1. Introduction

Following the seminal papers of Mankiw et al. (1992), and Barro (1991), there has been a revival of interest in the determinants of long-run economic growth, with the neoclassical Solow framework being the workhorse for empirical analysis of growth in industrial and developing countries. In this framework, steady state growth in the levels depends on the exogenous technological progress and population growth; without technological progress, output per capita does not grow. Economic policies do not affect steady state growth, although they can affect the level of output or its growth rate when the economy is in transition from one state to the other.

An important feature of the neoclassical model that has been the central focus of empirical work is the convergence property: output levels of countries with similar technologies converge to a given level in the steady state. On one hand, the Solow framework predicts a tendency towards absolute convergence in per capita income if we assume that all countries share the same technology, and savings and population growth rates. On the other hand, in light of the fact that economies differ in various respects such as propensities to save, growth rates of the population, and access to technology, this convergence may apply in conditional terms, that is convergence to different levels of per capita income but to the same steady state growth rates. In the end, ceteris paribus, the Solow framework predicts that the lagging poor countries will tend to catch up with the rich. The literature seems to have reached a broad consensus on the issue of convergence: the poor do catch up with the rich, at a rate of two to three percent per year.[1]

This study challenges the consensus. We argue that some estimates of the convergence rates and growth coefficients in the existing cross-country empirical work are unreliable because they fail to account for correlated individual effects and the endogeneity of explanatory variables. We construct a panel data, general method of moments estimator to examine rates of convergence for African and OECD countries and investigate the determinants of per capita growth rates drawing on the neoclassical and the endogenous growth theories. Our findings are summarized as follows. First, we estimate rates of convergence above 10 percent, which implies that countries are very close to their steady states. Thus, observed differences across per-capita incomes between countries are primarily due to differences in the countries' steady states and not the distance from the steady states. Second, various economic factors such as initial conditions, investment, population growth, human capital development, government consumption, openness, financial development, and the political environment, are found to contribute to economic growth. Finally, we observe that the Solow framework, both in its textbook and augmented form, is not consistent with the empirical evidence and therefore cannot account for the important features of cross-country income differences.

The rest of the paper is organized as follows. Section 2 presents the empirical model and discusses the two potential inconsistencies that may arise in the literature, namely the correlated individual effects and endogeneity of the explanatory variables, when inappropriate estimation methods are used. We then present the general method of moments estimator, which corrects for both inconsistencies. Section 3 summarizes the empirical results from testing the Solow models for both the Africa and OECD samples. We employ our consistent generalized method of moments estimator, as well as three other estimators commonly used in the literature in order to identify the magnitude of the inconsistencies resulting from their incorrect use. Section 4 extends

[1] Mankiw et al. (1992), Barro (1991), Barro and Sala-i-Martin (1992), Sala-i-Martin (1994) are such papers. Rates of convergence of two (three) percent imply that a country spends 35 (23) years to cover half of the distance between its initial position and its steady state.

the model to incorporate endogenous growth theory considerations focusing only on the Africa sample. Section 5 summarizes the main conclusions.

2. Theoretical Considerations

2.1 Model Specification

Following Mankiw et al. (1992) and consistent with the empirical literature on cross-country comparisons of economic growth we begin by assuming a Solow model with a Cobb-Douglas production function and labor-augmenting technological progress. Technology and population growth rates as well as the saving rate, are constant and exogenous. An approximation of the behavior of a country's growth rate around the steady state is:

$$\ln y - \ln y_0 = (1 - e^{\lambda t}) \begin{Bmatrix} -\left(\dfrac{\alpha + \beta}{1 - \alpha - \beta}\right)\ln(n + g + \delta) + \left(\dfrac{\alpha}{1 - \alpha - \beta}\right)\ln(s) \\ + \left(\dfrac{\beta}{1 - \alpha - \beta}\right)\ln(h) + \ln A_0 + gt - \ln y_0 \end{Bmatrix} \tag{1}$$

An empirical counterpart of equation (1) for the *i*-th country in the *t*-th period considered in this study is the dynamic equation with lagged dependent variable as a regressor, written as:

$$\ln y_{i,t} = \eta_0 \ln y_{i,t-\tau} + \eta_1 \ln(n_{i,t} + g + \delta) + \eta_2 \ln s_{i,t} + \eta_3 \ln h_{i,t} + \zeta_j Z_{i,t} + u_i + v_t + \varepsilon_{i,t} \tag{2}$$

where $y_{i,t}$ is per capita GDP in country *i,* period *t*; $n_{i,t}$ is the population growth rate; g is the rate of labor augmenting technological change; δ is the rate of depreciation; $s_{i,t}$ and $h_{i,t}$ are measures of physical and human capital accumulation, respectively; $Z_{i,t}$ are other determinants of economic growth; u_i is a country specific effect; v_t is a time constant; and $\varepsilon_{i,t}$ is an overall error term.

