WP/05/18

IMF Working Paper

Growth Empirics Under Model Uncertainty: Is Africa Different?

Charalambos G. Tsangarides

INTERNATIONAL MONETARY FUND

 WP/05/18

IMF Working Paper

African Department

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Prepared by Charalambos G. Tsangarides[1]

Authorized for distribution by Reza Vaez-Zadeh

January 2005

Abstract

This paper attempts to identify robust patterns of cross-country growth behavior in the world as a whole and Africa. It employs a novel methodology that incorporates a dynamic panel estimator, and Bayesian Model Averaging to explicitly account for model uncertainty. The findings indicate that: (i) in addition to initial conditions, various economic factors such as higher investment, lower inflation, lower government consumption, better fiscal stance, improved political environment, exogenous terms-of-trade shocks, and fixed geographical factors are robustly correlated with growth; (ii) what is good for growth around the world is, in principle, also good for growth in Africa; and (iii) political and institutional variables are particularly important in explaining African growth.

JEL Classification Numbers: O4, C11, C33

Keywords: Economic growth, growth regressions, Bayesian model averaging, dynamic panel estimation

Author(s) E-Mail Address: ctsangarides@imf.org

[1] I thank, without implicating, Mike Bradley, Pierre Ewenczyk, Michal Hulej, Fred Joutz, Carlos Leite, Cathy Pattillo, Bob Phillips, and Reza Vaez-Zadeh, for useful comments and suggestions. I also thank Alin Mirestean for assistance with the programming. Any errors are my responsibility.

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I. Introduction

The topics of economic growth and human development have been examined and debated since the beginning of recorded history.[2] Over the last two decades, the philosophical rhetoric has emphasized the primacy of human development as the ultimate objective of economic pursuits, while empirical work focused on trying to explain why some countries have experienced rapid long-term growth rates in income while others have performed poorly in this regard. The area of economic growth has been described as "the part of macroeconomics that really matters"[3] not least because relatively small differences in growth rates when cumulated over one or more generations can have major consequences for standards of living.

Despite the vast literature of cross-country growth studies following the seminal papers of Barro (1991) and Mankiw et al. (1992), the mechanics of economic growth and development are still not fully understood. While empirical work trying to explain the dynamics of growth has identified a number of variables that are partially correlated with economic growth, the major problem facing researchers is the lack of an explicit theory about what are the true determinants of growth. From a theoretical standpoint the Solow model admits a vast range of extensions, which are often highly correlated with one another, are not (necessarily) mutually exclusive, and are not ranked in order of importance as possible explanations of growth. Given the multiplicity of possible regressors, a more specific approach to growth determinants would be to investigate how robust empirical relations for economic growth are.

This paper contributes to the growth empirics debate by empirically identifying robust determinants of per capita growth rates across the world and Africa. It draws on neoclassical and endogenous growth theories to allow for differences in countries' steady state income levels, and uses Bayesian Model Averaging to address the problem of model uncertainty in the context of growth determinants. The empirical findings can be summarized as follows. First, in both the world as a whole and Africa, various economic factors such as initial conditions and a better macroeconomic environment (including higher investment, lower inflation, lower government consumption, and better fiscal stance), as well as an improved political environment, favorable exogenous terms-of-trade shocks, and fixed geographical factors, are robustly correlated with economic growth. Second, Africa's growth process follows, in principle, that of the rest of the world, although the marginal impacts and mechanisms of transmission of these determinants are very different. In addition, growth in Africa is robustly correlated with better political environment, better institutions, and lower debt service to GDP. The fact that what is good for growth around the world is also good for growth in Africa, suggests that lessons of modern growth economics are, at least in principle, general and not region specific.

The rest of the paper is organized as follows. Section II begins with the model specification, discusses estimation issues and describes the estimator used for the robustness analysis. Section III presents the data and identifies categories of possible growth determinants. Section IV summarizes the results. Section V concludes.

[2] Anand and Sen (2000), for example, quote Aristotle as favoring human development: "wealth is evidently not the good we are seeking, for it is merely useful and for the sake of something else."

[3] Barro and Sala-i-Martin (1995).

II. Theoretical Considerations

A. Model Specification

Recent cross-country empirical work on growth has been inspired by the neoclassical model extended to include government policies, human capital, and some measure of technology diffusion. Therefore, consistent with the empirical literature on cross-country comparisons of economic growth, we assume the typical specification

$$\ln(Y_{i,t}) - \ln(Y_{i,t-\tau}) = \beta_0 \ln(Y_{i,t-\tau}) + \beta_1' \mathbf{Z}_{i,t-\tau} + u_i + \nu_t + \varepsilon_{i,t} \tag{1}$$

where the growth rate of per capita income of country i in period t is a function of the logarithm of initial per capita income and a set of control variables $\mathbf{Z}$. The terms $u_i, \nu_t,$ and $\varepsilon_{i,t}$ represent country-specific, time constant and overall error terms, respectively. The textbook and augmented Solow models are nested in (1) as follows, respectively

$$\ln(Y_{i,t}) = \eta_0 \ln(Y_{i,t-\tau}) + \eta_1 \ln(n_{i,t} + g + \delta) + \eta_2 \ln(s_{i,t}) + u_i + \nu_t + \varepsilon_{i,t} \tag{2}$$

$$\ln(Y_{i,t}) = \eta_0 \ln(Y_{i,t-\tau}) + \eta_1 \ln(n_{i,t} + g + \delta) + \eta_2 \ln(s_{i,t}) + \eta_3 \ln(h_{i,t}) + u_i + \nu_t + \varepsilon_{i,t} \tag{3}$$

where $n_{i,t}$ is the population growth rate, g is the labor augmenting technological change, δ is the rate of depreciation, $s_{i,t}$ and $h_{i,t}$ measures physical and human capital accumulation, respectively.

To facilitate the discussion in the next section let $\gamma_0 = \beta_0 + 1$ and rewrite equation (1) as[4]

$$\ln(Y_{i,t}) = \gamma_0 \ln(Y_{i,t-\tau}) + \gamma_1' \mathbf{Z}_{i,t-\tau} + u_i + \nu_t + \varepsilon_{i,t} \tag{4}$$

B. Estimation Issues

The study of socioeconomic phenomena is typically plagued by (i) inconsistent empirical estimates and (ii) model uncertainty. The first case of inconsistent empirical estimates typically arises with omitted country specific effects which, if not uncorrelated with other regressors, lead to a misspecification of the underlying dynamic structure, or with endogenous variables which may be incorrectly treated as exogenous.[5] To simultaneously address both omitted variable bias and issues of endogeneity, we use a general method of moments estimator (GMM) panel data estimator proposed by Hansen (1982).[6] The estimator is

[4] The speed of convergence λ, can then be recovered from the estimated elasticities as $\lambda = \frac{\ln(1+\gamma_0)}{t}$.

[5] For example, cross-section growth regressions lead to biased estimates because the country specific error term u_i is likely to contain unobserved country effects such as differences in the initial level of technology across countries, and thus may be correlated with the lagged dependent variable.

[6] Bond et al. (2001), and Hoeffler (2002) present applications of the systems GMM estimator in the context of growth. Bond et al. (2001) presents a detailed explanation on the construction of both the system and differenced GMM estimators.

constructed in two steps: first, consider first differences of the levels equation (4), which eliminates the individual effect u_i

$$\ln(Y_{i,t})-\ln(Y_{i,t-\tau}) = \gamma_0(\ln(Y_{i,t-\tau})-\ln(Y_{i,t-2\tau}))+\gamma_1'(\mathbf{Z}_{i,t-\tau}-\mathbf{Z}_{i,t-2\tau})+(\nu_t-\nu_{t-\tau})+(\varepsilon_{i,t}-\varepsilon_{i,t-\tau}) \tag{5}$$

Then, for each equation, potentially endogenous right-hand side variables are instrumented using appropriate lagged values and differences. The levels equation (4) and the difference equation (5) are estimated as a system, forcing the estimated coefficients to be the same across equations. The first step deals with the omitted variable bias, eliminating the need to make any probabilistic assumptions on the country effect. The second step eliminates the inconsistency arising from potential endogeneity of the regressors. This GMM estimator addresses both estimation problems under the assumption that the lagged values of the regressors are valid instruments.[7]

The second case of model uncertainty arises because the lack of clear theoretical guidance on the choice of regressors results in a wide set of possible specifications and, often, contradictory conclusions. In practice, researchers usually arbitrarily select one model as the true model generating the data, ignoring model uncertainty altogether and risking overconfident inferences.[8] In theory, accounting for model uncertainty requires some version of a robustness check, essentially an attempt to account for all possible combinations of predictors. Earlier attempts to sort out the underlying empirical model in the context of growth include the work of Levine and Renelt (1992) and of Sala-i-Martin (1997).[9] A conceptually attractive solution to the problem of model uncertainty is provided by Bayesian Model Averaging (BMA) although difficulties at the implementation stage sometimes render it impractical.[10] In particular, with a large number of regressors, k^*, the procedure may be infeasible due to the large number of models to be estimated, 2^{k^*}. Additionally, the researcher is required to specify the prior distributions of all relevant parameters. In practice, most applications of BMA utilize an arbitrary set of priors, without examining the impact of this choice. Standard Bayesian Model Averaging techniques have been used in the context of investigating growth determinants by Brock and Durlauf (2000), Fernandez et al. (2001), and Sala-i-Martin et al. (2004).

This paper employs a limited information version of the BMA, labeled as LIBMA.[11] The LIBMA estimator incorporates a dynamic panel estimator in the context of GMM and a Bayesian robustness check to explicitly account for model uncertainty in evaluating the results of a universe of models generated by a set of possible regressors. The LIBMA esti-

[7]Blundell and Bond (1998) provide evidence that the systems GMM estimator that exploits additional moment restrictions has better finite sample properties than the difference GMM estimator.

[8]Leamer (1978), and Raftery (1996) are relevant papers.

[9]The first procedure, an extreme bounds analysis based on Leamer (1983), typically results in few variables being labeled as robust, while the second procedure, a Bayesian approach, suggests that a relatively large number of variables are significant determinants of growth.

[10]Hoeting et al. (1999) summarize recent work using BMA. Brock and Durlauf (2000) provide an accessible explanation of criticisms levied at growth empirics and the contribution of Bayesian analysis in dealing with model uncertainty.

