I JUST RAN FOUR MILLION REGRESSIONS

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Abstract:

In this paper I try to move away from the Extreme Bounds method of identifying "robust" empirical relations in the economic growth literature. Instead of analyzing the extreme bounds of the estimates of the coefficient of a particular variable, I analyze the entire distribution. My claim in this paper is that, if we do this, the picture emerging from the empirical growth literature is not the pessimistic "Nothing is Robust" that we get with the extreme bound analysis. Instead, we find that a substantial number of variables can be found to be strongly related to growth.

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JEL Classification: O51, O52, O53.

I have had useful conversations with Robert Barro, Casey Mulligan, and Chris Sims, and I thank them profoundly for that. I also benefited from Manuel Arellano, Fabio Canova, Juanjo Dolado, Kate Howe, Ed Leamer, Albert Marcet, Jane Marrinan, Rafa Repullo, Cava de Santsadurni, Albert Satorra, and Etsuro Shioji. This paper started when I was visiting Universitat Pompeu Fabra in the Spring of 1996 and the International Monetary Fund in the summer of 1996

(1) INTRODUCTION

Following the seminal work of Barro (1991), the recent empirical literature on economic growth has identified a substantial number of variables that are partially correlated with the rate of economic growth. The basic methodology consists of running cross-sectional regressions of the form[1]

$$\gamma = \alpha + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + \ldots + \beta_n \cdot x_n + \epsilon \qquad (1)$$

where γ is the vector of rates of economic growth, and $x_{1,}...,x_n$ are vectors of explanatory variables which vary across researchers and across papers. Each paper typically reports a (possibly non-random) sample of the regressions actually run by the researcher. Variables like the initial level of income, the investment rate, various measures of education, some policy indicators and many other variables have been found to be significantly correlated with growth in regressions like (1). I have collected around 60 variables which have been found to be significant in at least one regression.

The problem faced by empirical growth economists is that growth theories are not explicit enough about what variables x_j belong in the "true" regression. That is, even if we know that the "true" model looks like (1), we do not know exactly what variables x_j we should use. One reason is that economic growth theory is not explicit about what variables matter for growth. For example, almost all growth theories say that the "level of technology" [the constant "A" in Y=AF(K,L)] is an important determinant of growth. Neoclassical theories say that the level of A affects the growth rate along a transition towards the no-growth steady state. Endogenous growth theory says that A affects the steady-state growth rate. But whether it has a temporary or a permanent effect on growth, we all agree that A affects the growth rate. From a macroeconomic perspective, there are a lot of things other than the "engineering" level of technology, which can be thought of as "level of technology", A. In other words, there are many things that may affect the aggregate amount of output, given the aggregate amount of inputs. These may include market distortions, distortionary taxes, maintenance of property rights, degree of monopoly, weather,

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[1] Recently, a number of authors have broken up the period of analysis into various sub-periods and have estimated the same type of regressions using panel techniques.

attitudes towards work, and so on. A good theorist could make almost any variable affect the level of technology in this broad sense and, as a result, he could make almost any variable look like an important theoretical determinant of the rate of economic growth. This is the same as saying that the theory is silent when it comes to providing much guidance in our search for the "true" explanatory variables.

Another problem is that, even if theory was clear in pointing to the important "theoretical determinants" of growth, the empirical estimation of these determinants is not immediate. For example, we may have a theory that says that human capital is important for growth. How do we measure human capital? There are lots of imperfect measures and it is not clear a priori which one is better. Other theories may point to "efficient government" as a key to economic growth. How do we measure that? How do we compare "inefficient bureaucracies" across countries? How do we compare "degrees of corruption in the government" across countries? And even if we could measure both the level of "inefficient bureaucracy" and the "degree of corruption in the government", which one is a better measure "efficient government"?

All this has led empirical economists to follow theory loosely and simply "try" various variables relating the various potentially important determinants of growth. However, as soon as one starts running regressions combining the various variables one soon finds that variable x_1 is significant when the regression includes variables x_2 and x_3, but it becomes non-significant when x_4 is included. Since we don't know a priori the "true" variables that should be included, we are left with the question: what are the variables that are really correlated with growth?

An initial answer to this question was given by Levine and Renelt (1992). They applied Leamer's (1983, 1985) *extreme bounds test* to identify "robust" empirical relations in the economic growth literature. In short, the extreme bounds test works as follows: Imagine that we have a pool of N variables that have been previously identified to be related to growth and we are interested in knowing whether variable *z* is "robust". We would estimate regressions of the form:

$$\gamma = \alpha_j + \beta_{yj} \cdot y + \beta_{zj} \cdot z + \beta_{xj} \cdot x_j + \epsilon \qquad (2)$$

where *y* is a vector of *fixed* variables that always appear in the regressions (in the Levine and Renelt paper, these variables are the *initial level of income*, the *investment rate*, the *secondary* *school enrollment rate* and the *rate of population growth*), z is the variable of interest and $x_j \in X$ is a vector of up to three variables taken from the pool X of N variables available. One needs to estimate this regression or model for the M possible combinations of $x_j \in X$. For each model j, one finds an estimate, β_{zj}, and the corresponding standard deviation, σ_{zj}. The *lower extreme bound* is defined to be the lowest value of $\beta_{zj}-2\sigma_{zj}$ and the *upper extreme bound* is defined to be the largest value of $\beta_{zj}+2\sigma_{zj}$. The *extreme bounds test* for variable z says that if the lower extreme bound is negative and the upper extreme bound is positive, then variable z is not robust.[2]

Not surprisingly, Levine and Renelt's conclusion is that very few (or no) variables are robust. One possible reason for finding few or no robust variables is, of course, that very few variables can be identified to be correlated systematically with growth. Hence, some researcher's reading of the Levine and Renelt paper concluded that "*nothing can be learned from this empirical growth literature because no variables are robustly correlated with growth*". Another explanation, however, is that the test is too strong for any variable to really pass it: if the distribution of the estimators of β_z has some positive and some negative support, then one is bound to find one regression for which the estimated coefficient changes signs if enough regressions are run. Thus, giving the label of non-robust to all variables is all but guaranteed. This problem is especially strong if one considers that a lot of the variables used in the literature reflect similar economic phenomena so multicollinearity among variables is considerable. Hence, instead of rejecting the theory (or the data), one is tempted to reject the test!

