Do All Countries Follow the Same Growth Process?

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Abstract

We estimate a finite mixture model in which countries are sorted into groups based on the similarity of the conditional distributions of their growth rates. We strongly reject the hypothesis that all countries follow a common growth process in favor of a model in which there are four classes of countries, each with its own distinct growth process. Group membership does not conform to the usual categories used to control for parameter heterogeneity such as region or income. However, the growth processes we do identify correspond to a significant degree with established theories of economic growth. The behavior of one group is broadly consistent with the neoclassical model, the behavior of two of the groups are consistent with two different endogenous growth models, and results for the fourth group are consistent with a model in which growth is difficult due to random shocks. Overall, these results suggest that existing theories of growth may be complementary rather than competing. Furthermore, the findings of a typical cross-country growth regression may be misleading because they do not accurately reflect the experience of any particular group of countries.

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"What do Thailand, the Dominican Republic, Zimbabwe, Greece and Bolivia have in common that merits their being put in the same regression analysis?" -- Harberger (1987)

1 Introduction

Is there a universal growth model, a single set of equations that govern the evolution of per capita income in every country or a majority of countries? If countries follow different models, how can economists learn about long-run growth from studying country experiences? Is it possible to group countries in such a way that, within each group, we are able to draw inferences about their common growth experience? Or must we assume that each country's growth experience is fundamentally idiosyncratic, a position Hausmann, Rodrik and Velasco (2005:1) say results in an "attitude of nihilism" regarding our ability to understand economic growth? As these questions suggest, the issue of heterogeneity is of fundamental importance to the study of economic growth.

Pioneered by Barro (1991) and Mankiw, Romer and Weil (1992), the early empirical work on economic growth focuses on broad sample cross-country growth regression models. For Solow (1994: 51) these exercises raise "the recurrent suspicion that the experiences of very different national economies are not to be explained as if they represented different 'points' on some well-defined surface." Temple (1999: 126) points out that cross-country growth regressions will still provide useful information about parameter averages. But if Solow's suspicions are well-founded and the diversity of countries is such that the "average" country is not representative, then parameter averages will tell us little about the values that matter for any particular country.

The most common method for addressing heterogeneous growth is including regional dummy variables or country fixed effects when panel data are available. This approach controls for differences in average growth rates but does not allow for differences in the marginal effect of the regressors. An alternative is to identify groups of countries for which the growth process is assumed to be similar, for example, developed and developing country groups, but this approach requires we choose an a priori income threshold and it may still result in groups with countries that follow very different growth processes. This latter concern appears to underlie the further partition of developing countries into regional subgroups such as African or Latin American countries. But every regional group appears to contain outliers and omit similar countries from other regions. In studying development in East Asia, we may be tempted to omit the Philippines, which may follow a more Latin American pattern of development, and include Chile and Mauritius.

In contrast to these approaches, we employ a data-driven methodology to estimate multiple growth processes. We estimate a finite mixture model in which countries are sorted into groups based on the similarity of the conditional distributions of their growth rates. We model the distribution of growth rates as a function of a number of variables identified as proximate determinants of growth: initial income, proxies for the rates of investment of human and physical capital, and the population growth rate. We also extend our analysis to use variables that describe institutional and policy factors to improve the classification of countries into the different growth regimes.

Our results are as follows. First, we strongly reject the hypothesis that the countries in our sample follow a common growth process in favor of a model in which there are four distinct growth processes. Moreover, many of the parameter estimates differ across groups and from those found in a standard growth regression that assumes only one class. It follows that inference based on population averages will be faulty when applied to any of the groups of countries.

Second, we show that classification into the different growth regimes does not depend on categories such as income and geography. For example, we find two groups of mostly developed countries and two classes of less developed countries. Therefore, finite mixture regression modeling can improve upon the standard treatment of dividing countries by income level because it allows for parameter heterogeneity among countries with similar incomes. We also find that while institutional factors play a clear role in defining class membership, the role of macroeconomic policy is much weaker and the effect of openness is context dependent.