The textbook and augmented Solow models are nested in equation (1). The elasticities for the textbook and augmented Solow models may be obtained from equation (2). Further, the prediction that the elasticities sum to zero can be tested using the hypotheses $\eta_1 + \eta_2 = 0$ and $\eta_1 + \eta_2 + \eta_3 = 0$ for the textbook and augmented Solow models, respectively. Finally, the speed of convergence is obtained by $\lambda = \dfrac{\ln(1 + \eta_0)}{t}$ and the implied physical and human capital shares α, and β, can be recovered from the estimated coefficients.

2.2 Estimation Issues

Empirical work on growth can potentially suffer from two sources of inconsistency: omitted variable bias, and endogeneity bias. First, omitted variable bias may arise when country specific effects which represent differences in tastes or technology, are wrongly assumed to be uncorrelated with the other regressors. It is shown that this assumption is violated due to the dynamic structure of the model. Second, there is a strong theoretical basis for a number of the explanatory variables to be endogenous, and failing to control for this will bias the results.[2] With these in mind, we first describe how these biases affect cross section and panel data estimators and then present the generalized method of moment estimator which corrects for both of the biases. To facilitate the discussion, rewrite equation (2) as:

$$\ln y_{i,t} = \psi \ln y_{i,t-\tau} + \vartheta W_{i,t} + u_i + v_t + \varepsilon_{i,t} \tag{3}$$

where now $W_{i,t}$ is a vector of all determinants of economic growth, and ψ, ϑ are parameters.

2.2.1 Cross-section Regressions

Pure cross section analyses give inconsistent results because they suffer from both the omitted variable and endogeneity biases. In particular, the first problem that arises in these regressions is the country specific effect: OLS is consistent only under the assumption that the individual country effect is assumed to be uncorrelated with the regressors.[3] This assumption is clearly violated and the estimators are inconsistent, since, using (3) we can show that u_i and $lny_{i,t-\tau}$ are correlated:

$$E\left[u_i(\ln y_{i,t-\tau})\right] = E\left[u_i(\psi \ln y_{i,t-2\tau} + \vartheta W_{i,t-\tau} + u_i + v_{t-\tau} + \varepsilon_{i,t-\tau})\right] \neq 0, \text{since } E\left[u_i^2\right] \neq 0$$

The second problem has to do with the endogeneity of a subset of the *W* variables. It is sometimes difficult to justify why variables such as the rate of investment and the rate of population growth are not determined simultaneously with the rate of growth, and therefore, treating them as exogenous results in a bias. Despite the potential inconsistencies arising from its use, we apply this cross-section OLS estimation (CROSS) as one of the estimation methods to allow for comparison with results the literature and our GMM estimator.

2.2.2 Panel Data Estimators: Fixed and Random Effects

Combining cross-section and time-series data is useful for three main reasons. The use of panel data allows expanding the sample size, it is necessary when analyzing growth in Africa because the growth performance of developing countries varies substantially over time, and finally, it can improve upon the issues that cross-sectional data fail to address.

One issue that arises with the use of panel data is whether the individual effect is considered to be fixed or random. First, while random effects estimation addresses the endogeneity issue by instrumenting potentially endogenous variables, it also assumes that the individual country effects are uncorrelated with the exogenous variables, an assumption, which is violated, based on the arguments in Section 2.2.1. On the other hand, the fixed-effects method deals successfully with the correlated effects problem, yet it fails to account for potential endogeneity of the regressors.[4] Also, Nerlove (1996) shows that due to the dynamic character of the model, the parameter estimates under fixed effects estimation are inconsistent under a finite sample with the bias disappearing as t approaches infinity. In summary, both fixed and random

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[2] Caselli et al. (1996), and Durlauf and Quah (1998) discuss these issues in detail, so a brief summary will be presented here.
[3] Nerlove (1996) discusses the sign of the bias and describes estimators from other panel methods.
[4] Islam (1995), and Knight, Loyaza, and Villanueva (1993) are examples of studies where only the individual effects bias was addressed. Also, Barro and Sala-i-Martin (1995, Ch. 12), and Barro (1997) are examples of studies where only the endogeneity bias was addressed.

effects estimations address only *one* of the two biases, and thus give inconsistent estimates. For comparison with our GMM results and the rest of the literature we selected out of the panel methods the fixed effects estimation (FIXED) and the pooled estimation (POOLED) where all countries are restricted to have identical intercepts.[5]

2.2.3 A Consistent Panel Data Estimator: Generalized Method of Moments

We employ a panel data estimator that simultaneously addresses the issues of endogeneity and omitted variable bias. The estimator is an application of the generalized method of moments estimator (hereafter GMM) used by Caselli et al. (1996). The estimator is constructed in two steps: first, we take first differences from the dynamic model in equation (3) which eliminates the individual effect u_i; then, we instrument all the right-hand side variables using their lagged values. The first step eliminates the omitted variable bias, and we no longer need to make any probabilistic assumptions on the country effect. The second step eliminates the inconsistency arising from potential endogeneity of the regressors.