(2) MOVING AWAY FROM EXTREME TESTS

In this paper I want to move away from this "*extreme test*". In fact, I want to depart from the zero-one labeling variables of "robust" vs. "non-robust" and, instead, I want to assign some level of confidence to each of the variables. One way to move away from the extreme bounds test is to look at the whole distribution of the estimators of β_z. In particular, we might be interested in

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[2] Note that this amounts to saying that if one finds ONE regression for which the sign of the coefficient β_z changes, or becomes insignificant, then the variable is not robust.

the fraction of the cumulative distribution function lying on each side of zero[3]. The immediate problem is that we do not know the exact form of this distribution. Hence, I will operate under two different assumptions.

(A) Case 1: The distribution of the estimates of β_z across models is normal. When the density function is normal, we need to compute the mean and the standard deviation of this distribution. For each of the M models, we compute the (integrated) likelihood, L_j, the point estimate β_{zj}, and the standard deviation σ_{zj}. With all these numbers we will construct the mean estimate of $\hat{\beta}_z$ as the weighted average each of the M point estimates, β_{zj},

$$\hat{\beta}_z = \sum_{j=1}^{M} \omega_{zj} \cdot \beta_{zj} \qquad (4)$$

where the weights, ω_{zj}, are proportional to the (integrated) likelihoods:

$$\omega_{zj} = \frac{L_{zj}}{\sum_{i=1}^{M} L_{zi}} \qquad (5)$$

The reason for using this weighting scheme is that we want to give more weight to the regressions or models that are more likely to be the true model. To the extent that the fit of model j is an indication of its probability of being the true model, a likelihood-weighted scheme like the one proposed here should be reasonable. The weighted mean for each of the 59 variables of interest is reported in Column (4) of Table 1.

I also compute the average variance as the weighted average of the M estimated variances, where the weights are given by (5):

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[3] Zero divides the area under the density in two. For the rest of the paper, and in order to economize on space, the LARGER of the two areas will be called "CDF(0)", regardless of whether this is the area above zero or below zero (in other words, regardless of whether this is the CDF(0) or 1-CDF(0).) Hence, what I call CDF(0) will always be a number between 0.50 and 1.

$$\hat{\sigma}_z^2 = \sum_{j=1}^{M} \omega_{zj} \cdot \sigma_{zj}^2 \qquad (6)$$

The (square root of this) variance is reported in Table 1's Column (5). Once we know the mean and the variance of the normal distribution, we compute the CDF(0) using the normal tables, which we report it in Column (6).

(B) Case 2: The distribution of the estimates of β_z across models is NOT normal. If the distribution is not normal, we can still compute its CDF(0) as follows: For each of the M regressions, I will compute the area under the density function to the right of zero which I denote by $\Phi_{zj}(0/\hat{\beta}_{zj},\hat{\sigma}_{zj}^2)$. We then compute the aggregate CDF(0) of β_z as the weighted average of all the individual $\Phi_{zj}(0/\hat{\beta}_{zj},\hat{\sigma}_{zj}^2)$, where the weights are, again, the integrated likelihoods (5). In other words:

$$\Phi_z(0) = \sum_{j=1}^{M} \omega_{jz}\, \Phi_{zj}\,(0 \,/\, \hat{\beta}_{zj}\,,\, \hat{\sigma}_{zj}^2) \qquad (7)$$

The computed weighted CDF(0) is reported in Column (7) in Table 1.

A potential problem with this method is that it is possible that the goodness of fit of model j may not be a good indicator of the probability that model j is the true model. This might happen, for example, when some explanatory variables in our data set are endogenous: Models with endogenous variables may have a (spurious) better fit. Thus, the weights given to these models will tend to be larger and, in fact, they may very well dominate our estimates in Columns (4) through (7). We may find that only one or two of the models get almost all of the weight in our estimated weighted average and these one or two models may suffer from endogeneity bias. One could argue that, when this is a serious problem, the *unweighted average* of all the models may be superior to the weighted averages proposed here. As a way of comparison, Column (8) presents the simple average of the M CDF(0)s:

$$\Phi_z^{NW}(0) = \sum_{j=1}^{M} \frac{\Phi_{zj}\,(0 \,/\, \hat{\beta}_{zj}\,,\, \hat{\sigma}_{zj}^2)}{M} \qquad (8)$$

(3) SPECIFICATION AND DATA

Specification

Even though I depart from Levine and Renelt when it comes to "testing" variables, I keep their specification in the sense that I am going to estimate models like (2). Model j combines some *fixed variables* which appear in all regressions, *y*, the *variable of interest*, *z*, with the trio x_j taken from the pool X of the remaining variables proposed in the literature.[4] The reason for keeping some *fixed* variables in all regressions and the reason for allowing the remaining variables to come only in *trios* is that the typical growth regression in the literature has (at least) seven right hand side variables. I found a total of 63 variables in the literature plus the growth rate of GDP (throughout the paper, the only dependent variable is the average growth rate of per capita GDP between 1960 and 1992). If I tested one variable and allowed the remaining 62 to be combined in groups of 6, I would have to estimate 61 million regressions per variable tested. This would sum to a total of 3.9 billion regressions. My computer can estimate about 2,000 regressions per minute so it would take about 4 years to estimate all these models. In the second part of the paper I will allow for eight explanatory variables. If I combine the 62 remaining variables in groups of 7 instead of 6, then I would have to run a total of 30 billion regressions and it would take me 29 years! Since I am not currently equipped to wait 29 years, I decided NOT to allow for combinations of 7 variables taken from the pool of 62. A possible alternative was to run regressions with only three or four explanatory variables (and no fixed variables). The problem then would be that a lot of (and possibly all of) the regressions would be clearly misspecified

[4] Levine and Renelt allow the remaining N variables to be combined in sets of UP TO three variables. I will only allow for sets of exactly three variables. The reason is that regressions with more variables will tend to fit better and, as a result, get a larger weight in my estimations of equations (4) and (6). One way to solve this problem would be to introduce some kind of penalty for models involving more explanatory variables. Another solution is to restrict all the models to have the same number of explanatory variables.