Third, the growth processes that we find correspond to a significant degree with established theories of economic growth. Three of the groups may be interpreted as following Mankiw, Romer and

Weil's (1992) augmented neoclassical growth model, Lucas's (1988) model of education-driven growth and Rebelo's (1991) model of growth due to physical capital accumulation. The final group exhibits greater inconsistency in growth rates, perhaps because of greater susceptibility to random shocks as in Easterly, Kremer, Pritchett and Summers (1993).

These results have important implications for the study of economic growth. Cross-country growth empirics have been used to discriminate among competing models of growth, with the neoclassical model generally outperforming various models of endogenous growth. Our results suggest a more pluralistic interpretation of the evidence. No one model explains the experiences of all four classes of countries identified in our analysis. In terms of its general thrust, our results also support the growing theoretical literature that attempts to model regime switching as part of a unified growth theory. (See, for example, Galor, 2005; Hanson and Prescott, 2002; or Galor and Weil, 2000.) For growth empirics, our results suggest a middle ground to the two extremes mentioned at the start of the paper. All countries do not follow the same growth process, but neither is each country's growth process entirely unique. Our analysis shows that countries can be grouped in a meaningful way.

Our work is related to that of other researchers who have examined the heterogeneity of the growth process with increasing methodological sophistication. In a seminal paper in this literature, Durlauf and Johnson (1995) apply regression tree analysis to identify country groupings. These authors use output per capita and adult literacy rates to identify countries with common growth processes. Papageorgiou (2002) extends the work of Durlauf and Johnson (1995) by also exploring whether or not trade can be used as a threshold variable. More recently, Bloom, Canning, and Sevilla (2003), Canova (2004), Paap, Franses, and van Dijk (2005), and Sirimaneetham and Temple (2006) have explored the existence of multiple growth regimes. Sirimaneetham and Temple (2006) use principal components analysis to generate an index of policy quality, sort economies into groups based on the value of the index, and then explore whether average growth rates vary across groups. Canova (2004) draws on Bayesian ideas to examine income levels in Europe. His technique allows him to explore alternative means of ordering countries to form groups and he finds that using initial income as a splitting variable generates four groups of countries. Using methods more closely related to ours, Bloom, Canning, and Sevilla (2003) find evidence that a model with two income regimes is statistically superior to a model with one regime. These authors also argue that geographical variables determine the likelihood that a country is assigned to any of the two regimes. Finally, rather than assuming a priori the number of growth regimes, Paap, Franses, and van Dijk (2005) apply latent class models to a panel of countries allowing the growth rates data to determine the number of groupings. They find that a model assuming three groupings of countries is statistically superior to a model that assumes economies are homogenous.

Our research shares the same motivation of these papers but our methodology complements and advances the existing literature. Contrary to Durlauf and Johnson (1995), Papageorgiou (2002), Canova (2004), and Sirimaneetham and Temple (2006), we assign countries to growth regimes based on the conditional distribution of the growth rate itself rather than predetermined factors. Our method also has the advantage of assuming a class or regime structure in which the regimes are discrete and unordered in the usual sense (i.e., the regimes are *different*, not necessarily better or faster growing). In this aspect, our methodology is similar to the work by Paap, Franses, and van Dijk (2005).[1] However, this paper makes three additional original contributions. First, we examine long-run growth rates in both developed and developing economies. Second, by examining the conditional distribution of growth rates rather than the unconditional distribution, we are able to estimate the marginal effects of growth fundamentals within regimes. For example, we identify a group of countries for which investment in human capital appears to be more important in driving growth than investment in physical capital. Finally, our method allows us to perform hypothesis testing on the sources of systematic heterogeneity that explain the assignment of countries to specific latent regimes in a way that ties our empirical results into the current growth literature.

[1] In addition to Paap, Franses, and van Dijk (2005), other applications of latent class models in the economics literature include Owen and Videras (2007) and Clark, Etile, Postel-Vinay, Senik, and Van der Straeten (2005). There are relatively few applications of finite mixture models in economics; see Boxall and Adamowicz (2002) and Greene and Hensher (2003).