The GMM estimator addresses consistently and efficiently both estimation problems, but this consistency relies on the assumption that the lagged values of the regressors are valid instruments. Following Caselli et al. (1996) we make the following assumptions: (i) there is no τ-order serial correlation, (ii) the variables measured at the beginning of the period in the vector $W_{i,t-\tau}$ are predetermined, and (iii) the variables measured as an average of the τ periods are not predetermined for $\varepsilon_{i,t}$ but are predetermined for $\varepsilon_{i,t+\tau}$. The implications of these assumptions can be demonstrated by the following example: $y_{i,0}$ and the stock variables in $W_{i,0}$ (those measured at the beginning of the period) may be used as instruments for the equation $y_{i,2\tau}$ - $y_{i,\tau}$ with $y_{i,\tau}$ - $y_{i,0}$ and $W_{i,\tau}$ - $W_{i,0}$ as regressors. Furthermore, in the equation $y_{i,3\tau}$ - $y_{i,2\tau}$ we can use $y_{i,0}$ the stock and flow variables in $W_{i,0}$ and $y_{i,\tau}$ and the stock variables in $W_{i,\tau}$ as instruments.[6] The validity of the set of instruments is examined using the J-statistic specification test on the overidentifying restrictions and is discussed in the estimation section.

2.3 Data and Samples

Equation (1), which encompasses the textbook and augmented Solow model specifications is estimated with pooled and panel data. Annual data from the Summers and Heston data set is used, as made available by the Penn World Tables 5.6a, covering the period 1960 to 1990. Two samples of countries is considered, OECD and Africa, in order to check for robustness of our results when samples with different country characteristics are used. In order to allow comparisons with the literature, the first sample consists of the 22 OECD countries with population greater than one million. The second sample consists of the 42 African countries, with the sample size in each specification determined solely by data availability.

Switching from a single cross section to panel estimation is made possible by dividing the total period into shorter time spans. We focus on five-year time intervals (τ = 5), so we obtain a total of six panels: 1965, 1970, 1975, 1980, 1985, and 1990. For example, the saving and population rates at t-τ (say 1965) are non-overlapping averages over the five years preceding t

[5] The Hausman test was run for all the estimated equations: the hypothesis that the individual effects are uncorrelated with $\ln y_{i,t-\tau}$ is (strongly) rejected, so, $E[u_t (\ln y_{i,t-\tau})] \neq 0$. This confirms empirically the use of fixed effects (over random effects), so random effects estimation was not selected as one of the comparison estimation methods in this paper.

[6] Caselli et al. (1996) describe in detail the construction of this estimator, and for the interest of brevity we will not repeat the procedure here.

(1960-1964). Finally, following previous studies $(g+\delta)$ is set to 0.05.[7] The Appendix includes the list of countries in each of the samples, as well as variables definitions.

3. Results from the Solow Model

In order to see how our results differ from those in the literature because of differences in estimation methods, samples, and perhaps construction of variables, we first run the CROSS, POOLED, and FIXED estimators (which, as Section 2 discussed, are unreliable), and compare with our GMM estimator. The results from testing the convergence hypothesis using the four estimation techniques are shown in Tables 1-3. Depending on whether factors accounting for differences in the steady-state growth rates are included, conditional and unconditional convergence is tested in the textbook, and the augmented Solow model.

Approximating in a neighborhood of the steady states gives the textbook and augmented models, respectively, both nested in equation (1).

$$\ln y_{i,t} - \ln y_{i,t-\tau} = (1-e^{\lambda\tau})\left\{-\left(\frac{\alpha}{1-\alpha}\right)\ln(n+g+\delta)+\left(\frac{\alpha}{1-\alpha}\right)\ln(s)-\ln y_{i,t-\tau}\right\}+u_i+\varepsilon_{i,t} \quad (4)$$

$$\ln y_{i,t} - \ln y_{i,t-\tau} = (1-e^{\lambda\tau})\left\{\begin{array}{l}-\left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)\ln(n+g+\delta)+\left(\frac{\alpha}{1-\alpha-\beta}\right)\ln(s)+\\ \left(\frac{\beta}{1-\alpha-\beta}\right)\ln(h)-\ln y_{i,t-\tau}\end{array}\right\}+u_i+\varepsilon_{i,t} \quad (5)$$

3.1 The Textbook Solow Model

Our investigation of unconditional convergence begins by reporting regressions of the change in the log of income per capita without controlling for population growth, investment, and school enrollment. Table 1 presents the results for both the Africa and OECD samples.

The results show that there is a clear tendency toward convergence in the OECD sample, with significant and negative coefficients on the initial level of income per capita, and high adjusted R^2. For the Africa sample, evidence is found for unconditional convergence only with the FIXED estimator while our GMM estimator gives non-significant results. Overall, these results agree with the conclusions in the literature: Mankiw et al. (1992), and Barro and Sala-i-Martin (1992) reject unconditional convergence for a diverse group of countries (including developed). However, for studies focusing on homogeneous country groups like the OECD and African countries, factors such as technology, preferences, and natural resources that may account for discrepancies in the steady state growth rates are unlikely to be significant, and unconditional convergence is not rejected. In fact, Mankiw et al. (1992) and Savvides (1995) provide evidence in favor of unconditional convergence when they examine the OECD and African countries, respectively.

