with investment in equipment at the desired <0.10 level. The average estimated effect of investment in equipment on growth equals 0.30. The effect is significant in all cases, and it is highly invariant to the set of conditioning variables included. Again, the coefficient is substantially larger and more stable than in the analysis reported in Figure 1 and Table 4.

Finally, Figure 4c shows very similar results for absolute latitude. In this case, we use 13 conditioning variables in the robustness analysis. The coefficient of absolute latitude is positive and significant in all cases, and reasonably robust in terms of magnitude of the estimated effect across specifications including different conditioning variables. T his result deviates sharply from the results obtained in Figure 1 and Table 4.

[11] The reader should note that Figure 1 and Table 4 only report the mean conditional effect sizes, and not the associated confidence intervals.

6. Conclusions

The apparent lack of robustness constitutes the most severe critique of the extensive empirical economic growth literature that emerged during the past decade. Sala-i-Martin (1997) challenges this negative appraisal. He shows, that a reasonable set of variables is robustly correlated with economic growth, once a slightly less strict definition of robustness is used as compared to the Extreme Bounds Analysis (EBA) applied in a seminal paper by Levine and Renelt (1992).

In this paper, we show that applying Edward Leamer's EBA, even in the case were it is weighted and applied in a 'weak' version, leads to 'extreme' results. Sala-i-Martin's approach based on cumulative distribution functions has sufficient distinguishing power, and leads to 'reasonable' results. His approach is rather complicated, however, and we show that a simple weak sign test approach provides virtually identical results. More importantly, we show that the procedure of keeping three key variables 'fixed' during the quasi-experiments has an important effect on the results. The conditioning on life expectancy differentials, and to a lesser extent primary school enrollment, drives the robustness of the convergence/catch-up phenomenon. At the same time, the default specification based on the convergence/catch-up model is associated with estimated effects for conditioning variables that constitute outliers when compared to alternative specifications.

We also point out that robustness should not be interpreted solely as statistical significance. Our quasi-experiments, without fixed variables, indicate that there is substantial variation in estimated magnitudes of effect sizes. Some variables are evidently not robust in size, for instance, Public consumption share, Absolute latitude, Liquid liabilities to GDP, and Fraction Muslim. Of the remaining variables, some are very robust in size, such as St. dev. black market premium, Number of years open economy, Equipment and Non-equipment investment, and Fraction Buddhist and Confucian. For most variables, however, average effect sizes ranging from 70–130 percent of the average effect size in the overall sample turn out to be common. We show that this result is to a considerable extent caused by multicollinearity among the explanatory variables. The experiment in which we restrict the collinearity among the conditioning variables to 0.10 maximum, substantially improves the robustness of the estimated coefficient for the variable of interest. It is unavoidable in this experiment that the potential problem of omitted variable bias is exacerbated. This clearly emphasizes that the specification of growth regressions should blend in with the use of a sound underlying theoretical framework.

The combination of robustness in statistical significance and estimated magnitude of the effect further limits the number of variables that can be labeled robust. In effect, only the initial level of GDP and non-equipment investment and, at a considerably lower level, equipment investment, some indicators of the relative size of religious factions, the number of years of having an open economy, and primary school enrollment, show consistency in sign and statistical significance. The results of our multicollinearity experiments suggest that these variables are very likely to be robust in terms of size as well, providing that the correlation with other conditioning variables does not exceed 0.10.

Adhering to the principle that 'economically' significant results – as opposed to statistically significant results – is what ultimately matters casts further doubts on the usefulness of growth regressions. There is only a limited number of variables for which a one standard deviation change in the explanatory variable evokes a greater than one percentage point change in the growth rate. Unfortunately, in Barro regressions, many of the processes mimicked by these types of variables are not easily influenced by policymakers. They are not truly policy variables, but rather reflect differences in geography, socio-cultural characteristics, and relative historical economic performance. From the 'true' policy variables, investment in equipment and non-equipment, and human capital formation are the only variables that are robust in statistical significance and size, and have a reasonably large impact on economic growth.

Appendix A

Below, we show how the conditional mean effect sizes (i.e., the mean effect sizes conditional upon inclusion of a particular control variable) can be derived from Equation (3). We analyze the general case where I conditioning variables are considered in the analysis, and the number of regressors included in each regression equals R.

Since the mean of the transformed variable specified in Equation (2) is zero by construction for all is, it holds that:

$$\alpha_k = -\sum_{j \neq k} \alpha_j \; . \tag{A.1}$$

We can further derive the conditional mean of the transformed variable i in case the conditioning variable k is included, as:

$$\overline{\tilde{\beta}}\Big|_{D_{kj}=1} = \left(1 - \frac{R-2}{I-2}\right)\hat{\alpha}_k \; , \tag{A.2}$$

and in case the conditioning variable k is not included, as:

$$\overline{\tilde{\beta}}\Big|_{D_{kj}=0} = -\frac{R-1}{I-2}\alpha_k \; . \tag{A.3}$$

Note that the ratio (R–2)/(I–2) is the proportion of cases in which a conditioning variable *other than the conditioning variable k for which the conditional mean is determined* is included in the regressions, provided that $D_{kj} = 1$. Similarly, the ratio (R–1)/(I–2) is the proportion of cases in which a conditioning variable *other than the conditioning variable k for which the conditional mean is determined* is included in the regressions, provided that $D_{kj} = 0$. By means of equation (2), the conditional mean of variable i can then be straightforwardly derived as given in equation (4).