Finally, we note that an important theme in both the empirical and theoretical growth literature is the existence of multiple equilibria.[2] It is common in these models for observable initial conditions to determine to which steady state a country converges. Empirical estimation of models with multiple equilibria typically rely on using observable characteristics such as income or education levels to sort countries into regimes. Our work is related to this approach, with an important difference. Specifically, our methods allow us to sort countries into growth regimes based on an unobservable latent variable that is determined by the conditional distribution of growth rates and can be predicted by country characteristics that are often referred to as the "deeper determinants" of growth such as institutions, openness, and policy. Therefore, we believe our work extends this line of thinking because we are able to choose a number of country characteristics as indicators of the latent variable and statistically test the validity of these indicators. Furthermore, while the existence of "convergence clubs" may be a result of countries experiencing different growth processes, it does not necessarily have to be. Identifying these clubs is not the goal of our analysis; we examine a much broader phenomenon. In fact, our results suggest that conditional convergence occurs only within a subset of countries. For a majority of countries in our sample, we do not find evidence that initial income is a determinant of growth.

The remainder of the paper is organized as follows. The following section provides a theoretical framework for our results and discusses our choice of regressors and covariates. Section 3 presents our econometric approach. Section 4 presents and discusses our empirical findings, and the final section concludes.

2 Theoretical Framework

The empirical model we estimate includes regressors that capture the proximate determinants of economic growth. Investment, schooling, and population growth are direct measures of the growth of productive factors. Initial income controls for transitional dynamics that occur when earlier gains are

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[2] The literature on multiple equilibria in the growth process and convergence clubs is vast. Interested readers may want to see Azariadis and Stachurski (2005) for an introduction to this literature.

easier than later ones, either due to technical transfer or diminishing marginal returns to capital. The equation we estimate is:

$$g_i = \beta_0 + \beta_y \ln(y_{0,i}) + \beta_K \ln(s_{k,i}) + \beta_H \ln(s_{h,i}) + \beta_L \ln(n_i) \qquad (1)$$

where g_i is the 30-year average growth rate of real per capital income, $y_{0,i}$ is initial income, $s_{k,i}$ is the average investment rate, $s_{h,i}$ is the average secondary school enrollment rate, n_i is the average population growth rate over the period for country i, and the constant term captures increases in labor productivity that are orthogonal to factor accumulation and initial conditions. As shown by Mankiw, Romer, and Weil (1992), this specification can be derived directly from a Cobb-Douglas production function with capital, labor and human capital as inputs.[3]

This model deliberately lacks novelty. The regressors are those suggested by the augmented neoclassical model employed by Mankiw, Romer and Weil (1992). They are also among the handful of variables identified by Levine and Renelt (1992) as being robust determinants of economic growth. While neither of these papers has gone unchallenged, they both exerted a large impact on later growth empirics, allowing comparison of our results with other empirical work on growth.

As we explain in more detail below, we also employ covariates that are not direct determinants of growth but help to sort countries into different growth regimes. In choosing our covariates, we focus on variables that the literature suggests play a central role in determining a country's growth process, and more particularly how it responds to capital accumulation, population growth and the dynamics of convergence. We should note, however, that the recent growth literature suggests more covariates than our cross-country estimation can accommodate. Therefore, we proceed by choosing broad categories of country characteristics (institutions, openness, and macroeconomic policy) that have been suggested by a large body of work and then choosing indicators within each category that capture important features of

[3] Technically, if we derive the specification directly from the neoclassical model, the last term in Equation 1 should be ln(n+g+δ) where g is an exogenous rate of technological progress and δ is an exogenous depreciation rate. Mankiw, Romer and Weil (1992) assume that g+ δ is equal to .05 and add that to the rate of population growth. We do not follow this practice because we would like to test a broader set of theories than the neoclassical model. Nonetheless, adding .05 to the population growth rate does not change the conclusions we draw in the remainder of the paper.

this characteristic.[4] An advantage of our approach is that it recognizes that these covariates are indicators of class membership with error. In other words, our procedure recognizes that there is some error associated with the process of assigning countries to classes and, as we discuss in the following section, we can attempt to gauge the error associated with our country groupings. Nonetheless, we recognize that our data constraints cause us to omit country characteristics that might help to reduce the error in grouping countries. However, as we explain in more detail below, it is important to understand that the covariates do not define the groupings—the groupings are defined by the conditional distribution of growth rates and the covariates only play a supplementary role in improving our classification of countries into groups.