Adding to the list of regressors measures of the rates of investment and population growth, we apply our GMM estimator first to an unrestricted and then a restricted version of (4). The first panel of Table 2 gives the results of the estimations in unrestricted form, while the

[7] Various researchers point out that variation of this figure does not alter the results significantly.

second panel contains the results from the estimation after imposing the restriction that the sum of the coefficients of the investment and population growth is zero.[8]

In both samples the estimated coefficient on initial income is negative and highly significant, confirming the conditional convergence hypothesis. For the GMM estimator, the coefficient on the investment rate is positive and highly significant. The estimated coefficient indicates that an increase in the investment to GDP ratio by one percent is associated with an increase of 0.39 and 0.31 percent in the GDP growth rate for Africa and OECD respectively. As also predicted by the Solow model, the growth of population contributes negatively and significantly to the GDP growth rate: an increase in the annual growth rate of population by one percentage point reduces GDP growth by 0.26 and 0.13 percent for Africa and OECD, respectively. Comparisons of the coefficient estimates between the Africa and OECD samples confirm the greater impact that physical capital accumulation and population growth have on Africa's growth.

The rate of convergence λ can be estimated from the coefficient on lagged output for each of the estimation methods.[9] Rows 6 and 11 of Table 2 report the rates of convergence for the GMM and the other three estimation methods used in this paper, for both the Africa and OECD samples. The difference across estimation methods is striking. To identify the source of this difference we examine the results from the four estimation methods in Table 2.[10]

First, our estimate of λ is four times higher than the one estimated by CROSS and POOLED methods, and two times higher than the one estimated by FIXED. Taking each of the intermediate estimates separately, we observe that the POOLED method (which essentially applies least squares to a pooled regression of our panel) gives an estimate of λ that is only 0.0017 higher than the one found by the CROSS method; this suggests that our results are not driven by the breaking up of the thirty year period into smaller panels. Next, the FIXED column represents the estimation, which as argued in Section 2.2, treats correctly the correlated individual effects but fails to account for the potential endogeneity in the explanatory variables. The estimated rate of convergence is now higher than the one estimated by CROSS but still smaller than the one estimated by GMM. The improvement over CROSS reflects the correct treatment of the correlated individual effect; the difference between FIXED and GMM measures the bias resulting from failing to account for endogeneity. Finally, these results show that while the country effect is important, the correction for endogeneity accounts for the majority of the bias. Specifically, out of the 0.068 difference between the CROSS and GMM methods, correcting for the individual effect accounts for one-fifth while the correcting for endogeneity accounts for four-fifths of the difference.[11]

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[8] The restricted version of the model was estimated for the cases where the Wald test failed to reject the hypothesis that the sum of the coefficients was zero. Henceforth, unless specifically stated, the analysis of the results will refer to either the restricted *or* the unrestricted model, depending on whether the Wald test fails to reject or rejects the relevant null hypothesis, respectively.

[9] Due to differences in time intervals and variable definitions in different studies, the estimated variable coefficients are not directly comparable across studies. However, the convergence rate λ can be used as a normalizing variable for comparisons with other work in the literature (see Tables 4a and 4b).

[10] Mankiw et al. (1992) estimate λ to be 0.0173 using cross sectional data, five times lower than our GMM estimate. The estimator using CROSS-method essentially reproduces the results of Mankiw et al. (1992): our CROSS λ estimate of 0.0217 is 0.0044 higher than the one by Mankiw et al.

[11] In general, estimates of the rate of convergence are not affected by the use of the restricted over the unrestricted model. This implies that the result of correcting for endogeneity and individual country effects is robust to the model specification.

Similar conclusions are drawn from the Africa sample results. The GMM estimate of the convergence rate is 0.0418, which is eight and five times higher than the CROSS and POOLED estimates, respectively, but smaller than the FIXED estimate. In the Africa case, correcting for the individual effects accounts for a large part of the difference between the CROSS and GMM, and failing to account for endogeneity biases the convergence rate upwards.

The validity of the Solow model in both models may be tested by first, examining the restriction that the coefficients of $ln(s)$ and $ln(n+g+\delta)$ sum to zero, and second, estimating the implied physical capital share, α, and observing how it compares to one-third (which is the share of income paid to capital for most countries). For the OECD sample the Solow model is rejected at the 0.05 level of significance; this is in contrast to results from Islam (1995), and the CROSS, POOLED, and FIXED estimates presented in this paper.[12] In contrast to the OECD results, the model is not rejected in the Africa sample on the basis of the Wald test on the restriction, but the implied physical capital share is 0.64, about twice the magnitude of the value of one-third. Overall, on the basis of both the specification tests of the Solow model on the Africa and OECD samples, it is concluded that the Solow model is not adequate to describe the features of the cross-country income differences in either one of the samples.