[11]For a discussion of the LIBMA see Tsangarides (2004), and for the first practical application of the LIBMA see Ghura et al. (2002). The technical presentation in Appendix II supplements the overview provided in this section.

mator provides certain advantages over the existing literature (such as the Sala-i-Martin et al. (2004) Bayesian Averaging of Classical Estimates (BACE) approach, and the approach of both Brock and Durlauf (2000) and Fernandez et al. (2001)) by relaxing the otherwise restrictive underlying assumptions in two ways: first, while standard Bayesian Model Averaging is a full information technique where a complete stochastic specification is assumed, LIBMA is a limited information approach which relies on GMM, a limited information technique based on moment restrictions rather than a complete stochastic specification. Second, previous literature implicitly assumes exogenous regressors while the LIBMA can control for endogeneity through the use of GMM.[12]

III. Looking at the Data

A. Definitions and Sources

The database constructed for the robustness analysis consists of annual data from the Summers and Heston data set (made available by the Penn World Tables, version 6.1) and data from other sources. Switching from a cross section to panel estimation is made possible by dividing the total period into shorter time spans. Following earlier studies in the literature, we focus on five-year time intervals ($\tau = 5$), so we obtain a total of eight panels: 1965, 1970, 1975, 1980, 1985, 1990, 1995, and 2000.[13] After filtering out countries with less than two observations (in order to enable examination of within-country changes) as well as extreme values, we arrive at an unbalanced, regularly spaced panel set of observations covering 149 countries over the period 1960-2000. For each country, the data set includes observations that are at least five years apart, yielding a maximum of 983 observations.[14] Table A1 in Appendix I contains details for each category, the component variables, and their source.

In order to examine how the growth process varies across regions and/or samples of countries we consider two samples: first, we begin with "World," the most comprehensive data set of all (available) countries in the world covering 149 countries and 983 observations; next, we consider the "Africa" sample (41 countries, 328 observations) in order to compare the growth empirics of the African countries to the rest of the world.[15]

B. Determinants of Growth

This section presents a review of policies, institutional characteristics, and other exogenous factors that stimulate growth. In addition to the four variables suggested by the

[12] In addition, the application herein extends the approach of Sala-i-Martin et al. (2004) in four important ways: (i) the use of the systems GMM estimator instead of ordinary least squares; (ii) assigned weights to the different models proportional to an explicitly defined Limited Information Bayesian Information Criterion; (iii) the use of a balanced panel instead of balanced cross-section data, allowing a better analysis of the time-series dimension of the variables; and (iv) the estimation of the full set of models rather than sampling from the universe of models.

[13] For example, the saving and population rates at $t - \tau$ (say 1965) are non overlapping averages over the five years preceding t (1960-1964).

[14] For purposes of estimation, differences in data availability across countries and variables translate into further reductions in sample size for different combinations of explanatory variables.

[15] Details of the samples and country participation is shown in Appendix Table A2.

augmented Solow model, namely, initial income, rates of human and physical capital, and population growth, Durlauf and Quah's (1999) survey of the empirical growth literature identifies 36 different categories of variables and 87 examples. Our sample of growth determinants for the robustness analysis is a subset of the one identified by Durlauf and Quah (1999).[16] We consider the broad categories below.

Solow determinants and human capital

Empirical studies consistently report a positive role for the investment ratio in explaining international differences in both the standard of living (as measured by GDP per capita) and economic growth rates. A number of studies have also investigated the possibility that the public and private components of investment have different impacts on economic growth, for example Ghura and Hadjimichael (1996), although both components tend to be growth promoting. Given a conducive environment, the productivity of the labor supplied is an important determinant of their ability to benefit from the enhanced opportunities—a situation that points to important synergies between growth promotion and initial conditions. Recent work in development economics acknowledges that a fundamental reason for the success of some East Asian countries in promoting equitable growth was due not only to the labor-intensive nature of production but also to the relatively large stock of education and skills embodied in the labor force.

The consequences of rapid population growth on the pace of economic development have been debated since Malthus' visions of overcrowding, starvation, and resource exhaustion. During the recent decades views have shifted: high fertility hinders development as families with more children had to spend more on education and health, thus reducing the amount of savings and investment in physical capital. The latest report by the United Nations Population Fund (UNFPA) argues that larger families and rapid population growth obstruct development and perpetuate poverty by slowing growth and diverting consumption away from the poor, which creates a "demographic dividend" of growth.

This paper captures the effect of (i) physical capital through ratios of real investment to GDP; (ii) human capital development through measures of health and educational status (such as life expectancy and school enrollment rates);[17] and (iii) population through population growth rates.

Macroeconomic stability and external environment

Macroeconomic policies affect economic growth directly through their effect on accumulation of capital, or indirectly through their impact on the efficiency with which the factors of production are used. Macroeconomic stability is reflected in (i) sustainable budget deficits and low consumption to GDP ratios; (ii) low and stable rates of inflation and sound financial development; and (iii) outward oriented trade policies.

[16] This is due to computational and data availability constraints. Specifically, with a list of 87 explanatory variables and cross-country datasets of 100 or, in the best of cases, 150 country observations the empirical investigation of growth determinants essentially becomes an exercise in small sample econometrics. (Indeed, if sufficient observations were available, one could conceivably estimate slopes for each potential variable in any possible functional form using the appropriate econometric technique.)

[17] In the case of educational status, these result-oriented measures also capture the effects of local incentives to acquire the related skills (more so than public expenditure data).

Fischer (1993) shows that growth is negatively associated with inflation, large budget deficits and distorted foreign exchange markets. Keeping all else constant, higher budget deficits crowd out private investment due to higher real interest rates. Government investment can further be used as a proxy for government's involvement in capital accumulation, and an indicator of social infrastructure. Using the government consumption ratio to GDP as a measure of fiscal policy also captures the concern of supply-side theories that higher government spending creates expectations of future tax liabilities and hence, distorts incentives and lowers growth.

Monetary policy could promote a stable financial environment necessary for economic growth by maintaining a low inflation rate. High and variable rates of inflation are expected to lower the monetary authorities' credibility and reduce the returns on private savings and investment; thus high inflation rates are expected to decrease private investment and domestic savings. The literature has shown that financial development is robustly correlated with future rates of economic growth, physical capital accumulation, and economic efficiency improvements. For example, King and Levine (1993) present evidence that various measures of the level of financial development are strongly associated with real per capita GDP growth. Financial deepening lowers the cost of borrowing, increases the rate of domestic saving, and thus stimulates investment. Also, financial sector development may benefit growth by facilitating access to credit and improving risk-sharing and resource allocation.

The proposition that more outward-oriented economies tend to grow faster has been tested extensively in the literature. The majority of the evidence tends to support the idea that openness to international trade accelerates development and growth through increased access to free market and returns from specialization.[18] In addition, it is possible that policies such as trade openness affect human development more favorably in certain circumstances, for example, in a context of wider civil or economic freedom. Perhaps through improved equality of opportunity (either social mobility or degree of structural flexibility), a society characterized by a higher degree of economic freedom may allow its members faster access to the benefits of global competition. Finally, trade restrictions that tend to protect capital-intensive importables reduce the returns to labor, and overvalued exchange rates that reduce the profitability of tradeables, turn the terms of trade against those who are net producers of tradeables. Improvements in terms of trade have been associated with higher growth rates, through improvements in the country's international competitiveness.[19]

In summary, a stable macroeconomic environment characterized by low and predictable inflation, sustainable budget deficits, and limited departure of the real exchange rate from its equilibrium level sends important signals to the private sector about the commitment and credibility of a country's authorities to efficiently manage their economy and increase the opportunity set of profitable investments. In this paper, the impact of macroeconomic stability is captured by inflation, the government budget balance and government consumption relative to GDP; the level of financial sector development is measured by the ratio of broad money to GDP as well as the ratio of assets of deposit money banks to total bank

[18] Dollar and Kraay (2002) and Frankel and Romer (1999) find a strong positive effect of trade on growth after controlling for changes in other policies and addressing endogeneity.

[19] Easterly et al. (1993) show that while growth rates are highly unstable over time (with a correlation across decades of 0.1 to 0.3) country characteristics are highly stable (with cross-decade correlations of 0.6 to 0.9) and shocks to terms of trade play a large role in explaining variance in growth.

assets; and the trade regime/external environment are captured by the degree of openness and the exogenous terms-of-trade changes.

Institutions and governance

The role of democracy in the process of economic growth has been the source of considerable research effort, but still the inquiry, including the line of causality, remains a wide open topic of research.[20] The distribution, across income groups, of the benefits of growth are likely to depend, not just on the sectoral pattern of growth but also on the degree of popular representation at the policy making level and the effectiveness of the governing institutions. Through its likely positive impact on other variables (for example, the rule of law and the rate of investment), it may also be that democracy's main impact on overall income is indirect.[21] Theoretical models on the impact of economic development (and economic growth) on the extent of democracy "are not well developed" (Barro (1996)); conceptual arguments on the effect of democracy on economic growth support both a positive and a negative effect, emphasizing the role of secure property rights in the first case, and the avoidance of political cycles in the second case; and empirical evidence is mixed, with most empirical efforts failing to establish a significant and stable relationship.[22]

Empirically, Alesina et al. (1996), find that political instability reduces growth, while Easterly and Levine (1997) examine the hypothesis that ethnic divisions influence economic growth. Their rationale is that polarized societies have more difficulties agreeing on the provision of public goods such as infrastructure, education, and growth enhancing policies, simply because polarization impedes agreement between ethnic groups which engage in competitive rent-seeking. In this paper we examine the hypothesis that political freedom is a significant determinant of economic growth using the democracy and autocracy variables measuring the general openness of political institutions and they include considerations such as free and fair elections and decentralized political power.

Geography and fixed factors

The relationship between geography and growth is complex. While the majority of empirical evidence concludes that geographic attributes of countries (such as tropical climate or being landlocked) correlate negatively with recent rates of economic growth, some research finds evidence that geography explains nothing after controlling for institutions.

On one hand of the debate supporting the role of geography as a growth determinant,

[20] For a brief review of the relationship between democracy and economic growth, see Chapter 11 in Drazen (2000); for more detailed reviews, see Przeworski and Limongi (1993). On the links between political instability and economic growth, see Brunetti and Weder (1995), and Knack and Keefer (1995). For a more encompassing review of the empirical literature of political variables in cross-country growth analysis, see Brunetti (1997).

[21] Kormendi and Meguire (1985) and Scully (1988) do find favorable effects of political freedom on economic growth.

[22] Barro (1996) analyzes growth and democracy indexes of political freedom and concludes that when variables like maintenance of the rule of law, free markets, small government consumption, and high human capital, as well as initial income are held constant, the overall effect of democracy on growth is weakly negative. He also finds evidence of a nonlinear relationship in which more democracy enhances growth at low levels of political freedom but depresses growth when a moderate level of freedom has already been attained.

Hall and Jones (1997) show that show that latitude closely related to tropical climate is negatively associated with the level of per-capita GDP. Further, Gallup et al. (1999) emphasize that geography continues to matter importantly for economic development, alongside the importance of economic and political institutions. They conclude that tropical regions are hindered in development relative to temperate regions and that coastal regions and regions linked to coasts by ocean-navigable waterways are strongly favored in development relative to the hinterlands, with landlocked economies particularly disadvantaged. On the other hand of the debate, a series of papers by Acemoglu, Johnson and Robinson (2001) and (2002) investigates how "property rights institutions" matter for economic growth through their effect on investment and financial development, and the role of geography through institutions. Work by Acemoglu et al. (2002), Easterly and Levine (2003) and Rodrik et al. (2002) argues that the geography mechanism works predominantly or entirely through institutions, with little independent effects from geography once institutions are controlled for. In order to examine the extend to which geography matters for growth, we use a variety of geography factors including distance to coastline or sea-navigable river and percentage of land area in geographical tropics.