As there is an immense literature related to each of our covariates, we discuss only briefly some of the previous work that motivated our choice to use measures of institutional quality, openness, and macroeconomic policy to sort countries into growth regimes. Institutions are widely held to play a significant role in economic growth, e.g. Mauro (1995), Acemoglu, Johnson and Robinson (2001), Dollar and Kraay (2003) and Rodrik, Subramanian and Trebbi (2004). Keefer and Knack (1995) find that institutional quality directly affects the dynamics of convergence as indicated by the coefficient on initial income. Glaeser, Scheinkman and Shleifer (2003) and Zak and Knack (2001) argue that institutions and trust play a fundamental role in investment decisions. Murphy, Shleifer and Vishny (1993) suggest the absence of property rights distorts the allocation of resources as agents seek to avoid predation. Davis (2003a, 2003b) shows that institutional quality may separate countries into growth regimes associated with stagnation and industrialization, and Davis (forthcoming) argues that institutions play an important role in the realization of scale effects.

[4] We also experimented with the change in human capital (measured by the change in the secondary school enrollment rate) as an additional covariate as suggested by Galor, Moav and Vollrath (2006), Galor and Moav (2006), and Galor and Moav (2004) . However, the improvement in the model's log likelihood was not sufficient to compensate for the increase in the number of parameters (i.e., the AIC3 increases). Therefore, we do not keep this variable in the model. The ideas in this body of work, however, are very long-run and it is possible that our data set, which spans only 30 years, is not long enough to properly test the importance of this variable.

Democratic political institutions may also affect the economics of accumulation. A central thesis in the theoretical literature on democracy and growth is that populist policies may blunt incentives to invest in physical capital as in Alesina and Rodrik (1994) and Persson and Tabellini (1994), while also potentially subsidizing the accumulation of human capital as suggested by Bourguignon and Verdier (2000) and Benabou (2000). Openness potentially affects all the variables that influence economic growth. Ventura (1998) notes that factor price equalization implies that in an open economy capital accumulation will shift the composition of output rather than driving down the return to capital. Openness may also prove favorable to taking advantage of international technology flows, e.g. Fagerberg (1994). In Schumpeterian growth models, openness may also influence the incentives for innovation and imitation. (See Dinopoulos and Sener (2003) for a review of this literature.) Finally, there is an exhaustive literature on policies and economic growth, which is nicely reviewed in Easterly (2005) and also discussed in Sirimaneetham and Temple (2006). Our list of policy covariates is intended to capture the primary dimensions of macroeconomic policy variation.

Because we chose these covariates based on their prominence in the growth literature, our contribution to this literature is not to provide further evidence on their importance—it is to empirically model their effect in a way that is more consistent with the theory. In other words, we do not model these covariates as direct determinants of growth, but as indirect determinants that influence the environment in which growth occurs and the marginal productivity of the growth fundamentals.

Empirical Implications of Growth Theory

In interpreting our results we ask whether the estimated coefficients conform to any of the patterns suggested by prominent lines of growth theory. We briefly review the main lines of growth theory with an emphasis on their predictions regarding the coefficients of our empirical model. To facilitate the comparison of these models with each other and with our empirical results, in each case we assume fixed saving rates for physical and human capital. Our conclusions are summarized in Table 1. A more detailed review of these models is provided in the appendix.

Neoclassical Growth Theory

The empirics of the neoclassical “augmented Solow model” are detailed in Mankiw, Romer and Weil (1992) and are well known. It is characterized by conditional convergence, $\beta_y < 0$, positive coefficients on physical and human capital saving rates, $\beta_K > 0 \quad \beta_H > 0$, and a negative coefficient on population growth $\beta_L < 0$.