(missing important variables is more of a problem than introducing irrelevant variables). Instead of waiting for 29 years or misspecifying all the regressions, I decided to follow Levine and Renelt and allow all the models to include three *fixed* variables which we may consider a priori to be important determinants of growth. When we combine these three variables along with the tested variable and then with trios of the remaining 59 variables I always have regressions with seven explanatory variables.[5]

Data

A lot more than 63 variables have been used in the literature. From all of these I choose 63 variables by keeping mostly the variables that can in some ways represent *"state variables"* of a dynamic optimization problem. Hence, I choose variables measured as close as possible to the beginning of the sample period (which is 1960) and eliminate all those variables that were computed for the later years only. For example, of all the education variables computed by Barro and Lee (1995), I only use the values for 1960. I also neglect some of the political variables that were published for the late 1980s, even though these variables have been put forward by a number of researchers (in this category, for example, I neglect the Knack and Keefer's bureaucracy and corruption variables, which were computed for 1985 only; corruption and bad bureaucracy could very well be the endogenous response of a poor economic performance between 1960 and 1985).

Finally, I also keep some variables, not because they are good proxies for some initial state variable but because they are proxies for some "parameters" of some models. For example, the Solow-Swan model assumes that the *"savings rate"* is a fundamental (exogenous) determinant of the transitional growth rate (and so are the rate of population growth, the depreciation rate, and the level of technology.) One way to measure the savings rate is to use the average savings rate over the period of analysis (1960-1992). I reluctantly use some variables of this sort (the average savings or investment rate and the DeLong and Summers measures of equipment and non-equipment investment are examples in this category). The reason for being reluctant to the inclusion of such variables is that these may be "more endogenous" than the variables measured at

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[5] Even combining the remaining variables in sets of 4 at a time (rather than sets of 3) would be a large problem: it would entail estimating 26 million regressions which would take about 9 days in my computer.

the beginning of the period.

With these restrictions, the total size of the data set becomes 63 variables plus the growth rate of GDP per capita between 1960 and 1992.

Choosing the Fixed Variables

The next thing I need to do is to choose the three *fixed* variables (that is, the variables that appear in all regressions.) These variables need to have some properties: they have to be widely used in the literature, they have to be variables evaluated in the beginning of the period (1960) and they have to be somewhat "robust" in the sense that they systematically seem to matter in all regressions run in the previous literature. The main obvious candidate to become a fixed variable is the *level of income in 1960*. All the regressions I know of in the literature include the initial level of income and it is usually found to be significantly negative (this is the conditional convergence effect). The other two variables chosen are the *life expectancy in 1960* and the *primary school enrollment rate in 1960*. Life expectancy is a measure of non-educational human capital that is also often used and usually found to be significant. The primary school enrollment rate in 1960 was one of the first important variables identified by Barro (1991) and it has been widely used, although its success has been mixed.

One of the variables that is most widely used in the literature (and one of the *fixed* variables in the Levine and Renelt paper) is the *average investment rate.* The interpretation of the partial correlation between growth and a variable is different depending on whether the investment rate is in the regression or not. If the investment is in the regression and variable x is correlated with growth, we tend to think that variable x affects the "level of efficiency" in the sense that it has effects on growth "above and beyond its effects on the incentives to invest". If variable x is correlated with growth when investment is not held constant, then we do not know whether variable x affects growth directly or through the incentives to save and invest. Although this partial correlation interpretation can be made of any variable, the distinction in the case of investment appears to be much more significant given the central role that investment plays in growth theory. In order to make the distinction, I will estimate the whole set of close to 30,000 regressions first without the investment rate appearing in ANY of the regressions and then with the investment rate as a fixed variable.

In summary, I have a total of 63 variables. In the first part of the paper I neglect the average investment rate over the period 1960-1992 so I am left with 62 variables. I use three of them as *fixed* variables so, for each variable tested I combine the remaining 58 variables in sets of three. Hence, for each variable I estimate M=30,856 (M=58!/[3!55!]) models.

(4) RESULTS

Table 1 reports some summary results. For the interested reader, Columns (1) and (2) report the "two extreme bounds" (as defined in the previous section) for each of the 59 variables of interest. Inspection of Columns (1) and (2) of Table 1 shows that for 58 of the 59 variables, the lower extreme bound is negative and the upper extreme bound is positive. Thus, we should label all but one of the variables as non-robust. The exception is the fraction of the population that follows the *Confucius* religion. This variable takes the value zero for most countries, the exception being the East Asian miracles (among very few others). Hence, this acts pretty much a dummy variable for East Asian miracle economies.

Column (3) reports the fraction of the 30,856 regressions in which the *tested* variable was significantly different from zero (defined as a t-statistic with an absolute value larger than two.) We see that there are a few variables that were significant 90 or even 99 percent of the time while others were significant less than 1 percent of the time. The extreme bounds test, however, gave them all the same label: non-robust.

The first interesting result reported in Table 1 comes from the comparison of Columns (6) and (7). Column (6) reports the CDF(0) under the assumption that the distribution of the estimators of β_z is normal while Column (7) does not assume normality. The correlation between these two columns is 0.98, which can be interpreted as an indication that the density function of the estimates of β_z is fairly close to normal.[6]

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[6] Another possibility is that, for each variable, there is only one model that takes all the weight. Since each of the individual models is close to normal, a weighted average where one models gets all the weight will also be normal.

Variables that are Strongly Correlated with Growth

Column (4) reports the estimate of the weighted average of β_z for each variable z. This column can be used to check the sign of the partial correlation between the variable and growth.

If we look at Column (7), we see that 21 of the 59 variables have a CDF(0) above 0.95. If we take 95 percent to be the usual level of significance, we could say that 21 out of the 59 variables appear to be "significant".

(1) Regional Variables: *Sub-Saharan Africa, Latin American,* (negatively related to growth) and *Absolute Latitude* (far away from the equator is good for growth). These variables are from the Barro and Lee (1993) data set.