Appendix B

TABLE B1—BIVARIATE CORRELATIONS FOR KEY VARIABLES OF THE SALA-I-MARTIN DATABASE

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
Y Economic growth	1																					
X_1 log(GDP per capita 1960)	0.14†	1																				
X_2 Life expectancy 1960	0.41	0.86	1																			
X_3 Primary school enrolment 1960	0.44	0.73	0.82	1																		
X_4 Equipment investment	-0.30	-0.48	-0.48	-0.58	1																	
X_5 Fraction Confucius	-0.54	-0.13†	-0.26	-0.04†	-0.22†	1																
X_6 Number of years open economy	-0.34	-0.24	-0.27	-0.28	0.35	0.08†	1															
X_7 Rule of law	0.52	0.58	0.63	0.56	-0.41	-0.42	-0.24	1														
X_8 Fraction Muslim	-0.09†	-0.51	-0.39	-0.25	0.46	0.10†	0.20†	-0.44	1													
X_9 Fraction Buddhist	0.43	0.64	0.69	0.44	-0.39	-0.51	-0.29	0.54	-0.42	1												
X_{10} Non-equipment investment	-0.44	-0.60	-0.63	-0.41	0.29	0.44	0.34	-0.52	0.34	-0.74	1											
X_{11} Degree of capitalism	0.39	0.75	0.73	0.57	-0.22†	-0.41	-0.23	0.67	-0.33	0.68	-0.62	1										
X_{12} Absolute latitude	-0.27	-0.30	-0.36	-0.38	0.72	-0.03†	0.30	-0.33	0.26	-0.25	0.20†	-0.29	1									
X_{13} Liquid liabilities to GDP	0.53	0.69	0.75	0.58	-0.30	-0.48	-0.38	0.58	-0.35	0.70	-0.73	0.67	-0.14†	1								
X_{14} Public consumption share	0.57	0.45	0.58	0.60	-0.19†	-0.33	-0.29	0.52	-0.09†	0.36	-0.40	0.48	-0.08†	0.64	1							
X_{15} Exchange rate distortions	0.41	0.65	0.69	0.46	-0.28	-0.56	-0.29	0.66	-0.42	0.68	-0.71	0.69	-0.23†	0.62	0.51	1						
X_{16} St. dev. black market premium	0.40	-0.13†	0.01†	0.10†	-0.09†	-0.19†	0.08†	0.22†	0.09†	-0.15†	-0.01†	0.05†	-0.22†	0.06†	0.15†	0.06†	1					
X_{17} Fraction Catholic	-0.32	0.12†	0.01†	0.19†	-0.25	0.60	-0.04†	-0.09†	0.05†	-0.16†	0.09†	-0.01†	-0.12†	-0.22†	-0.21†	-0.06†	-0.31	1				
X_{18} Fraction Protestant	0.42	-0.15†	-0.07†	0.06†	-0.05†	-0.10†	-0.01†	0.05†	-0.05†	0.07†	-0.19†	-0.03†	-0.02†	0.07†	0.03†	-0.15†	0.08†	-0.12†	1			
X_{19} Latin American dummy	0.08†	-0.46	-0.49	-0.54	0.15†	-0.32	0.05†	-0.27	0.00†	-0.04†	0.27	-0.33	0.08†	-0.28	-0.26	-0.15†	-0.06†	-0.49	-0.06†	1		
X_{20} Primary exports in 1970	-0.05†	0.51	0.42	0.23†	-0.03†	-0.21†	-0.13†	0.30	-0.19†	0.45	-0.40	0.45	0.11†	0.45	0.29	0.28	-0.16†	-0.35	-0.03†	-0.25	1	
X_{21} Sub-Sahara African dummy	0.34	0.54	0.50	0.50	-0.32	-0.28	-0.18†	0.59	-0.47	0.51	-0.42	0.47	-0.01†	0.48	0.39	0.51	-0.04†	-0.10†	-0.08†	-0.07†	0.28	1

Notes: Correlations that are not significantly different from zero at the 10 percent level are marked by †.

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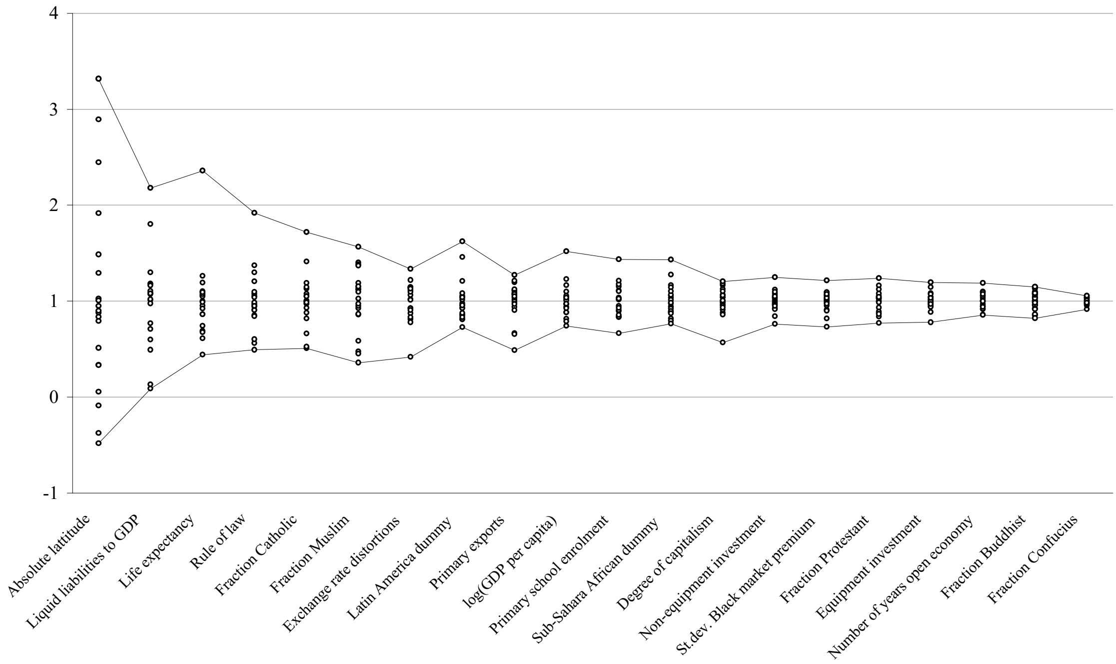

FIGURE 1—RESPONSE SURFACE ANALYSIS: CONDITIONAL MEAN EFFECT SIZES FOR THE 21 KEY VARIABLES RELATIVE TO THE GRAND MEAN (= 1)

Note: The results for the variable Public consumption share are not included for reasons of scale. The values range from –85.47 to 67.37.

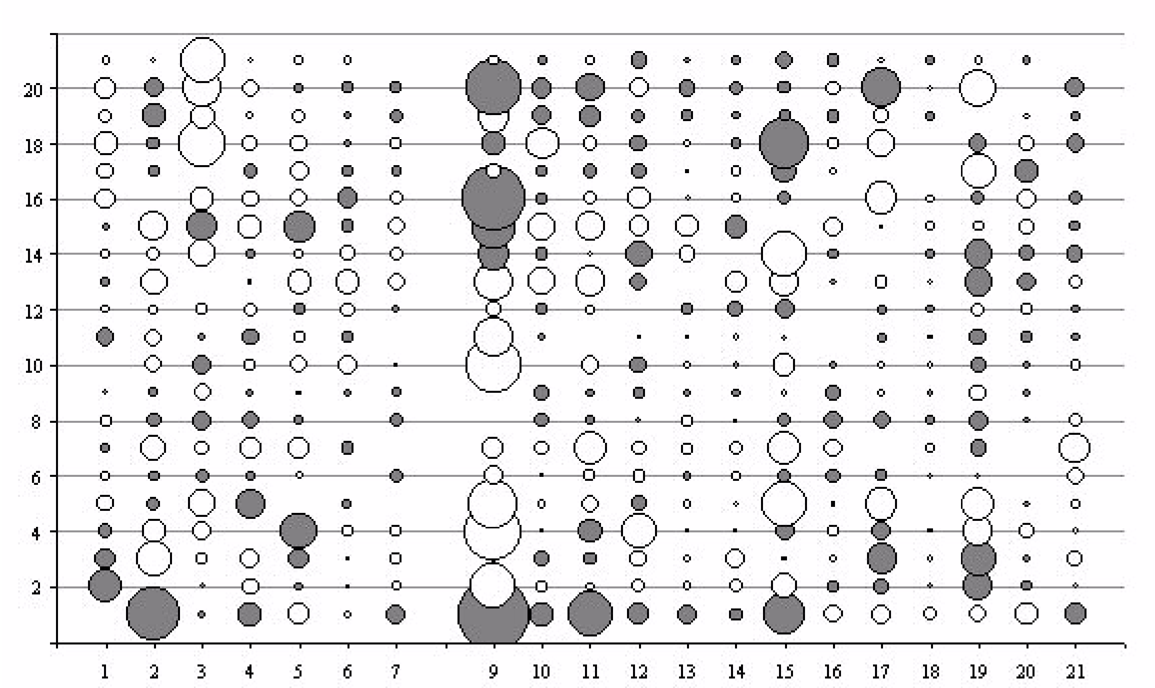

FIGURE 2—PERCENTAGE DEVIATIONS FROM THE GRAND MEAN OF THE CONDITIONAL MEAN EFFECT SIZE FOR THE 21 KEY VARIABLES

Note: The size of the circles represents the percentage deviation of the effect size of the variable of interest (on the *x*-axis), conditioned by the variable indicated on the *y*-axis, measured in terms of the grand sample mean. No circle appears when the deviation is zero, i.e., when the effect size equals the grand mean, with the exception of the diagonal elements, which are zero by definition, and key variable X_8, which is left out for reasons of scale. Circles in white refer to effect sizes smaller than the grand mean, and those in gray to effect sizes greater than the grand mean. The size of the circle at coordinate (1,2) equals approximately 50%. The numerical values on the axes refer to:

X_1	log(GDP per capita 1960)	X_8	Omitted (Public consumption share)	X_{15}	Liquid liabilities to GDP
X_2	Life expectancy 1960	X_9	Absolute latitude	X_{16}	Fraction Buddhist
X_3	Primary school enrollment 1960	X_{10}	Primary exports in 1970	X_{17}	Fraction Catholic
X_4	Sub-Sahara African dummy	X_{11}	Rule of law	X_{18}	Fraction Confucian
X_5	Latin American dummy	X_{12}	Exchange rate distortions	X_{19}	Fraction Muslim
X_6	St.dev. black market premium	X_{13}	Equipment investment	X_{20}	Fraction Protestant
X_7	Number of years open economy	X_{14}	Non-equipment investment	X_{21}	Degree of capitalism

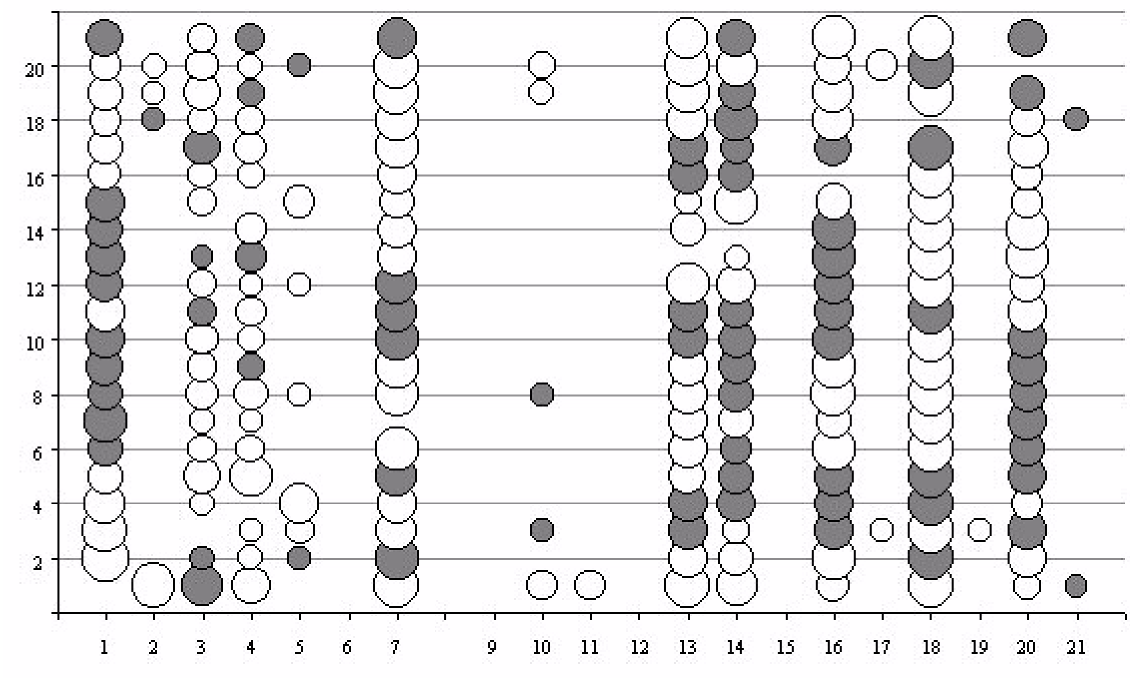

FIGURE 3—ROBUSTNESS OF CORRELATIONS WITH GROWTH ACCORDING TO SIZE AND SIGNIFICANCE

Note: The size of the circles represents the proportion of significant results. Circles in white are robust in significance applying the rule that at least 43 percent of the results should be significantly different from zero. Gray circles are robust in significance as well as in size. Robustness in size implies that the mean of the estimated parameter of the variable of interest (on the *x*-axis), conditioned by the variable indicated on the *y*-axis, lies within the 95% confidence interval of the grand mean of the estimated parameter of the variable of interest. The size of the circle at coordinate (1,2) is equal to 1. The numerical values on the axes refer to:

X_1	log(GDP per capita 1960)	X_8	Omitted (Public consumption share)	X_{15}	Liquid liabilities to GDP
X_2	Life expectancy 1960	X_9	Absolute latitude	X_{16}	Fraction Buddhist
X_3	Primary school enrollment 1960	X_{10}	Primary exports in 1970	X_{17}	Fraction Catholic
X_4	Sub-Sahara African dummy	X_{11}	Rule of law	X_{18}	Fraction Confucian
X_5	Latin American dummy	X_{12}	Exchange rate distortions	X_{19}	Fraction Muslim
X_6	St.dev. black market premium	X_{13}	Equipment investment	X_{20}	Fraction Protestant
X_7	Number of years open economy	X_{14}	Non-equipment investment	X_{21}	Degree of capitalism

See also the note to Figure 1.