Next, the validity of the moment restrictions in the GMM framework is checked by employing the J-test; all the specification tests from estimating equation (4) are presented in Table 6.[13] The J-statistic and corresponding p-values reported in column 2 of Table 6 marginally fail to reject the null hypothesis at the 0.05 level of significance. In light of these results, for both the Africa and OECD samples, the moment conditions underlying our GMM estimator are supported.

3.2 The Augmented Solow Model

Endogenous growth models have shown that the decision of individuals to invest in human capital enhances technological progress; this establishes a link between human capital accumulation and growth of per capita output. Human capital accumulation enhances economic growth because it is a direct input to research or because of positive externalities.[14] Thus, policies that promote investment in human capital development are expected to contribute to per capita growth; Mankiw et al. (1992) show that this conclusion is consistent with the predictions of the classical Solow model when the model is augmented to include human capital.

Table 3 presents results from estimating equation (5), adding the secondary school enrollment rate as a measure of human capital accumulation. Both restricted and unrestricted versions of the model are examined. The coefficients on the initial income, population growth, and investment ratio remain significant for both the Africa and OECD samples. However, the human capital measure enters significantly only for the OECD sample. Similar studies in the literature such as Barro (1991) estimate a positive and significant coefficient for the secondary

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[12] Islam (1995) performs the single cross-section, pooled regression, and fixed effects estimation methods for three samples of countries, among which the OECD. He fails to reject the Solow model for all four estimates with respective p-values of 0.70, 0.90, and 0.90.

[13] The J-statistic can be used to test the validity of the over-identifying restrictions when there are more instruments than parameters to estimate. Under the null hypothesis that the over-identifying restrictions are satisfied, the J-statistic multiplied by the number of regression observations is distributed as χ^2 with degrees of freedom equal to the number of over-identifying restrictions.

[14] The relevant papers are by Lucas (1988), and Romer (1990).

enrollment ratio (when examining a pool of both developed and developing countries), while other studies, such as Romer (1989), find no significant effect for literacy rates.

This finding should not be interpreted as an indication of lack of importance of human capital accumulation in African economic growth. The lack of significance may be attributed to collinearity of the enrollment ratios with one of the other regressors or measurement problems. Another explanation is offered by Knight et al. (1993): they observe that enrollment ratios have tended to rise over time in developing countries while growth rates have stagnated, or in some cases fallen. Empirically, they obtain a negative (and significant) coefficient when the variable measuring human capital accumulation is allowed to change over time but when the temporal nature of this human capital variable is suppressed, it contributes positively to growth.[15]

Inclusion of human capital raises the estimated rate of convergence for both samples. Starting with OECD, the estimated λ with our GMM estimator is 0.1285, which is much higher in magnitude than the one of Mankiw et al. (1992), and Islam (1995); comparisons of rates of convergence across some of the literature are summarized in Tables 4a and 4b. Next, using our estimate from CROSS as a proxy for the estimate of Mankiw et al. (1992), we can estimate the contribution of the omitted variable and endogeneity biases.[16] Once again, there is not much of a difference between the CROSS and the POOLED procedures, therefore, breaking up the period in panels does not significantly affect the results. However, controlling for the omitted variable and endogeneity biases explains one-fifth and four-fifths, respectively, of the difference between CROSS and our GMM estimator; so the contributions of these biases remain roughly unchanged compared to Section 3.1.

Similar conclusions are obtained for the Africa sample. The GMM estimate of the convergence rate is 0.0501, which is about three times higher than the CROSS estimate, respectively, but (still) smaller than the FIXED estimate. The FIXED estimate of λ corrects for the individual effects and accounts for a large part of the difference between the CROSS and GMM, but fails to account for the endogeneity bias, and tends to bias the convergence rate upwards compared to GMM.

Testing the validity of the augmented model is equivalent to testing that the sum of the coefficients on $ln(s)$, $ln(n+g+\delta)$ and $ln(h)$ is equal to zero, and examining the magnitude of the estimated shares of physical and human capital, α and β, respectively. The bottom row of Table 3 indicates that augmented Solow model is rejected for the OECD sample on the basis of the Wald test on the restriction, while the model is rejected for the Africa sample on the basis of an unrealistic value for the physical capital share, and a negative value of the human capital share.

It is interesting to note that for both samples the results from the CROSS estimation indicate that the augmented Solow model *is* appropriate (for both Africa and OECD), and give rates of convergence in the two to three percent range, and physical capital shares in the range of 30 to 40 percent (which are sufficiently close to the value of one-third). These results from the CROSS estimation method would mistakenly lead to a strong acceptance of the validity of the Solow model; however, based on the discussion in Section 2, OLS results are biased and should not be trusted. Finally, just as in the case of the textbook version of the Solow model the tests of

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[15] For example, cross section estimation suppresses the temporal nature of the human capital variable. Indeed, as shown in Table 3, the Africa CROSS estimate gives a positive and highly significant coefficient on $ln(h)$, while all the other estimation methods which allow the variable to vary with time, give insignificant results.