(2) Political Variables: *Rule of Law, Political Rights,* and *Civil Liberties,* (good for growth). *Number of Revolutions and Military Coups,* and W*ar Dummy* (bad for growth). All of these from the Barro and Lee (1993) data set. I should note that the Political Rights and Civil Liberties variables are measured "backwards" in the sense that they take larger values for countries with less political rights and less civil liberties. Hence, the negative coefficients corresponding to these variables in Column (4) do not mean that less rights and less liberties are associated with more growth.

(3) Religious Variables: *Confucius, Buddhist* and *Muslim* (positive) and *Protestant* and *Catholic* (negative) (all of them from Barro (1996).) Some of these religious variables tend to be more like regional dummies because they take a zero value for most countries. Most notably, the *Fraction of Confucius* and *Buddhist* are more like dummies for East Asian miracles. Among the religious variables we note *Muslim* has a positive coefficient and *Protestant* and *Catholic* are negative. I am not sure whether we should interpret these results strictly along religious lines or whether to think of these religion variables as proxies for some other regional phenomenon (for example, the Muslim variable may be correlated with oil production).

(4) Market Distortions and Market Performance: *Real Exchange Rate Distortions* and *Standard*

Deviation of the Black Market Premium (both from Barro and Lee (1993) and both negative). The real exchange rate distortions represents distortions in the foreign sector. The Standard Deviation of the Black Market Premium is often interpreted as a sign of economic uncertainty which should tend to discourage investment.

(5) Types of Investment: The distinction between Equipment and Non-Equipment investment has been emphasized recently by DeLong and Summers (1991). In Table 1 we note that both *Equipment Investment* and *Non-Equipment Investment* are positive (although, as predicted by DeLong and Summers, the coefficient for this variable (β=0.0562) is about one fourth the coefficient for Equipment Investment (β=0.2175).)

(6) Primary Sector Production: Sachs and Warner's (1995) *fraction of primary products in total exports* (negative) and Hall and Jones (1996) *fraction of GDP in mining* (positive). I am not sure that a direct Sachs and Warner interpretation can be applied to this contradictory finding.

(7) Openness: Sachs and Warner (1996) *"number of years an economy has been open between 1950 and 1990"* (positive). Surprisingly, among the various measures of openness proposed in the literature and included in my data set, only this one appears to be strongly correlated with growth.

(8) Type of Economic Organization. Hall and Jones's (1996) *Degree of Capitalism* based on a classification made by Freedom House (1994). The variable *Degree of Capitalism* gives countries one of six values according to how important private enterprise is in the organization of the economy. The categories and their corresponding values are: 0=statist (Iraq or Ethiopia belong in this category), 1=mixed statist (Egypt, Rwanda), 2=mixed capitalist-statist (Malta), 3=capitalist-statist (Italy, India), 4=mixed-capitalist (Greece, Senegal), and 5=capitalist (USA, Botswana). Column 4 suggests that the closer to capitalist the economy is, the more it grows. Columns 6 and 7 suggest that this correlation is quite strong.

(9) *Former Spanish Colonies*. This variable is significant according to Column (6) and borderline if we look at Column (7). I could provide a number of first-hand explanations for this phenomenon, but that would get me in trouble, so I will leave it to the reader to reach his own explanation.

Variables that are NOT Strongly Correlated with Growth

The reader can go over the list and see what his favorite variable is and how it scores and compares with the rest of the variables reported in the literature. It is interesting to note some variables that appear NOT to be important: no measure of *government spending* (including investment) appears to affect growth in a significant way. The various measures of *financial sophistication* also fail to appear significant. The *inflation rate* and its *variance* do not appear to matter much although, in fairness to the authors who proposed these variables, I should say that they specifically say that they affect growth in a non-linear ways (and my analysis allows these variables to enter in a linear fashion only). Other variables that do not seem to matter include various measures of *scale effects* (measured by total area and total labor force), various *measures of openness* (outward orientation, tariff restrictions, black market premium, free trade openness) and the recently publicized "*ethno-linguistic fractionalization*" (which is supposed to capture the degree to which there are internal fights among various ethnic groups).

Non-Weighted Results

As mentioned earlier, the likelihood-weights used up to now are valid only to the extent that all the models are true regression models. If, for some reason, some models have spurious good fits, then a non-weighted scheme may be superior. Column (8) reports the non-weighted CDF(0) as defined in Equation (8). A rapid comparison of Columns (7) and (8) suggests that the weighted results by and large go through when we do not use weights. Only four variables which are above the magic line of 0.95 according to the weighted CDF(0) drop below that mark when we use an unweighted average of the individual CDF(0)'s. These variables are *Civil Liberties, Revolutions and Coups, Fraction of GDP in Mining,* and the *War Dummy*. This means that, for each of these four variables, a single model (or a small set of models) has a likelihood much larger than the rest so it gets all the weight in the weighted average. Hence, the weighted average seems to be significant even though most of the regressions are not so that the unweighted average is not significant. On the other side, only one variable with a CDF(0) above 0.95 in Column (8) gets a CDF(0) below 0.95 in Column (7): the *Ratio of Liquid Liabilities to GDP* (which is a measure of the degree of financial development).

(5) ANALYSIS OF THE FIXED VARIABLES

In order to gain some confidence on the *fixed variables* which have appeared in all regressions, we now repeat the whole procedure by allowing each of the *fixed* variables to be just like a regular tested variable, z, while keeping the other two fixed variables in all regressions and allowing for combinations of three chosen among the remaining 59 (since now the pool of remaining variables is 59 rather than 58, we have M= 32,509 models per variable). The results are reported in the last three rows of Table 1.

$Log(GDP_{60})$:

The first fixed variable is the log of GDP per capita in 1960. This variable is often introduced in growth regressions to capture the concept of conditional convergence introduced by Barro and Sala-i-Martin (1992). Since the sign of the lower extreme bound (Column 1) is negative and the upper extreme bound (Column 2) is positive, the extreme bounds test would give this variable the label of "Non-Robust". However, a quick look at Column 3 shows that the initial level of income is significant in 99.98 of the regressions run (in fact, it is significant in ALL BUT 7 of the 32,509 regressions!)

The estimated coefficient for the initial level of income is β_{y0} = -0.0133, which implies a speed of convergence of 1.8 percent per year!!! Moreover, columns(6), (7), and (8) suggest that the initial level of income is strongly correlated with growth, regardless of whether we assume that the distribution is normal or non-normal, or whether we use weighted averages to compute the levels of signicance or not: the levels of significance are in all cases over 0.9999.