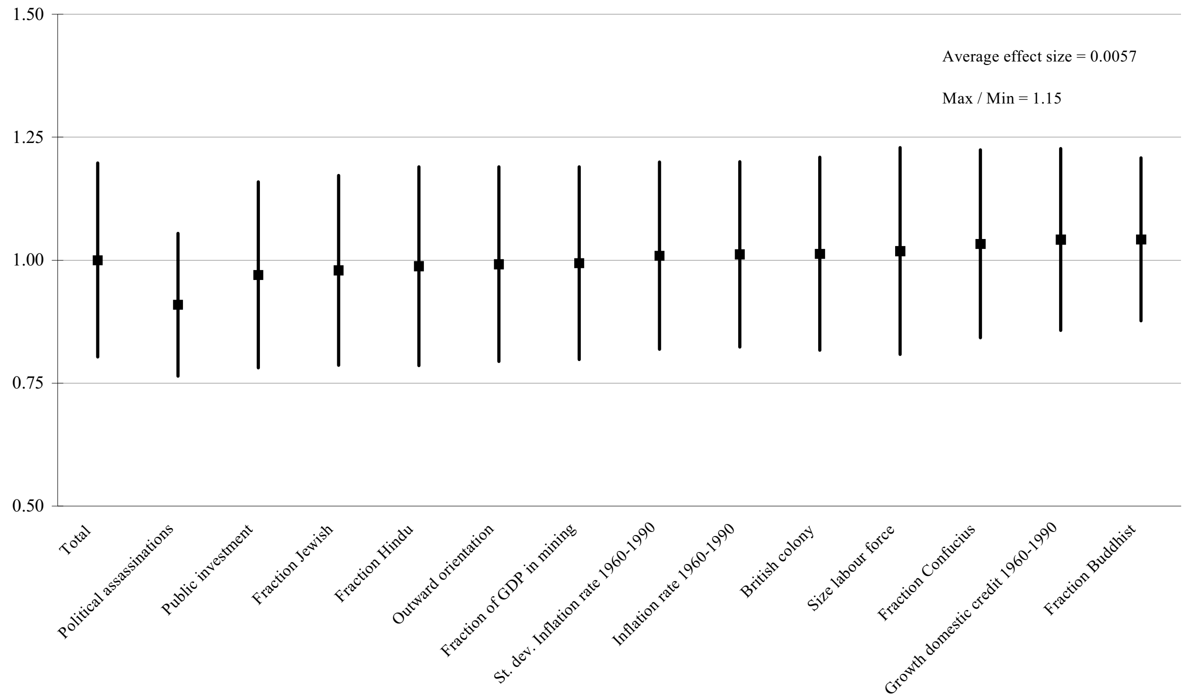

FIGURE 4A—RESPONSE SURFACE ANALYSIS:
CONDITIONAL MEAN EFFECT SIZE OF INITIAL INCOME RELATIVE TO GRAND MEAN (=1)

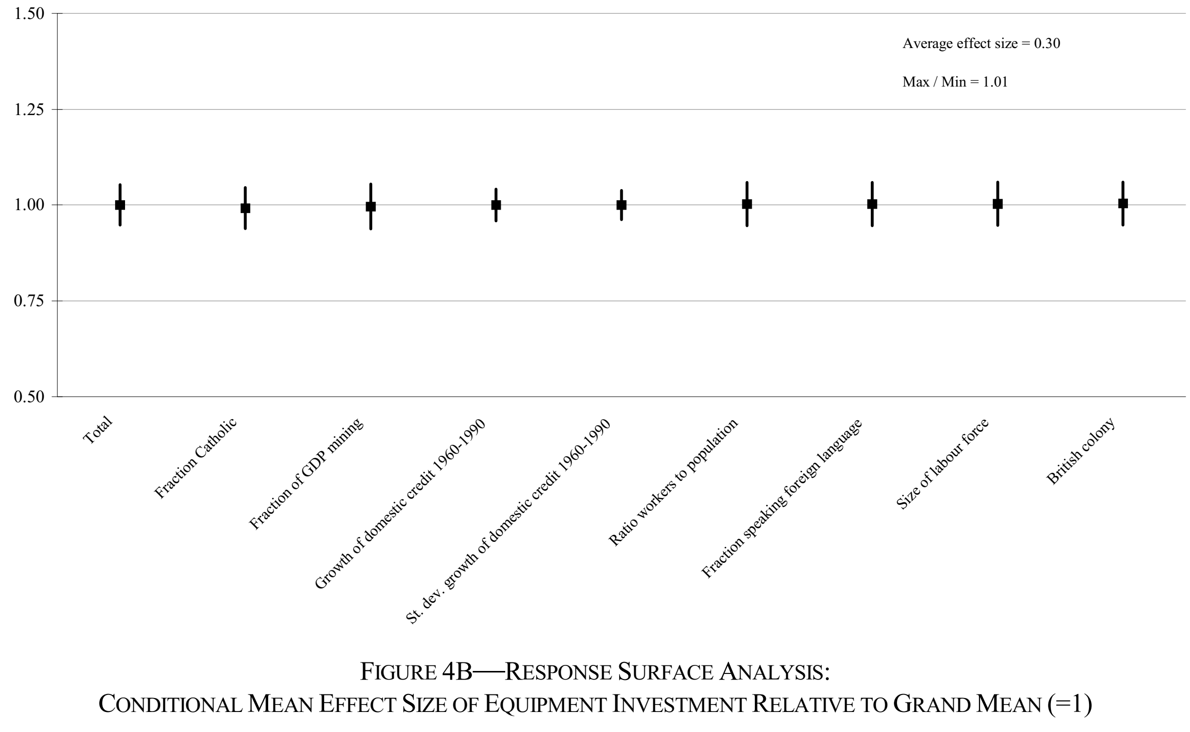

FIGURE 4B—RESPONSE SURFACE ANALYSIS:
CONDITIONAL MEAN EFFECT SIZE OF EQUIPMENT INVESTMENT RELATIVE TO GRAND MEAN (=1)

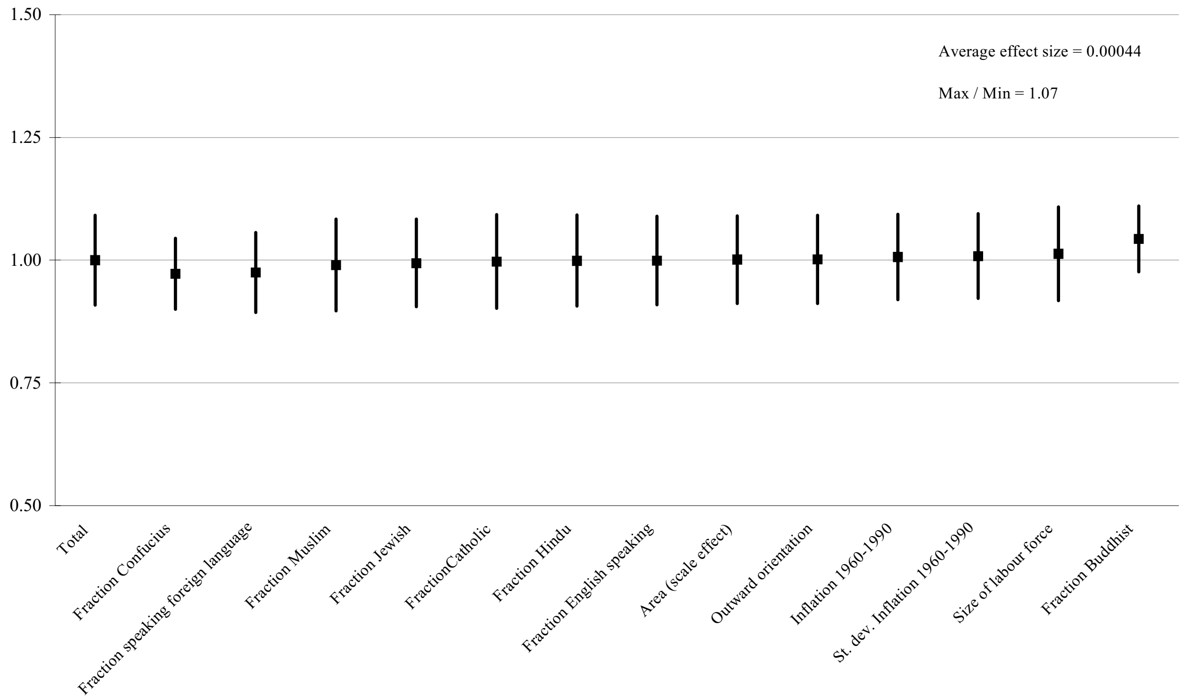

FIGURE 4C—RESPONSE SURFACE ANALYSIS:
CONDITIONAL MEAN EFFECT SIZE OF ABSOLUTE LATITUDE RELATIVE TO GRAND MEAN (=1)