[16] Mankiw et al. (1992) estimate λ to be 0.0206 and our corresponding CROSS estimate is 0.0239.

moment restrictions shown in Table 6 indicate that the moment conditions underlying our GMM estimator are robustly supported for both samples.

To reiterate, our results from Sections 2 and 3 indicate the importance of correcting for the endogeneity and omitted variable biases. Failure to do so results in dramatic changes in the results for both the Africa and OECD samples: the rates of convergence are four to five times higher for OECD and three times higher for Africa when both of these biases are eliminated. Using our GMM estimator we find that neither the textbook nor the augmented Solow model are consistent with the data for both the OECD and Africa samples; this contradicts the results of Mankiw et al. (1992) and Islam (1995). As a result, the Solow framework is extended to allow for a more general formulation based on the endogenous growth theory.

4. Results from the Endogenous Growth Theory

4.1 Theoretical Considerations

The obvious shortcoming of the neoclassical model is that long-run per capita growth is determined by the exogenous rate of technology. Work on endogenous growth theory has introduced alternative models that explain long-run growth, and provide a theory of technological progress: growth is generated by factors other than exogenous technical change. By assuming aggregate production functions that exhibit non-decreasing returns to scale, endogenous growth models have provided mechanisms through which economic and social policies can affect long-run growth through their effects on human and physical capital accumulation. 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. The remainder of this section reviews how macroeconomic policies and political variables influence growth.

Macroeconomic Stability

Researchers have identified a number of economic policies to be partially correlated with growth, and the role of these policies has been discussed at length in the literature.[17] Briefly, 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 low and stable rate of inflation, sustainable budget deficits and low consumption to GDP ratios, outward oriented trade policies, and sound financial development.

Appropriate monetary policy promotes 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

[17] Papers by Hadjimichael et al. (1995), Easterly et al. (1991), and Levine and Renelt (1992) who also list other relevant studies. In their paper, Levine and Renelt use Leamer's extreme bounds analysis on a large cross section of developed and developing countries, and conclude that the link between macroeconomic variables and economic growth is quite fragile. However, the same conclusion has *not* been established in the case of panel data studies. Further, some believe that the extreme bound test is too strong for any variable to pass it; Sala-i-Martin (1997) proposes that instead of analyzing the extreme bounds of the coefficient estimates, one should analyze the entire distribution of the coefficient.

and investment; thus high inflation rates are expected to decrease private investment and domestic savings. Also, the effect of the size of the financial sector and financial policies on the rate of economic growth has been examined in the literature since the seminal work of McKinnon (1973). Financial deepening lowers the cost of borrowing, increases the rate of domestic saving, and thus stimulates investment. In this study the ratio of M2 to GDP is used to test the effect of financial development on growth.

The role of fiscal policy and the extent of government involvement in the economy have received a lot of attention in the growth literature. Keeping all else constant, higher budget deficits crowd out private investment as result of higher real interest rates. Also, government investment can be used as a proxy for government's involvement in capital accumulation, and an indicator of social infrastructure. This study uses government consumption ratio to GDP as a measure of fiscal policy. This captures the concern of supply-side theories that higher government spending creates expectations of future tax liabilities and hence, distorts incentives and lowers growth.

Finally, the proposition that more outward-oriented economies tend to grow faster has been tested extensively in the literature, and the majority of the evidence tends to support this proposition. A measure frequently used in the literature is the ratio of the sum of import and exports to GDP. However, this measure is subject to the endogeneity problem: the volume of trade may be a consequence of the growth performance rather than a measure of how a country's openness contributes to its economic growth; said differently, the trade share may be jointly determined with economic growth rather than being an exogenous determinant of growth. In this study we use the trade share growth rate as a measure of openness, which avoids the endogeneity problem.

Economic Growth and Political Freedom

The impacts of political freedom on economic performance as well as the joint determination of political instability and economic growth have generated considerable interest in the literature.[18] Some observers such as Friedman believe that the two freedoms are mutually reinforcing; in this view, increasing political rights promotes economic rights and therefore stimulates growth.[19] Empirically, Alesina et al. (1992), have found that political instability reduces growth, and Fosu (1992) constructs an index of political instability, which he shows to be a significant determinant of per capita income in sub-Saharan Africa. Further, 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.

This paper examines the hypothesis that political freedom is a significant determinant of economic growth across Africa using the democracy data from PolityIII which contains coded annual information on regime and authority characteristics for all countries covering the years 1800-1998. The democracy variable measures the general openness of political institutions and it includes considerations such as free and fair elections and decentralized political power.[20]

[18] For example, Alesina et al. (1992), Knack and Keefer (1995).
[19] Barro (1997) has a chapter on *The Interplay Between Economic and Political Development* and argues that the connection between political and economic freedom is not always clear-cut.
[20] Refer to the Appendix for details on the construction of the index.