Endogenous Growth Models

There is no single endogenous growth model that we can posit as the counterpart to the neoclassical model presented above. Indeed, as shown by Rebelo (1991), endogenous growth may occur if there are constant returns to reproducible factors in the production of output or at least one form of capital. Here, we consider a version of the models developed by Lucas (1988) and Rebelo (1991) that helped to spawn a voluminous literature. To continue in the spirit of the neoclassical model above, we omit the human capital spillover and introduce labor augmenting technical change, returning to the potential roll of spillover effects below.

In the Lucas (1988) model, human capital accumulation takes on the linear “AK” structure that allows for endogenous growth. In this case, per capita income and physical capital grow at a uniform rate determined by the growth rates of human capital and technology. The predicted pattern of coefficients is $\beta_y = 0$, $\beta_K = 0$, $\beta_H > 0$, and $\beta_L = 0$.

In the Rebelo (1991) model, physical capital is the engine of growth. Steady state growth requires a constant ratio of human to physical capital and the rate of human capital growth converges to that of physical capital. As before, convergence dynamics are independent of initial income, implying $\beta_y = 0$. Because physical capital drives growth, $\beta_K > 0$ while $\beta_H = 0$ and $\beta_L = -n < 0$.

Relative to the neoclassical model, endogenous growth models place fewer restrictions on acceptable parameter values for our regression coefficients. Looking across the endogenous models, the one consistent prediction is the irrelevance of initial income. In each case, the steady state is defined by the ratio of the capital stocks, so that convergence dynamics are independent of initial income. A second difference is that the equilibrium growth rates reflect the characteristics of the accumulation equations rather than the production function. As a result, they provide no guidance about returns to scale at the aggregate level.

Models with Spillover Effects and Scale Effects

The neoclassical model and endogenous growth models discussed above may be augmented to allow for endogenous technical progress. The simplest models of technical progress assume it results from spillovers that occur during human or physical capital accumulation, e.g. Lucas (1988) and Romer (1986). In each of these models, the spillover effect will be reflected in a larger coefficient on the relevant form of capital. Note also that because our empirical results are driven by aggregate economic performance, they reflect the social returns to various factors; we are unable to distinguish empirically between private and external effects.

Other approaches to technical progress model the incentive to invest in new knowledge (Romer 1990, Aghion and Howitt 1991). Early versions of these models predicted that growth rates would be increasing in population size, a prediction criticized by Jones (1995) as fundamentally at odds with the empirical record. As reviewed by Dinpoulos and Sener (2003), in more recent models in this tradition, population size influences the equilibrium level of technology rather than its rate of growth. In these models, faster population growth is thus associated with higher rates of economic growth. The presence of scale effects will tend to partially or fully offset the negative impact of population growth predicted by most of the models above.

3 Method: Finite mixture regression model

We use a finite mixture approach to estimate the growth regression model in Equation 1. This approach is an extension of latent class models to estimate a latent discrete distribution of growth regimes. Our approach has four important features that allow us to contribute to previous work. First, the observed conditional distribution of growth rates is assumed to be a mixture of two or more distributions with different means and variances. Second, the parameters of the growth regression are allowed to differ across regimes. Third, the distribution of the latent regimes and the parameters of the growth regression for each regime are estimated jointly. Finally, in addition to accounting for heterogeneity in the growth process, finite mixture models can explain the sources of systematic heterogeneity. In our application, we explore whether indicators of macroeconomic policy, openness, and institutional quality can improve the assignment of countries to differing growth regimes.

Specifically, we assume that country growth regressions can be classified into *M* discrete classes. Letting the vector of independent variables in Equation 1 be z_i^p and letting *x* indicate class membership, the probability structure for this model is:

$$f(g_i \mid \mathbf{z}_i) = \sum_{x=1}^{M} P(x) f(g_i \mid x, \mathbf{z}_i^p). \qquad (2)$$

We extend our analysis by examining the sources of class membership. We use macroeconomic policy variables, openness, and quality of institutions as covariates that help predict class membership. Denoting the vector of *K* covariates as z_i^c, we can now write the probability structure for a model with covariates as:

$$f(g_i \mid \mathbf{z}_i) = \sum_{x=1}^{M} P(x \mid \mathbf{z}_i^c) f(g_i \mid x, \mathbf{z}_i^p). \qquad (3)$$