TABLE 1—ESTIMATION AND SENSITIVITY TEST RESULTS FOR GROWTH REGRESSIONS

Variable	Mean	St. dev.	Conf. int. left	Conf. int. right	Pos. signif.	Neg. signif.	SS	WS	SEB	WEB	WWEB	WCDF
log(GDP per capita 1960)	-0.01496	0.00239	-0.01532	-0.01461	0.00%	99.98%	+	+	-	+	+	0.000
Life expectancy 1960	0.00117	0.00032	0.00112	0.00121	95.81%	0.00%	-	+	-	+	+	1.000
Primary school enrolment 1960	0.01722	0.00835	0.01599	0.01846	48.33%	0.00%	-	+	-	-	+	0.966
Number of years open economy	0.02340	0.00334	0.02289	0.02390	99.97%	0.00%	+	+	-	+	+	1.000
Equipment investment	0.25724	0.03062	0.25265	0.26182	99.95%	0.00%	+	+	-	+	+	1.000
Fraction Confucian	0.07394	0.00740	0.07284	0.07505	100.00%	0.00%	+	+	+	+	+	1.000
Rule of law	0.02236	0.00605	0.02145	0.02326	93.87%	0.00%	+	+	-	-	+	1.000
Fraction Muslim	0.01579	0.00401	0.01519	0.01639	91.80%	0.00%	-	+	-	-	+	0.999
Fraction Buddhist	0.02548	0.00475	0.02477	0.02619	93.81%	0.00%	+	+	-	-	+	0.999
Non-equipment investment	0.07790	0.01902	0.07505	0.08076	79.75%	0.00%	+	+	-	-	+	0.993
Absolute latitude	0.00027	0.00008	0.00026	0.00028	66.61%	0.00%	-	+	-	-	+	0.987
Liquid liabilities to GDP	0.02419	0.00784	0.02301	0.02536	67.34%	0.00%	-	+	-	-	+	0.986
Degree of capitalism	0.00188	0.00075	0.00176	0.00199	36.08%	0.00%	-	+	-	-	+	0.953
Defense spending share	0.08464	0.03737	0.07904	0.09025	18.20%	0.00%	-	+	-	-	+	0.922
Fraction speaking foreign language	0.00502	0.00342	0.00451	0.00554	19.46%	0.00%	-	-	-	-	+	0.907
Free trade openness	0.02706	0.01714	0.02449	0.02963	3.27%	0.00%	-	-	-	-	+	0.854
Outward orientation	0.00231	0.00179	0.00204	0.00258	1.61%	0.00%	-	-	-	-	+	0.779
Size labor force	0.00000	0.00000	0.00000	0.00000	0.29%	0.00%	-	-	-	-	+	0.768
Urbanization rate	0.00742	0.00654	0.00644	0.00840	0.99%	0.00%	-	-	-	-	+	0.760
Secondary school enrolment	0.00968	0.00991	0.00820	0.01117	2.53%	0.01%	-	-	-	-	+	0.752
Fraction of GDP in mining	0.01339	0.02297	0.00995	0.01683	12.12%	0.18%	-	-	-	-	+	0.744
Public investment share	0.02046	0.02586	0.01658	0.02433	0.93%	0.04%	-	-	-	-	+	0.704
Gov. education expenditure share	0.07865	0.09787	0.06398	0.09331	0.30%	0.00%	-	-	-	-	+	0.687
French colony	0.00186	0.00217	0.00154	0.00219	0.15%	0.00%	-	-	-	-	+	0.662
Political instability	0.00527	0.00869	0.00397	0.00657	0.50%	0.00%	-	-	-	-	+	0.637
Average years of higher school	0.00761	0.01490	0.00538	0.00984	0.01%	0.00%	-	-	-	-	+	0.615
Average years of secondary school	0.00359	0.01261	0.00170	0.00548	3.04%	0.00%	-	+	-	-	+	0.582
Growth domestic credit 1960-1990	0.00001	0.00004	0.00001	0.00002	0.03%	0.00%	-	-	-	-	+	0.565
Area (scale effect)	0.00000	0.00000	0.00000	0.00000	0.02%	0.00%	-	-	-	-	-	0.555
Higher education enrolment	0.00503	0.02119	0.00185	0.00820	0.00%	0.01%	-	-	-	-	-	0.542
Terms of trade growth	0.00306	0.03031	-0.00148	0.00760	0.08%	0.01%	-	-	-	-	-	0.536
Average years of schooling	0.00004	0.01273	-0.00187	0.00195	0.23%	0.52%	-	-	-	-	-	0.501
St. dev. Inflation rate 1960-1990	0.00000	0.00001	0.00000	0.00000	2.41%	0.82%	-	-	-	-	-	0.494
Growth rate of population	-0.02533	0.17314	-0.05128	0.00062	0.23%	0.08%	-	-	-	-	-	0.472
Average years of primary school	-0.00178	0.01252	-0.00366	0.00010	0.00%	3.29%	-	-	-	-	-	0.459
Fraction Hindu	-0.00100	0.00808	-0.00221	0.00021	0.22%	0.23%	-	-	-	-	-	0.459
British colony	-0.00050	0.00214	-0.00082	-0.00018	0.03%	0.73%	-	-	-	-	-	0.448
Fraction Jewish	-0.03922	0.11266	-0.05611	-0.02234	0.02%	0.16%	-	-	-	-	+	0.384
Political assassinations	-0.01363	0.01625	-0.01606	-0.01119	0.01%	0.00%	-	-	-	-	+	0.338
Av. Years schooling × log(GDP60)	-0.00013	0.00031	-0.00017	-0.00008	0.00%	2.07%	-	-	-	-	+	0.333
Tariff restrictions	-0.04300	0.05578	-0.05136	-0.03464	0.09%	0.46%	-	-	-	-	+	0.301
Black-market premium	-0.00268	0.00482	-0.00340	-0.00195	0.86%	2.38%	-	-	-	-	+	0.297
Ethnolinguistic fractionalization	-0.00334	0.00366	-0.00389	-0.00279	0.00%	1.45%	-	-	-	-	+	0.282
Revolutions and coups	-0.00398	0.00475	-0.00469	-0.00327	0.01%	2.73%	-	-	-	-	+	0.267
Inflation rate 1960-1990	-0.00003	0.00004	-0.00004	-0.00002	0.00%	6.00%	-	-	-	-	+	0.204
St. dev. Domestic credit	-0.00003	0.00003	-0.00003	-0.00002	0.00%	5.19%	-	-	-	-	+	0.189
Civil liberties	-0.00151	0.00126	-0.00169	-0.00132	0.01%	12.00%	-	-	-	-	+	0.162
Ratio workers to population	-0.00775	0.00791	-0.00894	-0.00657	0.07%	22.41%	-	-	-	-	+	0.142
Index of democracy	-0.00877	0.00406	-0.00938	-0.00816	0.00%	9.50%	-	+	-	-	+	0.101
War dummy	-0.00421	0.00222	-0.00454	-0.00387	0.00%	19.59%	-	+	-	-	+	0.083
Political rights	-0.00210	0.00085	-0.00223	-0.00197	0.00%	30.65%	-	+	-	-	+	0.059
Fraction English speaking	-0.00979	0.00338	-0.01029	-0.00928	0.00%	26.09%	-	+	-	-	+	0.051
Spanish colony	-0.00684	0.00426	-0.00748	-0.00620	0.00%	45.98%	-	-	-	-	+	0.051
St. dev. Black market premium	-0.00003	0.00001	-0.00003	-0.00003	0.00%	24.69%	-	+	-	-	+	0.042
Public consumption share	-0.04744	0.02613	-0.05136	-0.04353	0.00%	37.18%	-	+	-	-	+	0.033
Fraction Protestant	-0.01393	0.00431	-0.01458	-0.01329	0.00%	57.58%	-	+	-	-	+	0.018
Exchange rate distortions	-0.00009	0.00004	-0.00010	-0.00008	0.00%	56.18%	-	+	-	-	+	0.014
Fraction Catholic	-0.01130	0.00297	-0.01174	-0.01085	0.00%	84.35%	-	+	-	-	+	0.003
Sub-Sahara African dummy	-0.01173	0.00397	-0.01232	-0.01113	0.00%	79.49%	-	+	-	-	+	0.003
Primary exports in 1970	-0.01942	0.00383	-0.01999	-0.01885	0.00%	93.70%	-	+	-	-	+	0.001
Latin American dummy	-0.01126	0.00338	-0.01176	-0.01075	0.00%	87.96%	-	+	-	-	+	0.001