4.2 Estimating African Growth and Convergence

The results in Table 5 show the role of adding to the set of the "conventional" regressors various political and policy-related variables as potential determinants of the long-run rate of economic growth. Equation (2) is estimated applying our GMM estimator to a set of cross-country regressions. First, in accordance with the literature, we find that policy variables and political environment matter for growth.[21] Second, correcting for the endogeneity and individual effect biases (by using the GMM estimator) changes the results concerning the speed of convergence: our estimated λ for Africa is several times higher than the one to two percent reported in the literature. Finally, based on the Wald test results, for all specifications we reject the hypothesis that the sum of the coefficients of $ln(s)$, $ln(n+g+\delta)$ and $ln(h)$ is zero. This is another indication that the Solow model does not explain the features of African growth, and justifies the need to extend the model to include endogenous theory considerations.

Columns 1-5 in Table 5 report GMM estimates for five different specifications of the growth regressions.[22] The first column of Table 5 adds to the augmented Solow formulation the ratio of government to GDP and growth of openness. Both of these variables enter significantly with the expected signs. Ceteris paribus, countries experienced faster growth rates (than others in the sample) if their government consumption to GDP was lower, or their growth rate of trade to GDP was higher: a one percent increase in the average consumption to GDP ratio decreases the growth rate of per capita income by 0.71 percent, while a one percent increase in the annual growth rate of openness increases per capita income growth by 0.35 percent. Also, compared to the augmented Solow model results, the coefficients for the "conventional" variables change only slightly in magnitude but still enter significantly, except for the human capital development variable, which is still insignificant. Finally, the speed of convergence increases by roughly one and a half percentage points reaching 6.4 percent, which is roughly four times higher than the one estimated by the CROSS method.[23] As discussed in Section 3, these differences in the estimated rates of convergence indicate that the inconsistencies arising from the endogeneity and omitted variable biases have strong qualitative and quantitative effects in the growth empirics.

The human capital variable, which was not significant in the first specification, is dropped in column 2. The magnitudes of the coefficients and the rate of convergence do not change by much and the rate of convergence is slightly higher; it was decided henceforth to keep the human capital variable out of the model. Then, the specification in column 3 investigates the impact of the financial sector on growth. The size of the financial sector proxied by the ratio of M2 to GDP contributes significantly to economic growth: a one percent increase in the M2 to GDP ratio raises the annual per capita GDP growth by 0.35 percent. However, the addition of this financial sector variable causes the population growth rate to become insignificant and, most importantly, the coefficient of initial income to increase dramatically; as a result, the rate of convergence rises to 11.6 percent.[24]

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[21] Some papers on determinants of African growth are: Easterly and Levine (1997), Ghura and Hadjimichael (1996), Sachs and Warner (1997), and Savvides (1995).

[22] Table 6 shows the results for the specification tests for all the regressions reported in Table 5. The J-test fails to reject the validity of the overidentifying restrictions for specifications 1 through 5 of Table 5.

[23] All equations in Table 5 were estimated and the convergence rate was calculated using the CROSS method for comparison purposes to the GMM. The results are available from the author.

[24] Both the insignificance of the population variable, and the dramatic change in initial income are partly due to the insignificance of the constant. Hence, we drop the constant for the remaining two specifications.

The democracy index is introduced in the last two columns of Table 5. After a brief specification search the constant is eliminated, and we first examine the effect of the democracy index on per capita income growth when it is added to the list of regressors of the model in column 3. This addition is successful, suggesting that a one percent increase in the democracy index increases the rate of per capita growth by 0.64 percent. Also, the remaining explanatory variables remain significant with the exception of government consumption. This does not imply that government consumption does not affect growth. One explanation for that is that the government consumption variable is sufficiently correlated with the democracy index that it loses its independent association with per capita growth in specification (4). Finally, excluding the government consumption variable in the last specification, we get an estimated rate of convergence around 14 percent; all the explanatory variables are significant and with the expected signs.

Overall, our results regarding the effect of policies on growth are standard. The negative sign on the initial income variable captures the idea of convergence, the positive effect of investment captures the effect of savings on the steady state, the negative sign on population growth captures the detrimental effect of overpopulation, government spending affects growth indirectly, the positive sign on openness underlines the effect of trade and interdependence, the positive sign on money growth captures the effect of a healthy financial system, and finally, the positive effect of the democracy index underlines the impact of a healthy political environment.

5. Summary and Conclusions

This paper investigates empirically the determinants of economic growth across the OECD countries and the developing countries of Africa over the period 1960-1990, with special focus on the issue of convergence. We have pointed out that cross-country empirical work which fails to account for the country specific effects and endogeneity of the explanatory variables yields inconsistent parameter estimates and rates of convergence, and we have demonstrated empirically the inconsistencies of some of those estimation methods. Our proposed panel data general method of moments estimator corrected for those inconsistencies that plague standard estimation techniques. Taking into account the country-specific effects, as well as potential endogeneity produced strikingly higher rates of convergence than the ones reported in the literature. From the theoretical viewpoint, these country-specific effects highlight the differences in the aggregate production functions and by taking into account the country-specific effect we have controlled for further sources of difference in the steady state levels of income.