This approach differs from the standard treatment in the literature since we treat these covariates as indicators of growth regimes rather than direct determinants of growth. Importantly, we sort countries into growth regimes based on the combination of these indicators rather than on the value of specific indicators. Thus, our method is not simply a substitute for interacting the individual indicators with the regressors.[5]

We assume growth rates come from a normal distribution and the latent variable follows a multinomial probability that yields a standard multinomial logit model:

$$P(x \mid \mathbf{z}_i^c) = \frac{\exp(\eta_{x|\mathbf{z}_i^c})}{\sum_{x'=1}^{M} \exp(\eta_{x'|\mathbf{z}_i^c})}, \qquad (4)$$

[5] We use 6 indicators. Combining these 6 indicators in all possible ways would yield more interaction terms than countries in our data set, making the model impossible to estimate.

where the linear predictor $\eta_{x|\mathbf{z}_i^c}$ is such that membership in class *m* is defined by:

$$\eta_{m|\mathbf{z}_i^c} = \log(\frac{P(x=m \mid \mathbf{z}_i^c)}{[\prod_{m'=1}^{M} P(x=m' \mid \mathbf{z}_i^c)]^{1/M}}) = \gamma_{m0} + \sum_{k=1}^{K} \gamma_{mk} z^c{}_{ik}. \qquad (5)$$

Under this formulation, we compare the probability of being assigned to class *m* with the average of the probabilities of all *M* classes.

The model is estimated via maximum likelihood.[6] In the case of the model without covariates, maximum-likelihood estimation involves finding the estimates of the beta and gamma parameters that maximize the log-likelihood function derived from the conditional probability density function in Equation 2:

$$\log L = \sum_{i=1}^{I} \log f(g_i \mid \mathbf{z}_i^p, \beta_0, \beta_y, \beta_K, \beta_H, \beta_L, \gamma_{m0}) = \sum_{i=1}^{I} \log[\sum_{x=1}^{M} P(x) f(g_i \mid x, \mathbf{z}_i^p)] = \qquad (6)$$

$$\sum_{i=1}^{I} \log[\sum_{x=1}^{M} \frac{\exp(\eta_x)}{\sum_{x'=1}^{M} \exp(\eta_{x'})} f(g_i \mid x, \mathbf{z}_i^p)],$$

where the linear predictor η_x is defined by equation 5

and $f(g_i \mid x, \mathbf{z}_i^p) = \frac{1}{\sqrt{2\pi\sigma_m^2}} \exp\{-\frac{(g_i - \mu_m)^2}{\sigma_m^2}\}$. (7)

In the case of the model with six covariates we maximize the log-likelihood function derived from the conditional probability density function in Equation 3:

$$\log L = \sum_{i=1}^{I} \log f(g_i \mid \mathbf{z}_i^p, \mathbf{z}_i^c, \beta_0, \beta_y, \beta_K, \beta_H, \beta_L, \gamma_{mk}) = \sum_{i=1}^{I} \log[\sum_{x=1}^{M} P(x \mid \mathbf{z}_i^c) f(g_i \mid x, \mathbf{z}_i^p)] =$$

$$\sum_{i=1}^{I} \log[\sum_{x=1}^{M} \frac{\exp(\eta_{x|z_i^c})}{\sum_{x'=1}^{M} \exp(\eta_{x'|z_i^c})} f(g_i \mid x, \mathbf{z}_i^p)], \qquad (8)$$

[6] We use Latent GOLD to perform the estimation. In practice, the likelihood functions for these types of models often feature local maxima. To ensure that we obtain the global maximum, we estimate each model using 10,000 starting values.

where the linear predictor $\eta_{x|\mathbf{z}_i^c}$ is again defined by Equation 5 and $f(g_i \mid x, \mathbf{z}_i^p)$ is defined above in Equation 7.