Note: The first three variables are "fixed" in all regressions, and the results are based on 30,856 regressions. The results for the other variables are based on 29,260 regressions. The abbreviations for the sensitivity tests are as follows: strong and weak sign test (SS and WS, respectively), strong and weak extreme bounds test (SEB and WEB, respectively), weighted weak extreme bounds test (WWEB), and weighted cumulative distribution function test (WCDF). The + indicates "pass," and the - "fail." Shading signals "pass" on the basis of a two-sided test at the 5% level.

TABLE—2A ESTIMATION AND SENSITIVITY TEST RESULTS FOR GROWTH REGRESSIONS WITH 21 KEY VARIABLES, OF WHICH 3 ARE FIXED

Variable	Mean	St. dev.	Conf. int. left	Conf. int. right	Pos. signif.	Neg. signif.	SS	WS	SEB	WEB	WWEB	WCDF
log(GDP per capita 1960)	-0.01516	0.00249	-0.01582	-0.01451	0.00%	100.00%	+	+	+	+	+	0.000
Life expectancy 1960	0.00082	0.00029	0.00074	0.00089	82.97%	0.00%	-	+	-	-	+	0.999
Primary school enrollment 1960	0.02008	0.00967	0.01754	0.02263	68.01%	0.00%	-	+	-	-	+	0.990
Equipment investment	0.22449	0.03020	0.21288	0.23610	99.41%	0.00%	+	+	-	+	+	1.000
Fraction Confucian	0.06550	0.00791	0.06245	0.06854	100.00%	0.00%	+	+	+	+	+	1.000
Number of years open economy	0.01917	0.00316	0.01795	0.02038	98.97%	0.00%	+	+	-	+	+	1.000
Rule of law	0.01847	0.00534	0.01641	0.02052	89.41%	0.00%	+	+	-	-	+	0.999
Fraction Muslim	0.01299	0.00412	0.01141	0.01458	82.50%	0.00%	-	+	-	-	+	0.998
Fraction Buddhist	0.02001	0.00560	0.01785	0.02216	75.00%	0.00%	+	+	-	-	+	0.994
Non-equipment investment	0.07095	0.02104	0.06286	0.07904	73.09%	0.00%	+	+	-	-	+	0.993
Degree of capitalism	0.00193	0.00072	0.00165	0.00220	46.32%	0.00%	-	+	-	-	+	0.970
Absolute latitude	0.00018	0.00010	0.00014	0.00022	32.94%	0.00%	-	+	-	-	+	0.939
Liquid liabilities to GDP	0.01534	0.00879	0.01196	0.01872	30.29%	0.00%	-	+	-	-	+	0.932
Public consumption share	-0.02545	0.02224	-0.03400	-0.01689	0.00%	13.68%	-	-	-	-	+	0.138
Exchange rate distortions	-0.00006	0.00003	-0.00007	-0.00005	0.00%	32.94%	-	+	-	-	+	0.058
St.dev. black market premium	-0.00002	0.00001	-0.00003	-0.00002	0.00%	22.06%	-	+	-	-	+	0.056
Fraction Catholic	-0.00823	0.00377	-0.00968	-0.00678	0.00%	56.47%	-	+	-	-	+	0.017
Fraction Protestant	-0.01314	0.00557	-0.01529	-0.01100	0.00%	59.26%	-	+	-	-	+	0.013
Latin American dummy	-0.00815	0.00464	-0.00994	-0.00637	0.00%	60.15%	-	+	-	-	+	0.010
Primary exports in 1970	-0.01570	0.00447	-0.01742	-0.01398	0.00%	79.26%	-	+	-	-	+	0.005
Sub-Sahara African dummy	-0.01104	0.00470	-0.01285	-0.00923	0.00%	72.94%	-	+	-	-	+	0.002

Note: The first three variables are "fixed" in all regressions, and the results are based on 3,060 regressions. The results for the other variables are based on 680 regressions. For the meaning of abbreviations, symbols and shading, see Table 1.

TABLE—2B ESTIMATION AND SENSITIVITY TEST RESULTS FOR GROWTH REGRESSIONS WITH 21 KEY VARIABLES, OF WHICH NONE ARE FIXED

Variable	Mean	St. dev.	Conf. int. left	Conf. int. right	Pos. signif.	Neg. signif.	SS	WS	SEB	WEB	WWEB	WCDF
Fraction Confucian	0.07750	0.01038	0.07605	0.07895	99.99%	0.00%	+	+	-	+	+	1.000
Equipment investment	0.20307	0.06204	0.19440	0.21173	85.35%	0.00%	-	+	-	-	+	1.000
Number of years open economy	0.01780	0.00513	0.01708	0.01852	89.66%	0.00%	+	+	-	-	+	1.000
Fraction Buddhist	0.02438	0.00766	0.02331	0.02545	87.14%	0.00%	-	+	-	-	+	0.999
Non-equipment investment	0.08338	0.02737	0.07956	0.08721	78.92%	0.00%	+	+	-	-	+	0.997
Primary school enrollment 1960	0.02059	0.01147	0.01899	0.02219	64.69%	0.01%	-	+	-	-	+	0.995
Life expectancy 1960	0.00043	0.00048	0.00037	0.00050	44.49%	0.19%	-	-	-	-	+	0.975
Degree of capitalism	0.00181	0.00094	0.00168	0.00195	32.76%	0.00%	-	+	-	-	+	0.938
Rule of law	0.00836	0.00795	0.00725	0.00947	29.49%	0.02%	-	-	-	-	+	0.919
Fraction Muslim	0.00631	0.00708	0.00532	0.00730	32.49%	1.78%	-	-	-	-	+	0.874
Liquid liabilities to GDP	0.00820	0.01264	0.00644	0.00997	21.12%	0.69%	-	-	-	-	+	0.786
Absolute latitude	0.00005	0.00017	0.00003	0.00007	13.14%	3.94%	-	-	-	-	+	0.651
Public consumption share	0.00027	0.02969	-0.00388	0.00442	1.59%	4.02%	-	-	-	-	-	0.470
Exchange rate distortions	-0.00005	0.00004	-0.00006	-0.00005	0.00%	27.30%	-	-	-	-	+	0.096
Fraction Catholic	-0.00622	0.00546	-0.00698	-0.00546	0.10%	33.74%	-	-	-	-	+	0.084
St.dev. black market premium	-0.00002	0.00001	-0.00003	-0.00002	0.00%	19.30%	-	+	-	-	+	0.066
Primary exports in 1970	-0.01195	0.00746	-0.01299	-0.01090	0.01%	43.53%	-	-	-	-	+	0.035
Latin American dummy	-0.00795	0.00559	-0.00873	-0.00717	0.01%	48.24%	-	-	-	-	+	0.031
Sub-Sahara African dummy	-0.01148	0.00615	-0.01234	-0.01062	0.00%	62.87%	-	+	-	-	+	0.006
Fraction Protestant	-0.01840	0.00660	-0.01933	-0.01748	0.00%	79.88%	-	+	-	-	+	0.002
Log(GDP per capita 1960)	-0.00970	0.00498	-0.01039	-0.00900	0.24%	81.76%	-	+	-	-	+	0.000