Primary School Enrollment in 1960:

As was the case with almost all other variables analyzed the primary school enrollment rate in 1960 is labeled non-robust by the extreme bounds test. Column 4 suggests that this variable is positively related to growth. The levels of significance reported in Columns 6 and 7 suggest a strong significance, although the unweighted average of individual CDFs (Column 8) is not as strong.

Life Expectancy in 1960:

Again, this variable is not robust according to extreme bounds test, even though it is significant in over 96 percent of the regressions. It is positively related to growth which suggests that human capital affects growth positively. The last three columns display strong significance regardless of the measure adopted.

(6) INTRODUCING THE INVESTMENT RATE AS A FIXED VARIABLE

Table 2 repeats the estimation of all the regressions with one fundamental change: it includes the average investment rate between 1960 and 1990 as a *fixed* variable appearing in all regressions.

Inspection of Table 2 suggests that, by and large, the main lessons we learned in Table 1 go through in that most of the variables that were significant in Table 1 are still significant in Table 2. There are, however, a few differences, which can be summarized as follows:

Variables that Were Significant When Investment was Excluded and are No Longer Significant.

These are variables that can be interpreted to have their effects on growth *only* through their effects on the investment rate. The variables that are no longer significant are

(A) *Revolutions and Coups* and the *War Dummy*. These two variables affect growth but only through their effect on the investment rate, perhaps they affect uncertainty, perhaps they affect the rate of return. But the truth is that, once the aggregate investment is held constant (and, therefore, once we net out the effects of these variables on investment), they are no longer correlated with growth in a significant manner.

(B) *Non-Equipment Investment*. Since in Table 1 we did not hold constant the investment rate in any of the regressions and the data seem to want to have the aggregate investment rate, then the non-equipment investment was significant. Now that we are holding the aggregate investment rate constant, the non-equipment is not significant. Hence, there seems to be nothing special about non-equipment investment in the sense that it does not matter once aggregate investment is held constant.

(C) Fraction of *Buddhist* and *Catholic*.

Variables that were NOT significant when Investment was neglected but are significant now.

The variables in this category are:

(A) *Public Investment Share*. This variable is significantly negative related with growth once aggregate investment is held constant. This suggests that public investment is less efficient than private investment so that, holding constant the aggregate, a larger fraction of public investment is bad.

(B) *Age*.

(C) *Standard Deviation of Domestic Credit*.

Finally, the last row of Table 2 analyzes the investment rate as an additional "tested" variable, keeping the other three fixed variables and combining the remaing 59 variables in trios. Once again, the extreme bounds label for the investment rate is non-robust since columns (1) and (2) have opposite signs, even though the variable is significant in 97.23% of the 32,509 regressions. The weighted average estimate of β_z is 0.1093, and the significance values are above 0.99 in Columns (6), (7), and (8).

(7) CONCLUSIONS

We are interested in knowing the coefficient of a particular variable in a growth regression.

Instead of looking at the two extreme bounds of the distribution of estimators of this coefficient, we look at the entire distribution. If we do this, the picture emerging from the empirical growth literature is not the pessimistic "*Nothing is Robust*" picture that we get with the extreme bounds analysis. Instead, we find that a substantial number of variables can be found to be strongly related to growth.

Appendix 1: Description and Sources of Variables:

1 Equipment Investment. See Delong and Summers (1991).
2 Number of Years Open Economy. Index computed by Sachs and Warner (1996).
3 Fraction of Confucius. Fraction of population that follows Confucius Religion (see Barro (1996)).
4 Rule of Law. See Barro (1996).
5 Fraction of Muslim. See Barro (1996).
6 Political Rights. See Barro (1996).
7 Latin American Dummy. Dummy for Latin American countries.
8 Sub-Sahara African Dummy. Dummy for Sub-Sahara African Countries.
9 Civil Liberties. Index of civil liberties from Knack and Keefer (1995).
10 Revolutions and Coups. Number of military coups and revolutions. (Barro and Lee (1995), from now on BL93).
11 Fraction of GDP in Mining. From Hall and Jones (1996).
12 S.D. Black Market Premium. Standard Deviation of Black Market Premium 1960-89. Levine & Renelt (1992).
13 Primary Exports in 1970. Fraction of primary exports in total exports in 1970. From Sachs and Warner (1996b).
14 Degree of Capitalism. Index of degree in which economies favor capitalist forms of production from Hall and Jones (1996).
15 War Dummy. Dummy for countries that have been involved in war any time between 1960 and 1990. BL93.
16 Non-Equipment Investment. See Delong and Summers (1991).
17 Absolute Lattitude. See Barro (1996).
18 Exch. Rate Distortions. See BL93.
19 Fraction of Protestant. See Barro (1996).
20 Fraction of Buddhist. See Barro (1996).
21 Fraction of Catholic. See Barro (1996).
22 Spanish Colony. Dummy variable for former Spanish colonies. See Barro (1996).
23 Public Investment Share. Investment Share as fraction of GDP (BL93).
24 Frac. Pop. Spk. English. Fraction of the popilation able to speak English. From Hall and Jones (1996).
25 Defense Spending Share. Public Expenditures in defence as fraction of GDP (BL93).
26 Age. Average age of the population. BL93.
27 Public Consumption Share. Public consumption minus education and defense as fraction of GDP (BL93).
28 Average Inflation Rate 60-90. See Levine and Renelt (1992).
29 Size Labor Force (Scale Effect). See BL93.
30 Frac. Pop. Spk. Foreign Language
31 Black Market Premium. Log of (1+Black Market Premium). (BL93).
32 S.D. Inflation 60-90. Standard Deviation of the Inflation Rate 1960-1990. Levine and Renelt (1992).
33 Growth Rate of Population. Average rate between 1960 and 1990. BL93.
34 Ratio Workers to Population. BL93.
35 Fraction of Jewish. See Barro (1996).
36 Liquid Liabilities to GDP. Ratio of liquid liabilities to GDP (a measure of financial development). King and Levine (1993).
37 Avg. Years of Primary School. Average years of primary schooling of total population in 1960 (BL93).