We applied our consistent estimator to examine two formulations of the Solow model and to explore the differences between the samples for Africa and OECD. First, we concluded that neither the textbook nor the augmented version of the Solow model is consistent with the data for both Africa and OECD samples. Next, we found evidence that the conditional convergence hypothesis is supported for both Africa and OECD, with rates of convergence for the textbook (augmented) version of four (five) percent for Africa, and nine (thirteen) percent for OECD. These rates of convergence are several orders of magnitude higher than the two to three percent generally reported in the literature, although Caselli et al. (1996) do report rates of convergence around ten percent for non-oil countries. Finally, differences in the rates of physical and human capital development as well as population growth rates between the OECD and Africa samples highlighted the greater importance placed upon higher human and physical capital development as well as low population growth rates for the African countries.

Second, focusing on the Africa sample only, we presented results from extending the Solow formulation to include some policy and political variables in accordance with the endogenous growth theory. We found evidence in support of the hypothesis that African economies with higher savings rates, lower population growth rates, more outward-oriented policies, a faster pace of financial development, and a more democratic environment, have tended to grow faster; there is only tentative evidence that government consumption impinges negatively on growth. Further, the estimated rate of convergence reaches magnitudes of thirteen to fourteen percent (which is slightly above the estimated OECD rate of convergence) indicating that on average, an African economy is expected to close half the distance between its initial and steady state position in five years.

The theoretical implication of finding rates of convergence in excess of ten percent for both African and OECD samples is that countries are very close to their steady states. First, this suggests that variations in the per capita income levels across countries can be explained primarily by differences in their steady state values, *not* the distance from their steady states. Second, this result calls for more policy activism. Traditionally, and under the Solow framework with the identical production functions setup, policies were directed to saving and labor force growth rates. Allowing differences in the production function the focus is now on the factors that may enter into the individual country effects; empirical work using endogenous growth theory has extended the role of policies to bring about improvements in the components of technology and efficiency in the economy. If we are primarily interested in convergence in the absolute terms, namely that countries converge to the same levels of income, discovering that countries in the world are converging at a faster rate than previously thought is of little interest if the points to which they are converging remain different. The results of this study point towards that direction: policies can not only accelerate the pace of countries reaching their long run levels of incomes, but most importantly, they can affect the long run income levels.

A final note on Africa. In order to be successful any growth-oriented adjustment strategy getting Africa out of the "low-level equilibrium trap" needs to address a lot of challenges, including the demographic trap of population, growth, savings and poverty, the restoration peace, social and political stability, the improvement of institutions and performance, and the improvement of human welfare. Each of these challenges involves interrelated and mutually reinforcing multiple factors interacting in a dynamic fashion.

The adjustment process is unlikely to be an easy one, given the declines in per capita incomes registered during the past two decades, the existing imbalances, and the deep-rooted developmental constraints that the African continent faces. The recent wave of political change and democratization in some of leading performers in Africa together with some hopeful signs of economic revival in several countries, generate some conservative optimism about the continent's future. However, this optimism is moderated by the fact that these leading performers have just begun to recover from civil wars and long periods of economic decline, and it will require solid growth at rates of East Asia in order to make up for the lost ground.

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Appendix

Samples

<u>*AFRICA*</u>*:* Algeria, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo (former Zaire), Congo (Republic of), Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Zambia, Zimbabwe.

<u>*OECD*</u>*:* Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America.

Definition of variables and sources

Ln(y): Logarithm of real GDP per worker.
Source: Penn World Table (Mark 5.6a).

Ln(y_0): Logarithm of initial real GDP per worker.
Source: Penn World Table (Mark 5.6a).

Ln(s): Logarithm of real investment as ratio to GDP (1985 international prices).
Source: Penn World Table (Mark 5.6a).

Ln($n+g+\delta$): Logarithm of population annual growth rate plus 0.05.
Source: Penn World Table (Mark 5.6a).

Ln(h): Logarithm of secondary education enrollment ratio.
Source: World Bank, *World Development Indicators*.

Government: Logarithm of real government consumption as ratio to GDP (1985 international prices).
Source: Penn World Table (Mark 5.6a).

Openness: Average annual rate of growth of openness where openness is the ratio of exports plus imports to GDP.
Source: Penn World Table (Mark 5.6a).

M2: Ratio of M2 to GDP.
Source: International Monetary Fund, *International Financial Statistics*.

Democracy: Index constructed additively (with scores 0-10) from the following four variables of authority characteristics: PARCOMP measuring the extent to which non-elites are able to access institutional structures for political expression, XRCOMP measuring the extent to which executives are chosen through competitive elections, XROPEN measuring the opportunity for non-elites to attain executive office, and XCONST measuring the independence of the chief executive.
Source: Polity98 Project (data available from the Center for International Development and Conflict Management, University of Maryland).