Note: None of the variables are "fixed," and the results are based on 38,760 regressions. For the meaning of abbreviations, symbols and shading, see Table 1.

TABLE 3—PROPORTIONS OF SIGNIFICANT RESULTS OF 21 KEY VARIABLES

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
X_1 log(GDP per capita 1960)		0.95	0.89	0.83	0.41	0.25	0.98	0.10	0.29	0.64	0.66	0.45	0.98	0.88	0.36	0.73	0.28	1.00	0.33	0.59	0.51
X_2 Life expectancy 1960	1.00		0.53	0.55	0.52	0.18	0.92	0.06	0.10	0.38	0.27	0.21	0.85	0.76	0.09	0.93	0.39	1.00	0.46	0.85	0.32
X_3 Primary school enrollment 1960	0.97	0.25		0.52	0.63	0.19	0.89	0.03	0.20	0.52	0.36	0.17	0.85	0.60	0.23	0.84	0.51	1.00	0.53	0.84	0.26
X_4 Sub-Sahara African dummy	0.90	0.35	0.56		0.87	0.16	0.87	0.04	0.17	0.44	0.41	0.00	0.86	0.82	0.28	0.85	0.45	1.00	0.27	0.69	0.34
X_5 Latin American dummy	0.75	0.48	0.79	0.91		0.22	0.89	0.07	0.17	0.40	0.24	0.38	0.82	0.78	0.13	0.86	0.10	1.00	0.18	0.84	0.32
X_6 St.dev. black market premium	0.80	0.44	0.63	0.64	0.46		0.92	0.07	0.17	0.41	0.26	0.22	0.85	0.72	0.25	0.92	0.36	1.00	0.35	0.78	0.19
X_7 Number of years open economy	0.92	0.34	0.59	0.52	0.40	0.28		0.03	0.14	0.39	0.12	0.22	0.86	0.76	0.16	0.78	0.34	1.00	0.37	0.85	0.07
X_8 Public consumption share	0.76	0.48	0.71	0.75	0.51	0.18	0.96		0.18	0.51	0.31	0.31	0.85	0.78	0.16	0.96	0.40	1.00	0.42	0.81	0.24
X_9 Absolute latitude	0.82	0.45	0.68	0.63	0.47	0.20	0.93	0.06		0.47	0.30	0.29	0.86	0.81	0.21	0.93	0.32	1.00	0.30	0.83	0.34
X_{10} Primary exports in 1970	0.83	0.41	0.69	0.60	0.40	0.02	0.93	0.08	0.11		0.22	0.32	0.84	0.81	0.17	0.91	0.32	1.00	0.36	0.83	0.29
X_{11} Rule of law	0.87	0.38	0.61	0.67	0.44	0.23	0.89	0.04	0.12	0.43		0.28	0.88	0.76	0.21	0.86	0.35	1.00	0.37	0.86	0.30
X_{12} Exchange rate distortions	0.82	0.43	0.62	0.52	0.53	0.14	0.91	0.06	0.15	0.49	0.28		0.91	0.87	0.26	0.87	0.35	1.00	0.31	0.75	0.35
X_{13} Equipment investment	0.88	0.34	0.50	0.69	0.35	0.03	0.83	0.04	0.11	0.25	0.13	0.37		0.55	0.10	0.94	0.32	1.00	0.44	0.97	0.28
X_{14} Non-equipment investment	0.81	0.39	0.36	0.68	0.47	0.15	0.82	0.01	0.23	0.50	0.29	0.44	0.78		0.08	0.94	0.35	1.00	0.43	0.92	0.42
X_{15} Liquid liabilities to GDP	0.85	0.29	0.67	0.33	0.71	0.16	0.74	0.06	0.14	0.13	0.15	0.13	0.57	0.92		0.79	0.34	1.00	0.28	0.67	0.24
X_{16} Fraction Buddhist	0.73	0.46	0.62	0.60	0.40	0.40	0.85	0.05	0.26	0.50	0.26	0.17	0.88	0.80	0.25		0.14	1.00	0.37	0.69	0.41
X_{17} Fraction Catholic	0.75	0.49	0.78	0.72	0.28	0.24	0.93	0.07	0.17	0.48	0.33	0.33	0.85	0.72	0.28	0.80		1.00	0.18	0.89	0.35
X_{18} Fraction Confucian	0.70	0.52	0.62	0.63	0.45	0.25	0.90	0.08	0.16	0.19	0.28	0.39	0.88	0.94	0.46	0.90	0.24		0.43	0.76	0.52
X_{19} Fraction Muslim	0.76	0.51	0.80	0.61	0.40	0.22	0.96	0.08	0.18	0.55	0.35	0.31	0.90	0.81	0.25	0.91	0.24	1.00		0.76	0.38
X_{20} Fraction Protestant	0.68	0.54	0.70	0.55	0.53	0.28	0.97	0.05	0.23	0.60	0.43	0.19	0.96	0.90	0.26	0.81	0.67	1.00	0.21		0.48
X_{21} Degree of capitalism	0.82	0.44	0.61	0.64	0.46	0.14	0.88	0.07	0.17	0.47	0.28	0.32	0.88	0.84	0.26	0.93	0.33	1.00	0.33	0.84	
Minimum	0.68	0.25	0.36	0.33	0.28	0.02	0.74	0.01	0.10	0.13	0.12	0.00	0.57	0.55	0.08	0.73	0.10	1.00	0.18	0.59	0.07
Maximum	1.00	0.95	0.89	0.91	0.87	0.40	0.98	0.10	0.29	0.64	0.66	0.45	0.98	0.94	0.46	0.96	0.67	1.00	0.53	0.97	0.52
Range	0.32	0.70	0.53	0.59	0.59	0.38	0.24	0.09	0.19	0.51	0.54	0.44	0.41	0.39	0.38	0.23	0.57	0.00	0.35	0.37	0.45