Foreign aid and external debt

The relationship between foreign aid and economic growth is a complex one, which makes it difficult to measure the causal impact of foreign aid while controlling for other factors that influence growth. Burnside and Dollar (2000) conclude that foreign aid has a larger impact on growth under a good policy management and that aid does not raise growth in countries with poor economic policies. Foreign aid to reforming governments may improve the environment for private investment by creating confidence in the reform program, thus crowding in private investment. In a poor management country foreign aid may crowd out private investment as it may encourage the public sector to undertake projects that would otherwise be undertaken by the private investors.

From the debt overhang theories it follows that larger levels of accumulated debt stocks may lead to lower growth, with the transmission mechanism of debt overhang to growth being primarily through the reduced volumes and efficiency of investment.[23] First, there is a likelihood that the future debt will be larger than the country's repayment ability thus the expected debt service will be increasing compared to the country's output. In addition, large accumulated debt combined with uncertainty about debt repayment by the country's own resources, possible rescheduling, and whether aid would be provided for debt relief may generate expectations that debt service will be financed by distortionary types of taxation, or with cuts in public investment. For example, Krugman (1988) discusses how under debt overhang returns from investing in that country face a higher marginal tax by the external creditors, and new domestic and foreign investment is discouraged. Finally, debt relief, or the granting of progressively more favorable terms for debt relief may also have perverse incentive effects, as countries borrow in anticipation of debt forgiveness and delay policy reforms waiting for the best deal thus delaying reforms necessary for growth. In this paper, we investigate the impact of foreign aid and external debt on growth by using ratios of aid

[23] It should be noted, however, that under the traditional neoclassical models allowing for perfect capital mobility and the ability to borrow and lend without constraint, debt inflows have a positive effect on growth. However, these underlying assumptions may be unrealistic.

flows, debt service, and debt stock to GDP.

Internal environment and resources

Empirical research has served to highlight how little we still know about the dynamics and causes of changes in income distribution. The current view is that: (i) growth does not consistently affect inequality one way or the other (the Kuznet's hypothesis having essentially been refuted by panel studies), and (ii) the initial level of inequality does appear to negatively impact subsequent growth. For the first proposition, Deiniger and Squire (1998) and Chen and Ravallion (1997) provide key evidence, leading Kanbur and Squire (2001) to conclude that "...inequality and income are not systematically related according to some immutable law of development". Also, it is likely that the source of the economic growth—for example dependence on natural resources—matters for inequality, poverty and human development. For instance, Lewis (1954), attributes the onset of growth to higher income in an enclave sector characterized by higher productivity of labor. Suppose, for example, that the sector initially more productive is either an oil- or mineral-extractive industry. Leite and Weidmann (1999) link economic dependence on oil and mineral resource sectors to the availability of appropriable rents, the higher incidence of corruption, and, subsequently, lower economic growth.

Returns that accrue initially to a wider set of agents, such as the case of a highly productive agricultural sector, may allow for more progress with respect to poverty alleviation. Ravallion and Datt (1996) find that the aggregate time-series data for India indicate that poverty measures have responded far more to rural economic growth than urban economic growth. For East Asia, some of the credit for the growth with equity experience is typically ascribed to the strong performance in the agricultural sector. Intuitively, it is likely that those poor economies with better-functioning credit and land markets, and with a distribution and system of landholding consistent with market incentives, are more likely to perform better in the area of poverty reduction. Given that a majority of poor people are in the agricultural (rural) sector, this paper also measures the impact of the sectoral distribution of growth by the relative productivity performance of the agricultural sector. To investigate the possible links of environmental influences like availability of arable land and inequality on growth, this paper measures inequality with the Gini index of inequality, and agricultural productivity by the ratio of arable land to total area.

IV. Econometric Results

A. Impact of Model Uncertainty

Our investigation for robust growth determinants began by examining how fragile the results of ad hoc cross country growth specifications are. We proceeded in two ways: first, by estimating various ad hoc growth regressions (starting from the Solow model and then extending it), using variables from our data set; and second, by summarizing results from empirical work in the literature. In our investigation of ad hoc growth regressions we discovered how drastically the policy conclusions change with relatively small variations in the set of explanatory variables.[24] Adding variables to, say, the Solow determinants changes

[24] These results are not reported here for brevity, but are available from the author.

the significance (insignificance) and sometimes the sign of various coefficients. Further, the fragility of parameter estimates and the impact of model uncertainty can be detected by observing Table A3. There we expand on the list of Durlauf and Quah (1999) to summarize the results of (a selective list of recent) empirical work on growth correlates. The significance of parameter estimates tends to fluctuate a lot across studies and authors which use different subsets of the control variables.[25] Sometimes it is even the case that the same authors present different conclusions in studies of various years and/or when their sets of control variables change.

This investigation confirmed that any lessons one may draw from ad hoc specifications can be problematic. The list of possible regressors can be a linear function of an arbitrary set of control variables and thus it is difficult to assign a statistical significance or make policy recommendations based on a subset of these control variables. This confirms not only the tendency for empirical investigations into socioeconomic phenomena to yield fragile econometric estimates but also underscores the importance of a formal robustness check, which is the purpose of our paper.

B. Robustness Analysis of Growth Determinants

Table 1 presents the results of the robust estimation based on estimating a universe of 2^{19} $(524,288)$ regressions for the most comprehensive sample, "World". In order to allow comparison of the growth empirics, we estimate the same universe of models for the "Africa" sample and the results are presented in Table 2. The 19 potential determinants we focus on are those identified in Section III.B. and we investigate their robustness across samples and model specifications.

The results shown in Tables 1 and 2 assume an initial prior model size of $\overline{k} = 9$. This choice of $\overline{k}$ is essentially arbitrary but Tables 4a and 4b provide evidence that the results in Tables 1 and 2 are not sensitive to the choice of $\overline{k}$. The posterior inclusion probability shown in the second column in Tables 1 and 2 reflects how much the data favors the inclusion of a variable in the regression. The conditional mean and variance, shown in the third and fourth columns, reflect only the regressions in which the variable actually occurs. The interpretation for the conditional mean is similar to a standard regression, which does not account for model uncertainty, in that it reflects a prior probability of inclusion equal to one for the particular variable, but equal to $\overline{k}$ divided by the total number of variables for the rest. The conditional standard deviation does provide one measure of how well a particular variable is estimated, but the ratio of the mean to the standard deviation cannot, strictly speaking, be interpreted as a t-statistic since the posterior density is not a sampling distribution.

The fifth column in Tables 1 and 2 shows the sign certainty probability, a measure of the "sign robustness" of each variable, defined as the probability that a coefficient has the same sign as its (posterior) mean. A sign certainty probability equal to one implies that the variable has the same sign in every single regression in which it is included, a clear indication of a strongly robust relationship. The boxed area in Tables 1 and 2 comprises

[25] Clearly, different authors also use different datasets, so presumably some (but not all) of the differences in the results can be attributed to that.

those variables for which (i) the posterior inclusion probability is high[26] *and* (ii) the sign certainty probability is at least 95 percent, analogous to performing a one-sided test of significance at the 5 percent level in classical statistics. The chosen cutoff is not strictly grounded in statistical theory and remains, therefore, merely indicative of a set of variables that are well estimated or robust. Thus, we are able to assign a degree of robustness and identify variables as "very strongly robust," "strongly robust," and "mildly robust" based on the following criteria shown.

Evidence of Robustness		
Classification	**Prob(Sign certainty)**	**Prob(Posterior inclusion)**
Very strong	≥ 0.99	≥ 0.90 (and above the prior)
Strong	$0.95 - 0.98$	≥ 0.90 (and above the prior)
Mild	$0.80 - 0.94$	Above the prior
Weak	$0.55 - 0.79$	Above the prior

The results from the robustness analysis on the World and Africa samples (Tables 1 and 2, respectively) are summarized in the sections below.

Convergence and Solow determinants

- The elasticity of per capita growth rate with respect to initial income (measured by $\lambda = \frac{\ln(1+\gamma_0)}{t}$ in equation (4)) is negative and very strongly significant providing further empirical evidence that conditional convergence holds. Across the World sample, the estimated rate of convergence λ is on average between 2 and 2.5 percent; for Africa λ is slightly slower, in the range of 1.5 and 2 percent.[27] This suggests that after controlling for model uncertainty, country sample, and other potential inconsistencies (arising from omitted variable and/or endogeneity biases), the estimated rate of convergence is surprisingly similar to the standard cross-section finding.

- For both the World and Africa samples, the Solow determinants, namely, initial income, investment, population growth, and education enter with a high inclusion probability, indicating that the data favors the inclusion of these variables. However, based on the classification of robustness discussed above, we identify only initial income and investment as "very strongly" robust, while education is "mildly" robust. For population growth, the evidence of robustness is weak in both the World and Africa samples, mainly because the coefficient changes sign rather frequently (i.e. the sign certainty probability is lower than 0.95).

- The findings on the importance of the Solow determinants are similar to the results found in the seminal work of Mankiw et al. (1992). The mild significance of education

[26] We took 0.90 as the posterior probability threshold following Fernandez et al. (2001b) who label a regressor that obtains a posterior probability that is equal to or greater than 0.90 as "highly effective." Sala-i-Martin et al. (2004) set the posterior probability threshold at the prior value for each variable (i.e. at $\overline{k}$ divided by the total number of variables).

[27] These estimates are based on the range of *all* the elasticities shown in Tables 1, 2, and 3, allowing $\overline{k}$ to vary in the specifications.

highlights the importance of incorporating human capital (in addition to physical) when analyzing growth patterns. An additional measure of human development is life expectancy, which, in addition to infant mortality rates and primary school enrolment, is reported be significantly and positively associated with progress on the human development front especially for sub-Saharan Africa.[28] Based on our robustness analysis, we find that although life expectancy has a high inclusion probability, it is only mildly robust, partly because many aspects of poverty (including education and health) are highly correlated.

- The weak significance of population growth echoes the on-going debate regarding its importance as a growth determinant. Empirical research in the 1960s and 1970s favored a neo-Malthusian view suggesting that high fertility hindered development (and growth) since families with more children had to spend more on education and health and thus reducing the amount of savings and investment in physical capital. However, research in the 1980s seemed to discredit these neo-Malthusian ideas, and favored the view that rather than physical capital, human capital and technical change were the engines for growth. Although the negative impacts of rapid population growth were judged to vary considerably by country, it also concluded that population growth had a lesser impact on growth compared to other determinants (such as macroeconomic policies and natural resources).[29]

Other determinants

- In addition to investment and initial income which are "very strongly" robust, we can identify five additional variables as "strongly"robust in *both* the World and Africa samples, for a total of seven "strongly" robust variables common to both samples. These are (i) three policy variables, namely, low inflation, small government size (captured by government consumption), lower fiscal balances (captured by lower taxation and/or higher spending), (ii) an exogenous factor (namely, the change in terms of trade); and (iii) a political environment variable (namely, the change in the political index capturing changes in the degree of autocracy and democracy in the country).