38 French Colony. Dummy variable for former French colonies. See Barro (1996).
39 Political Assassinations. Number of political assationations. Taken from BL93.
40 S.D. Domestic Credit. Standard Deviation of Domestic Credit 1960-89 (King and Levine (1993)).
41 H*log(GDP60). Product of average years of schooling and log of GDP per capita in 1960. (BL93).
42 Fraction of Hindu. See Barro (1996).
43 Avg. Years of Schooling = H. Average years of education of total population in 1960. (BL93).
44 Secondary School Enrollment. See BL93.
45 Ethnolinguistic Fractionalization. Probability two random people in a country do not speak same language. See Easterly and Levine (1996).
46 Outward Orientation. Measure of outward orientation. From Levine and Renelt (1992).
47 Index of Democracy 1965. Qualitative index of democratic freedom. From Knack and Keefer (1995).
48 Tariff Restrictions. Degree of tariff barriers. From BL93.
49 Free Trade Openness. Measure of Free Trade. From BL93.
50 Avg. Years of Higher School. Average years of higher education of total population in 1960. (BL93).
51 Avg. Years of Sec. School. Average years of secondary schooling of total population in 1960 (BL93).
52 Political Instability. From Knack and Keefer (1995).
53 Gov. Education Spending Share. Public Expenditures in education as fraction of GDP (BL93).
54 Higher Educ. Enrollment. Enrollment rates in higher education in 1960. (BL93).
55 British Colony. Dummy variable for former British colonies. See Barro (1996).
56 Urbanization Rate. Fraction of population living in cities. See BL93.
57 Growth of Domestic Credit 60-90. Growth rate of domestic credit 1960-90. Levine and Renelt (1992).
58 Area (Scale Effect). Total area of the country. BL93.
59 Terms of Trade Growth. Growth of Terms of Trade between 1960 and 1990. BL93.

log(GDP per capita 1960). Log of Summers-Heston GDP per capita in 1960. From BL93.
Life Expectancy. Life expectancy in 1960 (BL93).
Primary School Enrollment. Secondary School Enrollment Rate in 1960. BL93.