We use the empirical Bayes rule to calculate country-specific posterior membership probabilities,

$$\hat{P}(x \mid z_i, g_i) = \frac{\hat{P}(x \mid z_i)\hat{P}(g_i \mid x, z_i)}{\hat{P}(g_i \mid z_i)}. \tag{9}$$

Equation 9 emphasizes a key advantage of the finite mixture approach: the probability of class membership depends on both the conditional distribution of growth rates as well as the covariates. Once we calculate the probability of class membership for each country using Equation 9, we use the empirical Bayes modal classification rule to assign countries into classes; that is, each country is assigned to the class for which it has the largest posterior probability. Although for most countries the classification occurs with posterior probabilities very close to 1, the classification is probabilistic. The probability of misclassification for each country is $1 - \max \hat{P}(x \mid z_i, g_i)$ and the estimated average of classification errors is $E = \frac{\sum_{i=1}^{I}\left[1 - \max \hat{P}(x \mid z_i, g_i)\right]}{N}$ (Skrondal and Rabe-Hesketh, 2004).

In practice, the number of classes is unknown to the researcher. We start with a one-class model and then estimate subsequent models that increase the number of classes by one each time. We use information criteria based on the model's log likelihood to select the model that best fits the data. Given our relatively small sample size, we use the Akaike Information Criteria 3 (AIC3) which is calculated AIC3=-2*LL* + 3*Npar* where *LL* is the value of the log likelihood and *Npar* is the number of parameters estimated. The AIC3 is decreasing in the value of the log likelihood and increasing in the number of parameters estimated.[7] Therefore, we choose the model with the lowest AIC3. Once the model is

[7] The Akaike Information Criteria (AIC) can also be used to select models. It is calculated AIC=-2*LL*+2*Npar*, imposing a smaller penalty for additional parameters. When the model choice suggested by either the AIC or the AIC3 differ, typically the AIC indicates more classes because of the smaller penalty for additional parameters. In using the AIC3, we follow recent research that suggests the AIC3 is the best criterion to use in selecting the number of classes in a latent class or finite mixture model. See Andrews and Currim (2003) for further discussion of this issue.

selected, it is then possible to test for statistical significance of the regression coefficients, the differences between the regressions coefficients, and the usefulness of the covariates for sorting countries into classes.

4 Results and Discussion

4.1 Data and Results

Data

The dependent variable is the average annual growth of real GDP per capita over the 30-year period from 1970 to 2000. The independent variables are the log of real GDP per capita in 1970, the log of average annual population growth rates, the log of average investment rates, and the log of secondary school gross enrollment rates. The averages are taken over the 1970 to 2000 time period. As has been discussed by many others, growth regressions of this type are plagued by endogeneity so we must be cautious in inferring causality. Nonetheless, we use this standard specification so that we can focus on the issue of the heterogeneity of growth processes while our results can be easily compared to others.

As explained in Section 3, first we estimate a finite mixture model without covariates. This estimation yields significant classification error, however, and in the second step of our analysis, we use country characteristics to help predict class membership. These characteristics include indicators of a country's macroeconomic policy (government consumption as a percent of GDP and inflation rates), openness (trade volume as measured by exports plus imports as a percent of GDP, and the log of the black market premium), and institutional quality (an index of democracy to capture political institutions and an index of law and order to capture the essential elements of economic institutions).[8] We standardize all of these covariates to have a mean of 0 and a standard deviation of 1 in order to facilitate the interpretation of our results. We use the countries for which all data are available. In the first model, without the

[8] Rodriguez and Rodrik (2001) criticize both trade volume and the black market premium as measures of openness because the volume of trade is not a direct measure of policy and the black market premium may be capturing macroeconomic distortions in general. For our purposes, however, these characteristics may be useful in classifying countries, even if the policy implications may be less clear.

covariates predicting class membership, we have 79 countries. When we use covariates our sample is reduced to 69 countries. Table 2 provides descriptive statistics and the data sources.

We considered using the initial value of our covariates rather than period averages, but rejected this approach on two grounds.[9] First, the use of average levels is generally a better fit with theory. For example, while current and expected inflation rates may distort investment decisions, it is hard to argue that inflation in 1970 matters for investment 1990. Similar arguments apply to openness and institutional quality. Second, we believe the argument in favor of using initial values of covariates is weak. While initial values are clearly predetermined, it is difficult to argue that this renders them exogenous due to high levels of serial correlation in these country characteristics. Therefore, because in either case we still have to admit the possibility of endogeneity and interpret the results cautiously, we choose to measure the covariates in a manner that would be more consistent with the theory.