- Focusing on the Africa sample alone, we can identify three additional "strongly" robust variables, two political and institutional variables (the democracy index and the incidence of war in the last ten years) and debt service to GDP. Further, while the geography and the black market premium variables enter as "strongly" robust in the World sample, they are classified at best as "weakly" robust in the Africa sample. In summary, we can identify the following "very strongly" robust variables in the World and Africa samples as follows:

[28] See Moser and Ichida (2001), Ranis, Stewart and Ramirez (2000), Anand (1991), and Anand and Ravallion (1993).

[29] A seminal study by the National Research Council in 1986 concluded that "slower population growth would be beneficial to the economic development of developing countries" (p. 90), and highlighted the need for examining the feedbacks between population pressures and institutional and policy changes.

"Very Strongly" Robust Growth Determinants		
	World	**Africa**
Log(Inflation)	x	x
Fiscal balance (to GDP)	x	x
Log(Overall investment to GDP)	x	x
Log(Government consumption to GDP)	x	x
Log(Initial Income)	x	x
Annual change in the polity index	x	x
Percentage of land in geographical tropics	x	
Terms of Trade	x	x
Black market premium	x	
Democracy Index		x
Incidence of civil war in the last 10 years		x
Debt service to GDP		x

- The result on the impact of inflation confirms the result of Fischer (1993) and Easterly and Fischer (2001) as well as recent literature which finds that growth and inflation are negatively related. Bruno and Easterly (1998) establish the growth-inflation relationship in a long-run setting which is more relevant to our analysis, and find that growth falls sharply during high inflation crises and recovers strongly after inflation falls. On the impact of government consumption and budgetary stance, our conclusions agree with those of Fischer (1993), and Easterly and Rebelo (1993), confirming the strong association between development and the fiscal structure. The finding on the terms of trade suggests the vulnerability to adverse movements in the price of tradeables (for countries that are net sellers of tradeables) and confirms the results of Easterly et al. (1993).

- The importance of institutional/governance variables and geography factors confirms the conclusions of recent literature that underlines the importance of these factors in determining growth. The experience of nations where political environments are weak or with time periods with a high propensity of government collapse has shown that growth is significantly lower than otherwise. Our finding on the importance of the political/institutional variables confirms the results of Alesina et al. (1996), and Easterly and Levine (1997) who document that economic growth in Sub-Saharan Africa is associated (among others) with political instability and ethnic fragmentation. In addition, in accord with Easterly and Levine (2003), Rodrik et al. (2002) and Acemoglu et al. (2001), we find evidence of the "institutions hypothesis" since our robustness analysis has found little direct effect of geography once we control for institutions in the Africa sample.[30] Therefore, it is not surprising that (i) our analysis concludes that these institutional/political variables have a more robust and bigger marginal impact in the Africa sample compared to the World sample; and (ii) the link between geography and growth breaks in the sample in which institutions are weaker (e.g. the Africa sample) and its effect only operates through institutions. Finally,

[30] However, if the institutional/political variables are taken out of the sample of explanatory variables, we find a strongly robust relationship between geography and growth in the Africa samples.

the strong robustness of the debt service to GDP in the Africa sample (and not the World sample) confirms the prediction of the debt overhang theories as larger levels of accumulated debt stocks (and hence service of the debt) lead to lower growth.

- Comparison across the World and Africa sample shows a number of variables entering with as "mildly" robust, including education, trade openness (although openness barely misses the "strongly" robust cutoff in the Africa sample), and aid to GDP. In addition, a number of variables—such as financial development, life expectancy, inequality, and the black market premium—that have been shown in the empirical literature to have an impact on overall economic growth, appear to have (at best) a "weakly" robust association with growth in our robustness analysis. This does not suggest that these determinants are not important in the growth empirics, but that they have a less important role than the ones we identify as "strongly" robust.

Marginal impacts

- Finding certain variables that appear as "strongly"robust in *both* the World and Africa samples suggests that what is good for growth around the world is also good for growth in Africa and that, at least in principle, lessons of modern growth economics are general and not region-specific. In a sense growth in Africa can be explained in terms of specific variables (i) the identified common robust determinants which are universally important for growth and are low in Africa; and (ii) the three additional political and institutional variables which are also "strongly" robust variables in the Africa sample.

- The marginal impact of the (common) robust variables is between the Africa and World samples are quite different. The estimated elasticities at sample group means shown in Table 3 suggest that targets on increasing investment, lowering inflation, lowering fiscal imbalances, lowering government consumption, and improving political environment have a strong impact on raising per capita incomes. Further, looking at the estimated elasticities in the two samples of World and Africa we can identify how the marginal impact of the "strongly" robust variables. For inflation, and terms of trade the magnitudes are higher for Africa highlighting the adverse effect of these determinants on the poor. Investment turns out to have about the same marginal impact in Africa as in the world, highlighting the importance of investment in raising growth in Africa. For the rest of the robust determinants fiscal balance and government consumption to GDP have less of a marginal impact in Africa compared to the rest of the world.

V. Conclusions

This paper attempts to provide insights on the economic growth and development puzzle by investigating the existence of robust determinants of economic growth. The relevance of the findings of this paper is strengthened by the use of three econometric tools: a dynamic panel estimator, which allows the results to be interpreted both across countries and within a given country; a formal, Bayesian robustness check, which explicitly accounts for model uncertainty; and a wide set of growth determinants.

The empirical findings indicate that once model uncertainty and other potential inconsistencies are accounted for, there exist economic, political, and environmental factors that robustly affect growth. First, we identify certain strongly robust growth determinants that are common for both the world and Africa samples, suggesting that Africa's growth process follows that of the rest of the world. These are: various economic factors such as initial conditions and a better macroeconomic environment (including higher investment, lower inflation, lower government consumption, and better fiscal stance); improved political environment; favorable exogenous terms-of-trade shocks; and fixed geographical factors. Second, although Africa's growth process follows, in principle, that of the rest of the world, the marginal impact and mechanisms of transmission of these determinants is very different; in addition, two political and institutional variables and debt service to GDP appear as robust determinants of growth *only* in the Africa sample highlighting the importance of these factors in a region plagued by political instability, weak institutions, and excessive debt accumulation.

Although this paper concludes that the mechanism of growth operates more or less the same in Africa as elsewhere with particular emphasis on the role of better institutions and political environment, the methodology herein does not constitute an investigation into how growth and its underlying determinants are explicitly interconnected. Identifying the similarities and some of the differences of the growth processes only begins to tackle the problem, and may, in fact, raise more questions than it answers. For one, we recognize that the links between policies and institutional reform, on one hand, and policy and average per capita incomes, on the other, are complex with many transitions taking place under the surface of a generally favorable impact. In order to derive policy implications about how to improve average incomes in Africa and the world we must first understand why certain channels influence growth differently in Africa than the rest of the world, and second, recognize that the average experience of a large number of countries should not obscure the importance of dealing effectively with country-specific circumstances.

References

Acemoglu, D., S. Johnson, and J. Robinson, 2001, "The Colonial Origins of Comparative Development: An Empirical Investigation," *American Economic Review,* Vol. 91, pp. 1369-1401.

____, 2002, "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution," *Quarterly Journal of Economics,* Vol. 117, pp. 1231-94.

Alesina, A., S. Olzer, N. Roubini, and P. Swagel, 1996, "Political Instability and Economic Growth," *Journal of Economic Growth,* Vol. *1*, No. 2, pp. 189-213.

Anand, S., 1991, "Poverty and Human Development in Asia and the Pacific," *Poverty Alleviation in Asia and the Pacific* (New York: United Nations Development Program).

Anand, S., and M. Ravallion, 1993, "Human Development in Poor Countries: On the Role of Private Incomes and Public Services," *Journal of Economic Perspectives*, Vol. 7, pp. 133-50.

Anand, S., and A. Sen, 2000, "Human Development and Economic Sustainability," *World Development,* Vol. 28, pp. 2029-49.

Barro, R., 1991, "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics*, Vol. 106, No. 2, pp. 223-51.

____, 1996, "Democracy and Growth," *Journal of Economic Growth*, Vol. 1, No. 1, pp. 1-27.

____, 2000, "Inequality and Growth in a Panel of Countries," *Journal of EconomicGrowth*, Vol. 5, No. 1, pp. 87-120.

Barro, R., and X. Sala-i-Martin, 1992, "Convergence," *Journal of Political Economy*, Vol. 100, No. 2, pp. 223-51.

____, 1995, *Economic Growth* (New York: McGraw-Hill).

Blundell, R., and S. Bond, 1998, "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics*, Vol. 87, No. 1, pp. 114-43.

Brock, W., and S. Durlauf, 2000, "Growth Economics and Reality," NBER Working Paper No. 8041 (Cambridge: National Bureau of Economic Research).

Brunetti, A., and B. Weder, 1995, "Political Sources of Growth: A Critical Note on Measurement," *Public Choice*, Vol. 82, pp. 125-34.

Brunetti, A., 1997, "Political Variables in Cross-Country Growth Analysis," *Journal of Economic Surveys*, Vol. 11, pp. 163-90.

Bruno, M. and W. Easterly, 1998, "Inflation Crises and Long-Run Growth," *Journal of Monetary Economics*, Vol. 41, No. 1, pp. 3-26.

Burnside, C., and D. Dollar, 1997, "Aid, Policies, and Growth," Policy Research Working Paper No. 1777 (Washington: World Bank).

____, 1998, "Aid, the Incentive Regime, and Poverty Reduction," Policy Research Working Paper No. 1937 (Washington, DC: World Bank).

Chen, S., and M. Ravallion, 1997, "What Can New Survey Data Tell Us about Recent Changes in Distribution and Poverty?" *The World Bank Economic Review*, Vol. 11, pp. 357-82.

Collier, P., and J. W. Gunning, 1999, "Explaining African Economic Performance," *Journal of Economic Literature*, Vol. 37, No. 1, pp. 64-111.

Deininger, K., and L. Squire, 1998, "New Ways of Looking at Old Issues: Inequality and Growth," *Journal of Development Economics*, Vol. 57, No. 2, pp. 257-85.

Dollar, D., and A. Kraay, 2002, "Growth is Good for the Poor," *Journal of Economic Growth*, Vol. 7, pp. 195-225.

Doppelhofer, G., R. I. Miller, and X. Sala-i-Martin, 2000, "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," NBER Working Paper No. 7750 (Cambridge: National Bureau of Economic Research).

Drazen, A., 2000, *Political Economy in Macroeconomics* (Princeton: Princeton University Press).

Durlauf, S., and D. Quah, 1999, "The New Empirics of Economic Growth," in J. B. Taylor and M. Woodford (eds), *Handbook of Macroeconomics Vol. IA* (Amsterdam: North Holland).