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TABLE 1: MAIN RESULTS

	Number of Regressions = 30,856	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	NAME OF TESTED VARIABLE	Lower Extreme	Upper Extreme	Fraction Significant	Beta	Standard Deviation	CDF Normal	CDF Non-Normal (Weighted)	CDF Non-Normal Not Weighted)
1	Equipment Investment	-0.0396	0.5268	99.97%	0.21748	0.04081	1.000	1.000	1.000
2	Number of Years Open Economy	-0.0025	0.0438	99.97%	0.01948	0.00424	1.000	1.000	1.000
3	Fraction of Confucious	0.0038	0.1266	100.00%	0.06757	0.01492	1.000	1.000	1.000
4	Rule of Law	-0.0124	0.0599	92.04%	0.01895	0.00492	1.000	1.000	0.993
5	Fraction of Muslim	-0.0155	0.0368	88.67%	0.01421	0.00353	1.000	1.000	0.988
6	Political Rights	-0.0134	0.0077	33.73%	-0.00265	0.00087	0.999	0.998	0.926
7	Latin American Dummy	-0.0354	0.0112	88.28%	-0.01154	0.00291	1.000	0.998	0.986
8	Sub-Sahara African Dummy	-0.0377	0.0174	76.38%	-0.01212	0.00322	1.000	0.997	0.978
9	Civil Liberties	-0.0113	0.0130	16.90%	-0.00290	0.00102	0.998	0.997	0.848
10	Revolutions and Coups	-0.0377	0.0358	2.81%	-0.01179	0.00452	0.995	0.995	0.696
11	Fraction of GDP in Mining	-0.1654	0.1361	17.18%	0.03533	0.01383	0.995	0.994	0.729
12	S.D. Black Market Premium	-0.0001	0.0000	35.29%	-0.00003	0.00001	0.993	0.993	0.955
13	Primary Exports in 1970	-0.0450	0.0167	93.59%	-0.01399	0.00526	0.996	0.990	0.993
14	Degree of Capitalism	-0.0036	0.0089	51.03%	0.00184	0.00079	0.990	0.987	0.944
15	War Dummy	-0.0168	0.0126	17.09%	-0.00562	0.00233	0.992	0.984	0.870
16	Non-Equipment Investment	-0.0633	0.2468	76.32%	0.05622	0.02424	0.990	0.982	0.978
17	Absolute Lattitude	-0.0004	0.0009	66.20%	0.00023	0.00009	0.993	0.980	0.965
18	Exch. Rate Distortions	-0.0003	0.0001	54.29%	-0.00006	0.00003	0.975	0.968	0.958
19	Fraction of Protestant	-0.0480	0.0172	57.07%	-0.01286	0.00525	0.993	0.966	0.958
20	Fraction of Buddhist	-0.0142	0.0554	92.47%	0.01485	0.00755	0.975	0.964	0.994
21	Fraction of Catholic	-0.0305	0.0120	84.18%	-0.00891	0.00341	0.996	0.963	0.984
22	Spanish Colony	-0.0258	0.0286	45.42%	-0.00647	0.00321	0.978	0.938	0.889
23	Public Investment Share	-0.2309	0.2714	1.16%	0.04070	0.02758	0.930	0.915	0.691
24	Frac. Pop. Spk. English	-0.0350	0.0166	27.29%	-0.00682	0.00480	0.922	0.910	0.923
25	Defense Spending Share	-0.2120	0.3269	16.30%	-0.06417	0.04693	0.914	0.909	0.883
26	Age	-0.0002	0.0001	15.10%	-0.00004	0.00003	0.907	0.903	0.918
27	Public Consumption Share	-0.2754	0.1040	35.60%	-0.02205	0.01655	0.909	0.868	0.920
28	Average Inflation Rate 60-90	-0.0010	0.0005	6.56%	-0.00002	0.00002	0.859	0.856	0.752
29	Size Labor Force (Scale Effect)	-0.0003	0.0008	0.43%	0.00005	0.00005	0.846	0.835	0.744
30	Frac. Pop. Spk. Foreign Language	-0.0162	0.0245	19.43%	0.00486	0.00304	0.945	0.831	0.843
31	Black Market Premium	-0.0228	0.0381	3.36%	-0.00391	0.00356	0.864	0.825	0.707
32	S.D. Inflation 60-90	-0.1664	0.2322	3.81%	-0.00415	0.00465	0.814	0.811	0.560
33	Growth Rate of Population	-1.2817	1.1651	0.31%	0.20409	0.18643	0.863	0.807	0.531
34	Ratio Workers to Population	-0.0491	0.0456	21.75%	0.00482	0.00530	0.819	0.766	0.773
35	Fraction of Jewish	-1.8490	1.0118	0.16%	0.00923	0.01371	0.750	0.747	0.617
36	Liquid Liabilities to GDP	-0.0335	0.0802	69.32%	0.00819	0.01012	0.791	0.735	0.962
37	Avg. Years of Primary School	-3.5131	7.9705	3.91%	-0.00068	0.00117	0.720	0.704	0.811
38	French Colony	-0.0238	0.0306	0.11%	0.00177	0.00315	0.713	0.702	0.650
39	Political Assassinations	-0.1833	0.1587	0.02%	0.01338	0.02534	0.701	0.697	0.675
40	S.D. Domestic Credit	-0.0004	0.0002	4.75%	-0.00001	0.00001	0.696	0.696	0.715
41	H*log(GDP60)	-0.0055	0.0040	2.25%	-0.00006	0.00011	0.697	0.689	0.688
42	Fraction of Hindu	-0.3100	0.1018	0.50%	0.00306	0.00764	0.656	0.654	0.524
43	Avg. Years of Schooling = H	-7.9734	3.5109	0.85%	-0.00038	0.00100	0.646	0.653	0.623
44	Secondary School Enrollment	-0.0598	0.0771	2.47%	-0.00438	0.01058	0.661	0.649	0.711
45	Ethnolinguistic Fractionalization	-0.0302	0.0253	0.64%	-0.00183	0.00457	0.655	0.643	0.614
46	Outward Orientation	-0.0097	0.0157	2.51%	-0.00081	0.00233	0.635	0.634	0.794
47	Index of Democracy 1965	-0.0402	0.0233	17.73%	-0.00176	0.00498	0.638	0.633	0.890
48	Tariff Restrictions	-0.5715	0.4344	0.53%	0.01793	0.05657	0.624	0.624	0.670
49	Free Trade Openness	-0.1042	0.1490	3.84%	-0.00568	0.01893	0.618	0.617	0.818
50	Avg. Years of Higher School	-3.5045	7.9721	0.01%	-0.00357	0.01416	0.600	0.597	0.643
51	Avg. Years of Sec. School	-3.5069	7.9789	2.94%	0.00061	0.00259	0.593	0.592	0.800
52	Political Instability	-0.0684	0.1024	0.30%	-0.00193	0.01059	0.572	0.581	0.588
53	Gov. Education Spending Share	-0.6854	0.7519	0.53%	0.02822	0.12604	0.589	0.580	0.677
54	Higher Educ. Enrollment	-0.1833	0.2323	0.01%	-0.00692	0.03290	0.583	0.579	0.543
55	British Colony	-0.0180	0.0133	1.25%	-0.00047	0.00232	0.581	0.579	0.612
56	Urbanization Rate	-0.0438	0.0520	1.01%	-0.00156	0.00825	0.575	0.577	0.746
57	Growth of Domestic Credit 60-90	-0.0005	0.0008	0.02%	-0.00001	0.00004	0.565	0.565	0.542
58	Area (Scale Effect)	-0.0031	0.0043	0.02%	0.00005	0.00064	0.532	0.532	0.539
59	Terms of Trade Growth	-0.3437	0.2348	0.05%	0.00129	0.04117	0.512	0.511	0.628
	Number of Regressions = 32509								
	VARIABLES NOT TESTED								
	log(GDP per capita 1960)	-0.0336	0.0009	99.98%	-0.01325	0.00230	1.000	1.000	1.000
	Primary School Enrollment, 1960	-0.0384	0.0680	47.58%	0.01793	0.00683	0.996	0.992	0.899
	Life Expectancy, 1960	-0.0008	0.0029	96.30%	0.00083	0.00023	1.000	0.999	0.996