TABLE 4—RESPONSE SURFACE RESULTS FOR EFFECT SIZES OF 21 KEY VARIABLES

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
X_1 log(GDP per capita 1960)		2.36	1.43	1.27	0.81	0.98	1.19	-85.47	3.32	1.27	1.92	1.22	1.20	1.08	1.80	0.85	0.82	0.91	0.86	0.77	1.20
X_2 Life expectancy 1960	1.52		0.89	0.88	1.04	1.01	0.96	1.96	0.05	0.93	0.97	0.92	0.96	0.93	0.71	1.07	1.13	1.01	1.40	1.05	0.99
X_3 Primary school enrollment 1960	1.23	0.44		0.82	1.21	0.99	0.95	19.36	1.02	1.10	1.07	0.87	0.98	0.84	1.01	0.96	1.41	0.98	1.57	1.02	0.88
X_4 Sub-Sahara African dummy	1.10	0.74	0.83		1.62	0.95	0.94	14.14	-0.48	0.99	1.30	0.42	1.01	1.01	1.18	0.95	1.19	0.99	0.58	0.87	0.98
X_5 Latin American dummy	0.88	1.09	1.15	1.43		1.05	1.00	-33.15	-0.09	0.97	0.85	1.13	0.96	0.98	0.09	0.99	0.51	1.00	0.47	1.03	0.96
X_6 St.dev. black market premium	0.97	1.06	1.02	1.06	0.97		1.10	-7.80	0.83	1.01	0.94	0.93	1.04	0.96	1.08	1.09	1.07	1.03	1.02	1.00	0.86
X_7 Number of years open economy	1.04	0.69	0.84	0.79	0.81	1.09		37.75	0.79	0.91	0.49	0.90	0.94	0.91	0.49	0.86	1.00	0.96	1.12	1.00	0.57
X_8 Public consumption share	0.94	1.10	1.11	1.17	1.05	1.01	1.09		1.00	1.11	1.05	1.02	0.94	1.00	1.08	1.15	1.15	1.04	1.19	1.03	0.91
X_9 Absolute latitude	1.02	1.05	1.03	1.03	1.01	1.03	1.05	-13.56		1.12	1.04	1.06	1.04	1.04	0.98	1.13	0.97	1.03	0.87	1.04	1.00
X_{10} Primary exports in 1970	1.00	0.86	1.03	0.94	0.86	0.82	1.01	-19.24	-0.37		0.84	1.14	0.97	1.02	0.77	1.04	0.97	0.98	1.12	1.04	0.95
X_{11} Rule of law	1.17	0.86	1.02	1.14	0.93	1.06	1.00	15.38	0.34	1.03		1.01	1.02	0.97	1.02	1.00	1.05	1.01	1.15	1.08	1.04
X_{12} Exchange rate distortions	0.97	0.95	0.95	0.92	1.08	0.91	1.03	-10.41	0.88	1.07	0.95		1.08	1.12	1.18	1.00	1.05	1.03	0.92	0.93	1.04
X_{13} Equipment investment	1.05	0.67	0.84	1.01	0.73	0.73	0.86	67.38	0.33	0.67	0.56	1.14		0.76	0.60	1.03	0.93	0.97	1.38	1.16	0.93
X_{14} Non-equipment investment	0.97	0.92	0.67	1.06	0.96	0.90	0.91	21.14	1.49	1.09	0.98	1.33	0.89		0.13	1.06	1.00	1.03	1.37	1.12	1.13
X_{15} Liquid liabilities to GDP	1.03	0.61	1.10	0.76	1.46	1.09	0.85	55.85	1.91	0.65	0.60	0.81	0.78	1.25		0.82	0.99	0.96	0.95	0.89	1.06
X_{16} Fraction Buddhist	0.81	1.00	0.91	0.88	0.85	1.21	0.92	-24.51	2.89	1.06	0.91	0.78	0.99	0.96	1.10		0.52	0.97	1.09	0.84	1.10
X_{17} Fraction Catholic	0.88	1.07	1.18	1.10	0.83	1.06	1.05	-16.88	0.90	1.07	1.09	1.11	0.99	0.95	1.30	0.98		1.00	0.45	1.24	1.00
X_{18} Fraction Confucian	0.74	1.09	0.85	0.89	0.87	1.02	0.94	3.36	1.29	0.49	0.90	1.14	0.97	1.06	2.18	0.92	0.66		1.15	0.87	1.16
X_{19} Fraction Muslim	0.92	1.26	1.21	0.98	0.92	1.03	1.09	1.80	0.51	1.20	1.20	1.09	1.07	1.04	1.07	1.08	0.88	1.05		0.98	1.06
X_{20} Fraction Protestant	0.79	1.19	1.02	0.87	1.04	1.07	1.07	-1.95	2.44	1.21	1.37	0.83	1.14	1.09	1.08	0.91	1.72	0.98	0.36		1.18
X_{21} Degree of capitalism	0.97	0.99	0.93	0.98	0.96	0.97	1.00	-5.15	0.95	1.04	0.95	1.13	1.03	1.05	1.16	1.08	0.98	1.05	0.97	1.04	
Minimum	0.74	0.44	0.67	0.76	0.73	0.73	0.85	-85.47	-0.48	0.49	0.49	0.42	0.78	0.76	0.09	0.82	0.51	0.91	0.36	0.77	0.57
Maximum	1.52	2.36	1.43	1.43	1.62	1.21	1.19	67.38	3.32	1.27	1.92	1.33	1.20	1.25	2.18	1.15	1.72	1.05	1.57	1.24	1.20
Range	0.78	1.92	0.77	0.67	0.89	0.48	0.33	152.85	3.80	0.78	1.43	0.92	0.42	0.49	2.09	0.32	1.21	0.14	1.21	0.47	0.64
Mean effect size	-0.010	0.000	0.021	-0.011	-0.008	0.000	0.018	0.000	0.000	-0.012	0.008	0.000	0.203	0.083	0.008	0.024	-0.006	0.078	0.006	-0.018	0.002
Mean explanatory variable	7.297	52.268	0.692	0.321	0.216	43.946	0.336	0.097	22.786	0.748	0.504	125.336	0.039	0.139	0.324	0.040	0.340	0.013	0.252	0.154	3.293
Standard deviation expl. var.	0.902	12.427	0.321	0.469	0.413	87.298	0.347	0.072	15.939	0.279	0.316	40.271	0.034	0.057	0.243	0.159	0.369	0.070	0.371	0.227	1.546
Minimum explanatory variable	5.517	31.500	0.050	0.000	0.000	0.001	0.000	0.006	0.228	0.041	0.000	51.000	0.000	0.030	0.029	0.000	0.000	0.000	0.000	0.000	0.000
Maximum explanatory variable	9.187	73.400	1.000	1.000	1.000	588.627	1.000	0.384	63.892	1.000	1.000	277.000	0.148	0.280	1.599	0.950	1.000	0.600	1.000	0.980	5.000
Growth differential 1 st.dev. min.	-0.65	0.24	0.44	-0.41	-0.24	-0.16	0.53	-0.17	-0.04	-0.16	0.13	-0.09	0.53	0.36	0.02	0.32	-0.12	0.50	0.08	-0.32	0.16
Growth differential 1 st.dev. max.	-1.33	1.27	0.95	-0.77	-0.53	-0.26	0.73	0.13	0.26	-0.42	0.51	-0.29	0.81	0.59	0.43	0.45	-0.39	0.57	0.37	-0.52	0.34