Easterly, W., and S. Fischer, 2001, "Inflation and the Poor," *Journal of Money, Credit and Banking*, Vol. 33, pp. 160-78.

Easterly, W., M. Kremer, L. Pritchett and L. H. Summers (1993) "Good Policy or Good Luck? Country Growth Performance and Temporary Shocks," *Journal of Monetary Economics*, Vol. 32, No. 3, pp. 459-83.

Easterly, W., and R. Levine, 1997, "Africa's Growth Tragedy: Policies and Ethnic Divisions," *Quarterly Journal of Economics*, Vol. 112, No. 4, pp. 1202-50.

____, 2003, "Tropics, Germs and Crops: How Endowments Influence Economic Development," *Journal of Monetary Economics,* Vol. 50, pp. 3-39.

Easterly, W. and S. Rebelo, 1993, "Fiscal Policy and Economic Growth: An Empirical Investigation," *Journal of Monetary Economics*, Vol. 32, No. 3, pp. 417-58.

Fernandez, C., E. Ley, and M. Steel, 2001, "Model Uncertainty in Cross-Country Growth Regressions," *Journal of Applied Econometrics*, Vol. 16, pp. 563-76.

Fischer, S. (1993) "The Role of Macroeconomic Factors in Growth," *Journal of Monetary Economics*, Vol. 32, No. 3, pp. 485-512.

Frankel, J. A., and D. Romer, 1999, "Does Trade Cause Growth?," *American Economic Review*, Vol. 89, No. 3, pp. 379-99.

Gallup, J., J. Sachs, and A. Mellinger, 1999, "Geography and Economic Development," *International Regional Science Review*, Vol. 22, No. 2, pp. 179-232.

Ghura, D., and M. Hadjimichael, 1996, "Growth in Sub-Saharan Africa," *International Monetary Fund Staff Papers*, Vol. 43, No. 3, pp. 605-34.

Ghura, D. and C. Leite, and C. Tsangarides, 2004, "Is Growth Enough? Macroeconomic Policy and Poverty Reduction," IMF Working Paper No. 02/118 (Washington: International Monetary Fund).

Hall, R. E., and C. Jones, 1997, "Levels of Economic Activity Across Countries", *American Economic Review*, Vol. 87, No. 2, pp. 173-77.

Hansen, L. P., 1982, "Large Sample Properties of Generalized Methods of Moments Estimators," *Econometrica*, Vol. 50, No. 4, pp. 1029-54.

Helliwell J., 1994, "Empirical Linkages Between Democracy and Economic Growth," *British Journal of Political Science*, Vol. 24, pp. 225-48.

Hoeffler, A. E., 2002, "The Augmented Solow Model and the African Growth Debate", *Oxford Bulletin of Economics and Statistics*, Vol. 64, pp.135-58.

Hoeting, J. A., D. Madigan, A. E. Raftery, and C. T. Volinsky, 1999, "Bayesian Model Averaging: A Tutorial," *Statistical Science*, Vol. 14, No. 4, pp. 382-417.

Kanbur, R., 2000, "Income Distribution and Development," in A. Atkinson and F. Bourguignon (eds), *Handbook of Income Distribution* (Amsterdam: North Holland).

Kanbur, R., and L. Squire, 2001, "The Evolution of Thinking about Poverty: Exploring the Interactions," in G. Meier and J. Stiglitz (eds), *Frontiers of Development Economics* (New York: Oxford University Press).

Kass, R., and A. Raftery, 1995, "Bayes Factors," *Journal of the American Statistical Association*, Vol. 90, No. 430, pp. 773-95.

King, R., and R. Levine, 1993, "Finance and Growth: Schumpeter Might be Right," *Quarterly Journal of Economics*, Vol. 108, No. 3, pp. 717-37.

Knack, S., and P. Keefer, 1995, "Institutions and Economic Performance: Cross-country Tests Using Alternative Institutional Measures," *Economics and Politics*, Vol. 7, No. 3, pp. 207-27.

Kormendi, R., and P. Meguire, 1985, "Macroeconomic Determinants of Growth: Cross-Country Evidence," *Journal of Monetary Economics*, Vol. 16, No. 2, pp. 141-63.

Krugman, P., 1988, "Financing Vs. Forgiving a Debt Overhang," *Journal of Development Economics*, Vol. 29, pp. 253-68.

Leamer, E., 1978, *Specification Searches: Ad Hoc Inference with Non-experimental Data* (New York: Wiley).

Leite, C., and J. Weidmann, 1999, "Does Mother Nature Corrupt? Natural Resources, Corruption and Economic Growth," IMF Working Paper No. 99/85 (Washington: International Monetary Fund).

Levine, R., and D. Renelt, 1992, "A Sensitivity Analysis of Cross-country Growth Regressions," *American Economic Review*, Vol. 82, No. 4, pp. 942-63.

Lewis, A., 1954, "Economic Development with Unlimited Supplies of Labor," *Manchester School*, Vol. 28, pp. 139-91.

Mankiw, G., D. Romer, and D. Weil, 1992, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, Vol. 107, No. 2, pp. 407-37.

Moser, G., and T. Ichida, 2001, "Economic Growth and Poverty Reduction in Sub-Saharan Africa," IMF Working Paper No. 01/112 (Washington: International Monetary Fund).

National Research Council, 1986, *Population Growth and Economic Development: Policy Questions* (Washington: National Academy Press).

Przeworski, A., and F. Limongi, 1993, "Political Regimes and Economic Growth," *Journal of Economic Perspectives*, Vol. 7, No. 3, pp. 51-71.

Raftery, A. E., 1996, "Approximate Bayes Factors and Accounting for Model Uncertainty in Generalized Linear Models," *Biometrica*, Vol. 83, pp. 251-66.

Ranis, G., F. Stewart, and A. Ramirez (2000) "Economic Growth and Human Development," *World Development*, Vol. 28, No. 2, pp. 197-219.

Rodrick, D., A. Subramanian, and F. Trebbi, 2002, "Institutions Rule: The Primacy of Institutions over Geography and Integration in Economic Development," NBER Working Paper No. 9305 (Cambridge: National Bureau of Economic Research).

Sala-i-Martin, X., 1997, "I Just Ran Four Million Regressions," NBER Working Paper No. 6252 (Cambridge: National Bureau of Economic Research).

Sala-i-Martin, X., Doppelhofer, G., R., and I. Miller, 2004, "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review*, Vol. 94, No. 4, pp. 813-35.

Scully, G.W., 1988, "The Institutional Framework and Economic Development," *Journal of Political Economy*, Vol. 96, No. 3, pp. 652-62.

Tsangarides, C., 2004, "A Bayesian Approach to Model Uncertainty," IMF Working Paper No. 04/68 (Washington: International Monetary Fund).

Table 1: Robustness of Growth Determinants
Marginal Evidence of Importance in World Sample

	Regressors	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior Variance Conditional on Inclusion	Sign Certainty Probability
1	Log of Inflation	0.90	-0.0225	0.0004	1.00
2	Fiscal balance (to GDP)	0.94	0.8339	0.0828	1.00
3	Log (overall investment to GDP)	0.94	0.0475	0.0008	1.00
4	Log(Government consumption to GDP)	0.94	-0.0688	0.0009	0.99
5	Log(Initial Income)	0.94	-0.1595	0.0024	0.99
6	Annual change in the polity index	0.94	-0.2937	0.4133	0.98
7	Percentage of land in geographical tropics	1.00	-0.2868	0.0080	0.97
8	Terms of Trade (Growth)	0.94	0.0275	0.0124	0.96
9	Black market premium	0.94	-0.0002	0.0000	0.95
10	Overall schooling	0.77	0.0572	0.0011	0.94
11	Arable land	0.94	-0.0233	0.0002	0.93
12	Trade openness (X+M as share of GDP)	0.94	0.0889	0.0027	0.86
13	Aid (to GDP)	0.89	-0.4519	0.0644	0.84
14	Democracy index	0.94	0.3749	0.0475	0.78
15	Incidence of civil war in the last 10 years	0.94	0.0258	0.0006	0.72
16	Life expectancy	0.93	0.0012	0.0000	0.60
17	Population growth	0.94	0.1607	0.0181	0.52
18	Financial depth (M2 to GDP)	0.94	-0.0934	0.0071	0.49
19	Debt service to GDP	0.87	0.2334	0.0889	0.30

Table 2: Robustness of Growth Determinants
Marginal Evidence of Importance in Africa Sample

	Regressors	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior Variance Conditional on Inclusion	Sign Certainty Probability
1	Log of Inflation	0.90	-0.1360	0.0047	1.00
2	Log(Government consumption to GDP)	0.92	-0.0616	0.0015	1.00
3	Terms of Trade (Growth)	0.92	0.2510	0.0238	1.00
4	Democracy index	0.91	0.6421	0.1660	1.00
5	Annual change in the polity index	0.91	-1.2164	1.1457	1.00
6	Debt service to GDP	0.91	-0.4808	0.1153	0.99
7	Log(Initial Income)	0.92	-0.0947	0.0015	0.99
8	Log (overall investment to GDP)	0.92	0.0475	0.0016	0.99
9	Incidence of civil war in the last 10 years	0.92	-0.0230	0.0008	0.96
10	Fiscal balance (to GDP)	0.92	0.1493	0.0503	0.96
11	Trade openness (X+M as share of GDP)	0.92	0.0516	0.0035	0.94
12	Aid (to GDP)	0.91	-0.1503	0.0214	0.89
13	Arable land	0.92	-0.0091	0.0005	0.86
14	Population growth	0.92	0.2253	0.0363	0.81
15	Life expectancy	0.90	0.0045	0.0000	0.81
16	Financial depth (M2 to GDP)	0.92	0.1738	0.0284	0.81
17	Percentage of land in geographical tropics	1.00	-0.0126	0.0193	0.80
18	Overall schooling	0.73	0.0103	0.0005	0.71
19	Black market premium	0.91	0.0018	0.0001	0.49

Notes:
1. Bayesian Model averaging techniques are applied using a panel data systems GMM estimator; the dependent variables in the system are $\ln y_t - \ln y_0$ and the first difference of $\ln y_t - \ln y_0$.
2. The results are ranked by the sign certainty probability. The boxed area indicates variables identified as (at least) "strongly robust".
3. The prior mean model size kbar is 9; qualitative conclusions are robust to the choice of kbar (as shown in Tables 4a and 4b).
4. See Table A2 for details on sample groupings.