TABLE 2:
RESULTS WHEN THE INVESTMENT IS INCLUDED AS A FIXED VARIABLE

	Number of Regressions = 30,856	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	NAME OF TESTED VARIABLE	Lower Extreme	Upper Extreme	Fraction Significant	Beta	Standard Deviation	CDF Normal	CDF Non-Normal (Weighted)	CDF Non-Normal (No Weight)
1	Number of Years Open Economy	0.0001	0.0402	100.00%	0.01790	0.00380	1.000	1.000	1.000
2	Fraction of Confucious	0.0048	0.1157	100.00%	0.05891	0.01403	1.000	1.000	1.000
3	Rule of Law	-0.0109	0.0587	88.42%	0.01616	0.00457	1.000	0.999	0.991
4	Fraction of Muslim	-0.0152	0.0340	71.69%	0.01139	0.00314	1.000	0.999	0.974
5	Political Rights	-0.0127	0.0072	58.38%	-0.00270	0.00079	1.000	0.999	0.963
6	Exch. Rate Distortions	-0.0003	0.0001	87.69%	-0.00008	0.00003	0.999	0.998	0.987
7	Civil Liberties	-0.0112	0.0118	44.42%	-0.00299	0.00091	0.999	0.997	0.921
8	Absolute Lattitude	-0.0003	0.0008	76.43%	0.00023	0.00008	0.998	0.996	0.979
9	Sub-Sahara African Dummy	-0.0356	0.0232	82.40%	-0.00993	0.00284	1.000	0.996	0.982
10	Latin American Dummy	-0.0356	0.0098	72.95%	-0.00836	0.00267	0.999	0.994	0.975
11	Equipment Investment	-0.1357	0.6459	87.90%	0.12872	0.04947	0.995	0.992	0.990
12	Degree of Capitalism	-0.0030	0.0088	71.20%	0.00178	0.00072	0.994	0.991	0.973
13	Fraction of Protestant	-0.0456	0.0156	65.93%	-0.01070	0.00447	0.992	0.983	0.969
14	Primary Exports in 1970	-0.0431	0.0157	93.93%	-0.01128	0.00479	0.991	0.979	0.993
15	Age	-0.0002	0.0001	23.91%	-0.00005	0.00003	0.971	0.964	0.934
16	S.D. Domestic Credit	-0.0004	0.0001	20.16%	-0.00002	0.00001	0.960	0.959	0.925
17	Public Investment Share	-0.2907	0.2646	54.32%	-0.05257	0.03057	0.957	0.946	0.948
18	Defense Spending Share	-0.2119	0.2666	3.02%	-0.07141	0.04610	0.939	0.921	0.787
19	Size Labor Force (Scale Effect)	-0.0002	0.0008	5.41%	0.00006	0.00004	0.924	0.915	0.868
20	S.D. Black Market Premium	-0.0001	0.0000	0.17%	-0.00002	0.00001	0.917	0.908	0.827
21	Frac. Pop. Spk. English	-0.0307	0.0165	21.44%	-0.00592	0.00427	0.917	0.902	0.897
22	Public Consumption Share	-0.2456	0.1083	40.43%	-0.02011	0.01567	0.900	0.877	0.932
23	Spanish Colony	-0.0218	0.0285	7.90%	-0.00403	0.00293	0.915	0.875	0.808
24	Fraction of Buddhist	-0.0148	0.0474	75.27%	0.00914	0.00692	0.907	0.874	0.978
25	Fraction of Catholic	-0.0262	0.0153	27.15%	-0.00420	0.00309	0.913	0.871	0.916
26	Avg. Years of Sec. School	-4.5621	6.0114	6.15%	0.00214	0.00216	0.839	0.833	0.862
27	Growth Rate of Population	-1.3714	0.8799	1.40%	0.20029	0.17100	0.879	0.831	0.729
28	Urbanization Rate	-0.0384	0.0504	3.24%	0.00779	0.00747	0.852	0.821	0.829
29	Revolutions and Coups	-0.0339	0.0399	1.63%	-0.00451	0.00452	0.841	0.820	0.645
30	Higher Educ. Enrollment	-0.1645	0.2388	1.90%	0.02776	0.02992	0.823	0.820	0.848
31	Fraction of GDP in Mining	-0.1951	0.1379	9.51%	0.01238	0.01368	0.817	0.811	0.677
32	Non-Equipment Investment	-0.1039	0.2011	0.89%	0.02473	0.02621	0.827	0.801	0.609
33	Area (Scale Effect)	-0.0027	0.0043	0.27%	0.00043	0.00056	0.777	0.775	0.723
34	Political Assassinations	-0.1524	0.1523	0.01%	0.01725	0.02271	0.776	0.771	0.527
35	Avg. Years of Higher School	-4.5584	6.0084	0.03%	0.00831	0.01227	0.751	0.750	0.698
36	S.D. Inflation 60-90	-0.2348	0.1782	0.74%	-0.00282	0.00411	0.754	0.747	0.538
37	Free Trade Openness	-0.1028	0.1282	0.90%	-0.01230	0.01832	0.749	0.746	0.737
38	Fraction of Jewish	-1.4276	1.3103	0.02%	0.00812	0.01219	0.747	0.745	0.634
39	Tariff Restrictions	-0.5951	0.4205	0.24%	0.03553	0.05507	0.741	0.737	0.622
40	Black Market Premium	-0.0191	0.0373	1.65%	-0.00366	0.00408	0.816	0.732	0.509
41	Average Inflation Rate 60-90	-0.0008	0.0007	0.87%	-0.00001	0.00002	0.726	0.723	0.656
42	Ethnolinguistic Fractionalization	-0.0266	0.0257	0.47%	-0.00258	0.00411	0.735	0.722	0.643
43	Frac. Pop. Spk. Foreign Language	-0.0144	0.0207	4.62%	0.00149	0.00265	0.713	0.689	0.762
44	Outward Orientation	-0.0103	0.0144	0.13%	-0.00108	0.00208	0.699	0.687	0.625
45	Political Instability	-0.0646	0.0973	0.51%	0.00453	0.00963	0.681	0.667	0.642
46	War Dummy	-0.0149	0.0149	0.55%	-0.00122	0.00218	0.713	0.666	0.627
47	H*log(GDP60)	-0.0046	0.0046	0.38%	0.00004	0.00009	0.662	0.662	0.516
48	Growth of Domestic Credit 60-90	-0.0005	0.0008	0.05%	-0.00002	0.00004	0.661	0.661	0.506
49	Terms of Trade Growth	-0.3264	0.2199	0.17%	-0.01767	0.03889	0.675	0.661	0.716
50	Liquid Liabilities to GDP	-0.0365	0.0759	37.86%	0.00518	0.00999	0.698	0.654	0.914
51	Avg. Years of Schooling = H	-6.0061	4.5661	0.48%	0.00029	0.00078	0.643	0.643	0.544
52	Index of Democracy 1965	-0.0361	0.0233	5.29%	-0.00145	0.00499	0.614	0.609	0.823
53	French Colony	-0.0229	0.0260	0.00%	-0.00028	0.00286	0.540	0.539	0.609
54	Avg. Years of Primary School	-4.5672	6.0041	0.61%	0.00009	0.00098	0.536	0.537	0.680
55	Ratio Workers to Population	-0.0420	0.0486	4.22%	0.00057	0.00443	0.552	0.528	0.670
56	Fraction of Hindu	-0.2893	0.1016	1.00%	0.00044	0.00686	0.526	0.523	0.505
57	Gov. Education Spending Share	-0.6887	0.6717	0.02%	-0.00476	0.11253	0.517	0.514	0.527
58	Secondary School Enrollment	-0.0560	0.0634	1.25%	0.00024	0.00927	0.510	0.514	0.703
59	British Colony	-0.0178	0.0108	1.40%	-0.00003	0.00206	0.506	0.504	0.673
	Number of Regressions = 32,509								
	VARIABLE NOT TESTED								
	Investment Rate (1960-1990)	-0.1109	0.2699	97.23%	0.10930	0.01855	1.000	1.000	0.998