Table 3: Elasticities at Country/Sample Group Means
Robust Growth Determinants (Various Samples)

		Sample	
	Regressors	World	Africa
1	Log of Inflation	-0.0225	-0.1360
2	Fiscal balance (to GDP)	-0.0357	-0.0087
3	Log (overall investment to GDP)	0.0475	0.0475
4	Log(Government consumption to GDP)	-0.0688	-0.0616
5	Log(Initial Income)	-0.1595	-0.0947
6	Annual change in the polity index	-0.0215	-0.0476
7	Percentage of land in geographical tropics	-0.1582	...
8	Terms of Trade (Growth)	0.0295	0.4761
9	Black market premium	-0.0282	...
10	Democracy Index		-2.5510
11	Incidence of civil war in the last 10 years		-0.0051
12	Debt service to GDP		-0.0219

Notes:
1. Bayesian Model averaging techniques are applied using a panel data systems GMM estimator; the dependent variables in the system are $\ln y_t$-$\ln y_0$ and the first difference of $\ln y_t$-$\ln y_0$.
2. Elasticities for each group calculated only for the robust variables identified in Tables 1 and 2.
3. The prior mean model size kbar is 9.
4. See Table A2 for details on sample groupings.

Table 4a: Sensitivity Analysis on Prior Model Size in World Sample

Posterior Conditional Means and Variances With kbar = 5, 7, 9, 11, 13

		Sign	Mean		Variance	
	Regressors	Certainty	Minimum	Maximum	Minimum	Maximum
1	Log of Inflation	1.00	-0.0274	-0.0204	0.0004	0.0006
2	Fiscal balance (to GDP)	1.00	0.7878	0.8609	0.0574	0.1301
3	Log (overall investment to GDP)	1.00	0.0418	0.0565	0.0006	0.0012
4	Log(Government consumption to GDP)	0.99	-0.0720	-0.0624	0.0008	0.0013
5	Log(Initial Income)	0.99	-0.1650	-0.1521	0.0015	0.0042
6	Annual change in the polity index	0.98	-0.4534	-0.1954	0.3878	0.4576
7	Percentage of land in geographical tropics	0.97	-0.2943	-0.2839	0.0073	0.0113
8	Terms of Trade (Growth)	0.96	0.0180	0.0448	0.0123	0.0125
9	Black market premium	0.95	-0.0004	-0.0001	0.0000	0.0000
10	Overall schooling	0.94	0.0544	0.0586	0.0007	0.0017
11	Arable land	0.93	-0.0237	-0.0230	0.0002	0.0003
12	Trade openness (X+M as share of GDP)	0.86	0.0823	0.0935	0.0024	0.0032
13	Aid (to GDP)	0.84	-0.4853	-0.3854	0.0457	0.0937
14	Democracy index	0.78	0.3521	0.3881	0.0415	0.0607
15	Incidence of civil war in the last 10 years	0.72	2.2447	2.7598	5.9143	6.6376
16	Life expectancy	0.60	0.0011	0.0012	0.0000	0.0000
17	Population growth	0.52	0.1403	0.1750	0.0166	0.0202
18	Financial depth (M2 to GDP)	0.49	-0.0999	-0.0851	0.0067	0.0077
19	Debt service to GDP	0.30	0.1775	0.2653	0.0803	0.1017

Table 4b: Sensitivity Analysis on Prior Model Size in Africa Sample

Posterior Conditional Means and Variances With kbar = 5, 7, 9, 11, 13

		Sign	Mean		Variance	
	Regressors	Certainty	Minimum	Maximum	Minimum	Maximum
1	Log of Inflation	1.00	-0.1379	-0.1336	0.0024	0.0081
2	Log(Government consumption to GDP)	1.00	-0.0672	-0.0569	0.0012	0.0021
3	Terms of Trade (Growth)	1.00	0.2323	0.2642	0.0203	0.0298
4	Democracy index	1.00	0.6055	0.6816	0.1313	0.2373
5	Annual change in the polity index	1.00	-1.2388	-1.2157	1.0333	1.3980
6	Debt service to GDP	0.99	-0.4965	-0.4687	0.0935	0.1513
7	Log(Initial Income)	0.99	-0.0972	-0.0908	0.0010	0.0024
8	Log (overall investment to GDP)	0.99	0.0395	0.0575	0.0013	0.0021
9	Incidence of civil war in the last 10 years	0.96	-2.9446	-2.0809	7.6658	10.9885
10	Fiscal balance (to GDP)	0.96	0.1127	0.1971	0.0452	0.0600
11	Trade openness (X+M as share of GDP)	0.94	0.0473	0.0604	0.0031	0.0047
12	Aid (to GDP)	0.89	-0.1570	-0.1417	0.0173	0.0287
13	Arable land	0.86	-0.0141	-0.0052	0.0004	0.0005
14	Population growth	0.81	0.2033	0.2352	0.0313	0.0483
15	Life expectancy	0.81	0.0032	0.0054	0.0000	0.0000
16	Financial depth (M2 to GDP)	0.81	0.1281	0.1955	0.0241	0.0349
17	Percentage of land in geographical tropics	0.80	-0.0627	0.0168	0.0157	0.0296
18	Overall schooling	0.71	0.0087	0.0115	0.0004	0.0006
19	Black market premium	0.49	0.0009	0.0021	0.0001	0.0001

Notes:

1. Bayesian Model averaging techniques are applied using a panel data systems GMM estimator; the dependent variables in the system are $\ln y_t - \ln y_0$ and the first difference of $\ln y_t - \ln y_0$.
2. The results are ranked by the sign certainty probability.
3. See Table A2 for details on sample groupings.

Appendix I

Tables

Table A1: Sample Data
Variable Definitions and Sources

Variable	Source	Definition
Dependent Variable		
LNY	Penn World Table 6.1	Logarithm of real GDP per capita (1996 US dollars at PPP).
Explanatory Variables		
1 LNY0	Penn World Table 6.1	Logarithm of initial real GDP per capita (1996 US dollars at PPP).
Solow determinants		
2 LNI	Penn World Table 6.1	Logarithm of real investment to GDP (1996 US dollars at PPP).
3 LNNPOPGR	Penn World Table 6.1	Logarithm of annual population growth rate plus 0.05.
Macroeconomic stability		
4 LNINFL	International Financial Statistics	Logarithm of one plus the inflation rate.
5 BALY	World Economic Outlook	Government balance as share of GDP, current LCU.
6 G	Penn World Table 6.1	Real government consumption to GDP (1996 US dollars at PPP).
6 LNG	Penn World Table 6.1	Logarithm of G.
Foreign Aid		
7 AIDGDP	Global Development Finance	Foreign aid as percentage of GDP.
Financial development		
8 DMBCB	International Financial Statistics	Ratio of assets of deposit money banks to total bank assets.
8 BRMY	World Economic Outlook	Ratio of broad money to GDP.
External debt		
9 DEBTGDP	World Development Indicators	Nominal debt to GDP.
9 DSGDP	World Development Indicators	Debt service to GDP.
9 DSX	World Development Indicators	Debt service to exports.
9 NPDSX	Easterly	NPV debt service to exports of goods and services.
Trade regime		
10 OPEN	Penn World Table 6.1	Exports plus Imports as share of GDP (1996 US dollars at PPP).
10 OPENGR	Penn World Table 6.1	Average annual rate of growth of openness.
External environment		
11 TOT	World Economic Outlook	Terms of trade (goods and services).
11 TOTGR	World Economic Outlook	Terms of trade (goods and services) growth.
Human capital		
12 PYR	Barro and Lee dataset	Average stock of years of primary education.
12 SYR	Barro and Lee dataset	Average stock of years of secondary education.
12 LTOTED	Barro and Lee dataset	Logarithm of total stock of years of primary and secondary education.
Health		
13 LFEXP	World Development Indicators	Life expectancy at birth (total).
Internal environment/resources		
14 GINI	Dollar and Kraay/Lynn and Squire	GINI coefficient (initial value).
14 LLAND	World Development Indicators	Logarithm of arable land per capita, hectares, average over five years.
14 EHET	Sambanis	Ethnic heterogeneity.
14 ELFO	Sambanis	Updated index of ethno linguistics fractionalization.
Corruption/War		
15 BLK	Easterly and Sewadeh	Ratio of black market rate and official exchange rate minus one.
15 PW10	Sambanis	Incidence of civil war in the last 10 years.
Institutions/governance		
16 DEMOC	Polity IV	Aggregate index of democracy.
16 DEMOCLAG	Polity IV	Aggregate index of democracy, lagged once.
16 POLITY	Polity IV	Aggregate index of autocracy and democracy.
16 POLITYLAG	Polity IV	Aggregate index of autocracy and democracy, lagged once.
16 CHANGE	Polity IV	Annual change in the Polity index.
Geography/Physical Factors		
17 CENLAT	Gallup, Mellinger, Sachs	Latitude of country centroid.
17 DISTCR	Gallup, Mellinger, Sachs	Mean distance to nearest ice-free coastline or sea-navigable river.
17 CENCR	Gallup, Mellinger, Sachs	Distance of country s centroid to nearest coast/sea-navigable river.
17 POP100CR	Gallup, Mellinger, Sachs	Percentage of population within 100 km of coast/sea-navigable river.
17 TROPICAR	Gallup, Mellinger, Sachs	% Land area in geographical tropics
17 LCR100KM	Gallup, Mellinger, Sachs	% Land area within 100 km of ice-free coast/navigable river.
Dummy variables		
18 EAP		East Asia and Pacific Regional Dummy.
19 ECA		Europe and Central Asia Dummy.
20 MENA		Middle East and North Africa Dummy.

Table A2: Sample Data
Country Group Membership

						Africa	
Countries	Obs.	Countries	Obs.	Countries	Obs.	Countries	Obs.
Albania	1	Iran	8	Trinidad &Tobago	8	Angola	8
Algeria	8	Ireland	8	Tunisia	7	Benin	8
Angola	7	Israel	8	Turkey	8	Botswana	8
Antigua	4	Italy	8	Uganda	8	Burkina Faso	8
Argentina	8	Jamaica	8	Ukraine	2	Burundi	8
Armenia	1	Japan	8	United Kingdom	8	Cameroon	8
Australia	8	Jordan	8	Uruguay	8	Cape Verde	8
Austria	8	Kazakhstan	1	USA	8	Central African Republic	8
Azerbaijan	1	Kenya	8	Venezuela	8	Chad	8
Bangladesh	8	Korea, Republic of	8	Vietnam	1	Comoros	8
Barbados	8	Kyrgyzstan	1	Yemen	2	Congo, Dem. Rep.	8
Belarus	2	Latvia	2	Zambia	8	Congo, Republic of	8
Belgium	8	Lebanon	2	Zimbabwe	8	Cote d'Ivoire	8
Belize	4	Lesotho	8			Equatorial Guinea	8
Benin	8	Lithuania	1	**149**	**983**	Ethiopia	8
Bolivia	8	Luxembourg	8			Gabon	8
Botswana	8	Macao	2			Gambia, The	8
Brazil	8	Macedonia	1			Ghana	8
Bulgaria	1	Madagascar	8			Guinea	8
Burkina Faso	8	Malawi	8			Guinea-Bissau	8
Burundi	8	Malaysia	8			Kenya	8
Cambodia	1	Mali	8			Lesotho	8
Cameroon	8	Mauritania	8			Madagascar	8
Canada	8	Mauritius	8			Malawi	8
Cape Verde	8	Mexico	8			Mali	8
Central African Republic	7	Moldova	1			Mauritania	8
Chad	8	Morocco	8			Mauritius	8
Chile	8	Mozambique	8			Mozambique	8
China	8	Namibia	8			Namibia	8
Colombia	8	Nepal	8			Niger	8
Comoros	8	Netherlands	8			Nigeria	8
Congo, Dem. Rep.	7	New Zealand	8			Rwanda	8
Congo, Republic of	8	Nicaragua	8			Sao Tome and Principe	8
Costa Rica	8	Niger	8			Senegal	8
Cote d'Ivoire	8	Nigeria	8			Seychelles	8
Croatia	1	Norway	8			Sierra Leone	8
Cuba	2	Pakistan	8			South Africa	8
Cyprus	7	Panama	8			Tanzania	8
Czech Republic	2	Papua New Guinea	8			Togo	8
Denmark	8	Paraguay	8			Uganda	8
Dominica	3	Peru	8			Zambia	8
Dominican Republic	8	Philippines	8			Zimbabwe	8
Ecuador	8	Poland	6				
Egypt	8	Portugal	8			**41**	**328**
El Salvador	8	Puerto Rico	5				
Equatorial Guinea	8	Romania	8				
Estonia	1	Russia	1				
Ethiopia	8	Rwanda	8				
Fiji	8	Sao Tome and Principe	5				
Finland	8	Senegal	8				
France	8	Seychelles	8				
Gabon	8	Sierra Leone	6				
Gambia, The	8	Singapore	7				
Germany	6	Slovak Republic	2				
Ghana	8	Slovenia	2				
Greece	8	South Africa	8				
Grenada	4	Spain	8				
Guatemala	8	Sri Lanka	8				
Guinea	8	St. Kitts & Nevis	4				
Guinea-Bissau	8	St. Lucia	4				
Guyana	8	St.Vincent & Grenadines	4				
Haiti	7	Sweden	8				
Honduras	8	Switzerland	8				
Hong Kong	8	Syria	8				
Hungary	6	Taiwan	7				
Iceland	8	Tanzania	8				
India	8	Thailand	8				
Indonesia	8	Togo	8				

Table A3: Growth Regressions Compilation

Correlations from the Literature

Explanatory Variable	Reference/Source	Finding
Solow determinants and initial income		
Initial Income	Barro (1991), (1997)	Negative (significant)
	Barro and Sala-i-Martin (1992)	Negative (significant)
	Caselli, Esquivel and Lefort (1996)	Negative (significant)
	Kormendi and Meguire (1985)	Negative (significant)
	Levine and Renelt (1992)	Negative (robust)
	Mankiw, Romer and Weil (1992)	Negative (significant)
Investment	Barro (1991)	Positive (significant)
	Barro (1997)	Positive (not significant)
	Barro and Lee (1994)	Positive (significant)
	Caselli, Esquivel and Lefort (1996)	Positive (significant)
	Levine and Renelt (1992)	Positive (robust)
	Mankiw, Romer and Weil (1992)	Positive (significant)
Population growth	Barro and Lee (1994)	Positive (not significant)
	Kormendi and Meguire (1985)	Negative (significant)
	Levine and Renelt (1992) (-,not robust)	Negative (not robust)
	Mankiw, Romer and Weil (1992)	Negative (significant)
Macroeconomic stability		
Inflation	(Growth) Kormendi and Meguire (1985)	Negative (significant)
	(Level above 15%) Barro (1997)	Negative (significant)
	(Level) Bruno and Easterly (1995)	Negative (significant)
	(Level) Fischer (1993)	Negative (significant)
	(Level) Levine and Renelt (1992)	Negative (not robust)
	(Variability) Barro (1997)	Positive (not significant)
	(Variability) Fischer (1993)	Negative (significant)
	(Variability) Levine and Renelt (1992)	Negative (not robust)
Government deficit as share of GDP	Easterly and Levine (1997)	Negative (significant)
	Fischer (1993)	Negative (significant)
	Levine and Renelt (1992)	Negative (not robust)
Government consumption to GDP	(Growth) Kormendi and Meguire (1985)	Positive (not significant)
	(Level) Barro (1991)	Negative (significant)
	(Level) Barro (1997)	Negative (significant)
	(Level) Barro and Lee (1994)	Negative (significant)
	(Level) Caselli, Esquivel and Lefort (1996)	Positive (significant)
	(Level) Levine and Renelt (1992)	Negative (not robust)
Foreign Aid		
External transfers	Easterly, Kremer, Pritchett and Summers (1993)	Mixed (not significant)
	Burnside and Dollar (1998)	Positive (significant)
Financial development		
Financial sophistication	Easterly and Levine (1997)	Positive (significant)
	King and Levine (1993)	Positive (significant)
	Levine and Zervos (1993)	Positive (robust)
Money growth	Kormendi and Meguire (1985)	Positive (not significant)
External debt		
Dummy	Easterly, Kremer, Pritchett and Summers (1993)	Negative (not significant)
Debt to GDP	(Level above 35%) Patillo, Poirson and Ricci (2002)	Negative (significant)
Trade regime		
Exports plus Imports as share of GDP	Frankel and Romer (1996)	Positive (significant)
	Frankel, Romer and Cyrus (1996)	Positive (significant)
	Levine and Renelt (1992)	Positive (not robust)
Openness	(Growth) Harrison (1995)	Positive (significant)
	(Level) Harrison (1995)	Positive (significant)
	(Level) Levine and Renelt (1992)	Not robust
	(Level) Sachs and Warner (1995)	Positive (significant)
External environment		
Terms of trade improvement	Barro (1997)	Positive (significant)
	Barro and Lee (1994)	Positive (not significant)
	Caselli, Esquivel and Lefort (1996)	Positive (significant)
	Easterly, Kremer, Pritchett and Summers (1993)	Positive (significant)
	Fischer (1993)	Positive (significant)
Human capital/education proxies		
Overall level	Azariadis and Drazen (1990)	Positive (significant)
	Barro (1991)	Positive (significant)

Table A3: Growth Regressions Compilation
Correlations from the Literature

Explanatory Variable	Reference/Source	Finding
	Easterly and Levine (1997)	Positive (significant)
	Levine and Renelt (1992)	Positive (robust)
	Mankiw, Romer and Weil (1992)	Positive (significant)
Primary level	Barro (1997)	Negative (not significant)
	Sachs and Warner (1995)	Positive (not significant)
Secondary level	Sachs and Warner (1995)	Positive (not significant)
Health		
Various proxies	Barro (1997)	Positive (significant)
	Barro and Lee (1994)	Positive (significant)
	Knowles and Owen (1995)	Positive (significant)
Internal environment/resources		
GINI coefficient	Alesina and Rodrik (1994)	Negative (significant)
	Forbes (1997)	Positive (significant)
Ethno linguistics fractionalization	Easterly and Levine (1997)	Negative (significant)
Corruption/War		
Black market premium	Barro (1996)	Negative (significant)
	Barro and Lee (1994)	Negative (significant)
	Easterly and Levine (1997)	Negative (significant)
	Fischer (1993)	Negative (significant)
	Harrison (1995)	Negative (significant)
	Levine and Renelt (1992)	Negative (not robust)
	Levine and Zervos (1992)	Negative (robust)
	Sala-i-Martin (1997)	Negative (significant)
Incidence of civil war	Sala-i-Martin (1997)	Negative (significant)
	Barro and Lee (1994)	Negative (not significant)
Institutions/governance		
Civil liberties indices	Barro and Lee (1994)	Negative (significant)
	Kormendi and Meguire (1985)	Positive (not significant)
	Levine and Renelt (1992)	Not robust
	Sala-i-Martin (1997)	Positive (significant)
Political rights indices	Barro and Lee (1994)	Positive (significant)
	Sala-i-Martin (1997)	Positive (significant)
Overall indices	Sachs and Warner (1995)	Positive (significant)
Political instability indices	Alesina, Ozler, Roubini and Swagel (1996)	Negative (significant)
	Barro (1991)	Negative (significant)
	Barro and Lee (1994)	Negative (significant)
	Caselli, Esquivel and Lefort (1996)	Negative (significant)
	Easterly and Levine (1997)	Negative (significant)
	Levine and Renelt (1992)	Negative (not robust)
	Sala-i-Martin (1997)	Negative (significant)
Geography/Physical Factors		
Latitude	Sala-i-Martin (1997)	Positive (significant)
Location and climate	Gallup, Sachs, Mellinger (1999)	Negative (significant)
	Sachs and Warner (1997)	Negative (significant)
Tropics	Hall and Jones (1997)	Negative (significant)
Dummy variables/regional effects		
East Asia and Pacific Regional Dummy	Barro (1997)	Positive (not significant)
	Barro and Lee (1994)	Positive (not significant)
Latin America and Caribbean Dummy	Barro (1991)	Negative (significant)
	Barro and Lee (1994)	Negative (significant)
	Easterly and Levine (1997)	Negative (significant)
	Sala-i-Martin (1997)	Negative (significant)
Sub-Saharan Africa Dummy	Barro (1991)	Negative (significant)
	Barro (1997)	Negative (not significant)
	Barro and Lee (1994)	Negative (significant)
	Easterly and Levine (1997)	Negative (significant)
	Sala-i-Martin (1997)	Negative (significant)

Notes:
1. Correlations from Durlauf and Quah (1999) and author's calculations.

Table A4: Sample Data

Country Group Unweighted Averages

Variable	ALL	Non-oil	Intermediate	OECD	Africa
	Country Group				
Dependent Variable					
LNYT-LNY0	0.08	0.07	0.08	0.11	0.03
Explanatory Variables					
1 LNY0	8.14	8.11	8.36	9.47	7.27
Solow determinants					
2 LNI	2.55	2.52	2.71	3.14	2.06
3 LNNPOPGR	1.92	1.95	1.93	1.74	2.01
Macroeconomic stability					
4 LNINFL	0.17	0.17	0.16	0.07	0.16
5 BALY	-4.28	-4.10	-3.76	-2.98	-5.83
6 LNG	2.88	2.82	2.72	2.48	3.01
Foreign Aid					
7 AIDGDP	6.60	5.52	3.98	0.35	11.87
Financial development					
8 BRMY	40.41	37.13	40.76	57.60	25.02
External debt					
9 DSGDP	5.31	5.56	6.03	4.38	4.55
Trade regime					
10 OPEN	69.26	58.57	57.42	44.78	73.73
External environment					
11 TOTGR	1.07	0.75	0.84	0.31	1.90
Human capital					
12 LTOTED	1.26	1.22	1.44	1.96	0.48
Health					
13 LFEXP	60.23	59.79	63.09	73.34	47.29
Internal environment/resources					
14 GINI	38.77	39.33	39.12	32.14	47.15
14 LLAND	-1.58	-1.53	-1.53	-1.23	-1.32
Corruption/War					
15 BLK	122.90	56.58	52.66	1.50	56.85
15 PW10	0.19	0.21	0.19	0.05	0.22
Institutions/governance					
16 POLITYLAG1	0.71	0.95	2.28	8.74	-3.97
16 CHANGE	0.07	0.08	0.09	0.06	0.04
Geography/Physical Factors					
17 TROPICAR	55.16	58.32	50.51	1.76	91.65
17 LCR100KM	46.57	43.33	51.05	65.85	18.49
Memorandum items:					
Number of countries	149	94	74	22	41

Notes:

1. See Table A2 for details on sample groupings.
2. The average number of periods is the average number of observations of each group in the data set. A period consists of two observations that are, at minimum five years apart.

Appendix II

Computational Aspects

This Appendix provides a summary of the LIBMA approach and presents all the calculated quantities and summary statistics on which the robustness analysis is based. The complete derivation of the LIBMA can be found in Tsangarides (2004).

Bayesian Hypothesis Testing and BMA

We begin with a probability model for the data D,which is specified by a vector of d unknown parameters $\boldsymbol{\theta} = (\theta_1, ..., \theta_d)$. Prior to observing the data, our beliefs are represented by a prior probability density $p(\boldsymbol{\theta})$, and the probability model is specified by the likelihood $p(D|\boldsymbol{\theta})$,the probability of observing the data D given that $\boldsymbol{\theta}$ is the true parameter. Having observed the data D we update our beliefs about $\boldsymbol{\theta}$ using Bayes' theorem to get the posterior distribution of $\boldsymbol{\theta}$ given the data D, or $p(\boldsymbol{\theta}|D) = \frac{p(D|\boldsymbol{\theta})p(\boldsymbol{\theta})}{\int p(D|\boldsymbol{\theta})p(\boldsymbol{\theta})d\boldsymbol{\theta}}$.

Suppose now that we want to use data D to test two competing hypotheses presented by the models M_1 and M_2 with parameter vectors $\boldsymbol{\theta}_1$ and $\boldsymbol{\theta}_2$. By Bayes' rule the posterior probability that M_1 is the correct model is:

$$p(M_1|D) = \frac{p(D|M_1)p(M_1)}{p(D|M_1)p(M_1) + p(D|M_2)p(M_2)} \tag{6}$$

where (for $k = 1, 2$), $p(D \mid M_k)$ is the marginal probability of the data given M_k, and $p(M_k)$ is the prior probability of model M_k.

The *marginal likelihood* (or marginal probability of data) is obtained by integrating over $\boldsymbol{\theta}_k$, so for the numerator of (6)

$$p(D|M_1) = \int p(D|\boldsymbol{\theta}_1, M_1)p(\boldsymbol{\theta}_1|M_1)d\theta_1 \tag{7}$$

which suggests that the posterior distribution is proportional to the likelihood times the prior.

The *posterior odds* ratio for M_2 against M_1 (i.e. the ratio of their posterior probabilities $\frac{p(M_2|D)}{p(M_1|D)}$ can be used to measure the extend to which the data support M_2 over M_1. Using (6) the posterior odds ratio is

$$\frac{p(M_2|D)}{p(M_1|D)} = \frac{p(D|M_2)}{p(D|M_1)} \times \frac{p(M_2)}{p(M_1)} \tag{8}$$

where the first term on the RHS of (8) is the *Bayes factor* for M_2 against M_1,denoted by B_{21}, and the second term is the *prior odds* ratio. Sometimes the prior odds ratio is set to 1, representing the lack of preference for either model, in which case the posterior odds ratio is equal to the Bayes factor. When the posterior odds ratio is greater (less) than 1 the data favor M_2 over M_1 (M_1 over M_2).

Evaluating the Bayes factor in (8) requires calculating the marginal likelihood which can be a high-dimensional and intractable integral. Various analytic and numerical approximations have been proposed. The BIC approximation is a simple and accurate method to estimate Bayes factors. We focus on approximating the marginal likelihood for a single model, i.e. the RHS of (7). As discussed in Kass and Raftery (1995), an approximation to the Bayes factor B_{21} is the *Bayesian Information Criterion* (BIC)

$$BIC = 2\log B_{21} = 2[\log p(D|\widehat{\boldsymbol{\theta}}_2, M_2) - \log p(D|\widehat{\boldsymbol{\theta}}_1, M_1)] - (d_2 - d_1)\log n + O(n^{-\frac{1}{2}}) \quad (9)$$

Now suppose we can divide the parameter space into regions (models). Let Δ be the quantity of interest. Then Bayesian inference about Δ is constructed using *Bayesian Model Averaging*, based on the posterior distribution

$$p(\Delta|D) = \sum_{k=1}^{K} p(\Delta|D, M_k)p(M_k|D) \quad (10)$$

This follows by the law of total probability. Thus, the *full* posterior distribution of Δ is a weighted average of the posterior distributions under each model $(M_1, ..., M_K)$, where the weights are the posterior model probabilities $p(M_k|D)$.

Using Bayes' theorem, the posterior model probabilities are obtained using

$$p(M_k|D) = \frac{p(D|M_k)p(M_k)}{\sum_{j=1}^{K} p(D|M_j)p(M_j)} \quad (11)$$

which is essentially (6) extended from 2 to K models. Further, it can be shown that $p(D|M_k) \propto \exp(-\frac{1}{2}BIC_k)$ (11) becomes

$$p(M_k|D) = \frac{\exp(-\frac{1}{2}BIC_k)p(M_k)}{\sum_{j=1}^{K} \exp(-\frac{1}{2}BIC_j)p(M_j)} \quad (12)$$

The expression in (12) uses the "full information" BIC shown in (9). In the framework of our GMM analysis, we modify (12) to incorporate the "limited information" criterion, namely the LIBIC.

$$p(M_k|D) = \frac{\exp(-\frac{1}{2}LIBIC_k)p(M_k)}{\sum_{j=1}^{K} \exp(-\frac{1}{2}LIBIC_j)p(M_j)} \quad (13)$$

Equation (13) defines the LIBMA estimator, an extension of the BMA in the case of a limited information likelihood. The LIBMA incorporates a dynamic panel estimator in the context of GMM and a Bayesian robustness check to explicitly account for model uncertainty in evaluating the results of a universe of models generated by a set of possible regressors.[31]

[31] The derivation of the LIBIC as well as further details of the LIBMA approach to model uncertainty can be found in Tsangarides (2004).

Computed Statistics for the Robustness Simulations

We now have all the needed information to calculate the statistics required for the robustness analysis. From (8) the posterior odds ratio for two models M_j, M_l is $B_{jl} = \frac{p(M_j|D)}{p(M_l|D)} = \frac{p(D|M_j)}{p(D|M_l)} \times \frac{p(M_j)}{p(M_l)}$. The first term on the RHS, $\frac{p(D|M_j)}{p(D|M_l)}$ is the Bayes factor and can be approximated using (9). The second term, $\frac{p(M_j)}{p(M_l)}$is the prior odds ratio. In the case where there is no preference for a specific model, $p(M_1) = p(M_2) = ... = p(M_K) = \frac{1}{K}$ and the posterior odds ratio is equal to the Bayes factor. We *do not* assume equal inclusion probability for each model. Instead, following Sala-i-Martin et al. (2004), we represent a model M_j as a length k^* binary vector in which a one indicates that a variable in included in the model and a zero indicates that it is not. Assuming that each variable has an equal inclusion probability, the prior probability for model M_j is

$$p(M_j) = (\frac{\overline{k}}{k^*})^{k_j}(1 - \frac{\overline{k}}{k^*})^{1-k_j} \tag{14}$$

and the prior odds ratio is

$$\frac{p(M_j)}{p(M_l)} = (\frac{\overline{k}}{k^*})^{k_j-k_l}(1 - \frac{\overline{k}}{k^*})^{k_j-k_l} \tag{15}$$

where k^* is the total number of regressors, $\overline{k}$ is the researcher's prior about the number of regressors with non-zero coefficients, k_j is the number of included variables in model M_j, and $\frac{\overline{k}}{k^*}$ is the prior inclusion probability for each variable. Since $\overline{k}$ is the only prior that is arbitrarily specified in the simulations, robustness checks of the results can be estimated by changing the value of this parameter.

If the set of possible regressions is small enough to allow exhaustive calculation, we can substitute (14) into (16), to calculate the posterior model probabilities (where the weights for different models are assigned based on posterior probabilities of each model, essentially normalizing the weight of any model by the sum of the weights of all possible $K = 2^{k^*}$ models):

$$p(M_j|D) = \frac{\exp(-\frac{1}{2}LIBIC_j)p(M_j)}{\sum_{l=1}^{2^{k^*}}\exp(-\frac{1}{2}LIBIC_l)p(M_l)} \tag{16}$$

Next, we can use (16) to estimate the *posterior mean* and *posterior variance* as follows:

$$E(\theta_k|D) = \sum_{j=1}^{2^{k^*}} p(M_j|D)E(\theta_k|D, M_j) \tag{17}$$

and

$$
\begin{aligned}
Var(\theta_k|D) &= E[Var(\theta_k|D,M_j)|D] + Var[E(\theta_k|D,M_j)|D] \qquad (18)\\
&= \sum_{j=1}^{2^{k^*}} p(M_j|D)\left\{Var(\theta_k|D,M_j) + E(\theta_k|D,M_j)^2\right\} - E(\theta_k|D)^2
\end{aligned}
$$

Other statistics relevant to the paper are the posterior mean and variance *conditional on inclusion*. First we calculate the *posterior inclusion probability*, which is the sum of all posterior probabilities of all the regressions including the specific variable (regressor). Essentially, the posterior inclusion probability is a ranking measure to see how much the data favors the inclusion of a variable in the regression, and it is calculated as

$$
posterior\ inclusion\ probability = p(\theta_k \neq 0|D) = \sum_{\theta_k \neq 0} p(M_j|D) \qquad (19)
$$

If $p(\theta_k \neq 0|D) > p(\theta_k \neq 0) = \frac{\bar{k}}{k^*}$ then the variable has high marginal contribution to the goodness of fit of the regression model. Then, the posterior mean and variance conditional on inclusion are the ratios of the posterior mean and variance divided by the posterior inclusion probability, $\frac{E(\theta_k|D)}{\sum_{\theta_k \neq 0} p(M_j|D)}$, and $\frac{Var(\theta_k|D)}{\sum_{\theta_k \neq 0} p(M_j|D)}$, respectively.

Finally, we compute the *sign certainty probability*. This measures the probability that the coefficient is on the same side of zero as its mean (conditional on inclusion) and is calculated as

$$
\begin{aligned}
sign\ certainty\ for\ \theta_k &= p[sgn(\theta_k) = sgnE(\theta_k|D)|D, \theta_k \neq 0] \qquad (20)\\
&= \sum_{j=1}^{2^{k^*}} p(M_j|D)\left\{p[sgn(\theta_k) = sgnE(\theta_k|D)|M_j, D]\right\}
\end{aligned}
$$