Results for Model with no Covariates

In this section we discuss the results of maximizing the log-likelihood function defined by Equation 6. Table 3 presents the fit statistics and classification errors. The AIC3 indicates that the 4-class model fits the data the best. As noted above, there is a significant amount of uncertainty in classifying the countries, with a classification error of 29 percent. In Table 3, we also report R^2 (unadjusted) as a point of comparison to standard regression models. Because of the high classification error, it would be unwise to place too much confidence in the specific country groupings that result from this regression. However, two points are worth making. First, the list of countries belonging to each class, shown in Table 4, does not fit any of the expected patterns. All four classes include at least two non-developing countries, and none of the classes is clearly associated with a regional classification. Indeed class 1, which includes the most non-developing countries, also includes a plurality of developing countries from each region including eight each from Latin America and sub-Saharan Africa.

[9] For a few countries in our sample, we do not have observations over the entire period for all the covariates. We still calculated “30-year averages” if we had observations for 20 or more years. In addition, the measures of law and order and democracy from the ICRG start in 1984.

Second, there is strong statistical evidence to reject the usual assumption that the parameters are uniform across countries. Wald tests reject the null hypothesis that the coefficients are equal across all four classes with p-values less then .01 in all four cases. While these initial results are suggestive that the growth process is qualitatively and quantitatively different across four groups of countries, we do not emphasize the details of these results due to the relatively high probability of misclassification. We now turn to a model that uses additional information to classify countries, giving us greater confidence in the groupings.

Results for Model with Covariates

To improve country classification, we add the measures of institutions, macroeconomic policy, and openness discussed above as covariates to the model. Once we add these covariates to our model to help predict class membership, our sample is reduced to 69 countries, but we are able to reduce the model's classification error from almost 30 percent to 4 percent. When we restrict the sample to only the 69 countries for which we have all the covariates, the model with covariates stills fits the data better than the model without covariates.[10]

The regression results are presented in Table 5. This table contains both the estimates of the beta parameters of the growth regression model and the estimates of the gamma parameters of the covariates. The first column of Table 5 provides the results from a standard, one-class OLS regression for comparison. Focusing first on the results for the four-class model (columns 2 through 6), we note that the Wald statistics in column 6 provide strong evidence that these coefficients are not equal across the four classes.

[10] Note that the AIC3 for the initial model presented initially is not directly comparable to the 69 country estimation because of the different samples used. However, fit statistics comparing the 69 country sample, no-covariate model to the 69 country model with covariates indicate that the inclusion of the covariates does improve the fit. The AIC3 for the 69 country model without covariates is -409, compared to -431 for the model with covariates on the same sample. The classification error for the 69 country model without covariates is .23, compared to .04 for the model with covariates. To further assess the fit of the model, we also calculate a bootstrapped p-value for the likelihood ratio test comparing the four class model to the three class model, the two class model and the one class model. P-values indicate that we can reject the models with fewer classes at significance levels less than one percent.

The coefficients that are reported in the bottom half of Table 5 for each covariate correspond to the gamma parameters γ_{mk} in equations 5 and 7. These coefficients are reported relative to class 1. In other words, a positive coefficient indicates that higher values of the covariate are associated with greater probability of membership relative to membership to class 1. Class 1 is the largest class, and, as we discuss in more detail below, features coefficients that are closest to the expected results for the augmented neoclassical model. Because all the covariates have a mean of 0 and a standard deviation of 1, it is possible to compare the magnitude of the coefficients across covariates—larger values of these coefficients indicates that a particular covariate is especially important in determining probability of class membership, everything else equal. That said, it is important to recall that the probability of class membership is determined by a combination of all these covariates as well as the conditional distribution of growth rates. Therefore, high or low values of any one particular covariate may not necessarily always correspond with high values of probability for class membership. We discuss the role of covariates further below.

Table 6 provides a list of countries in each group that is obtained by assigning countries to the group for which they have the highest posterior probability. In examining this grouping, it is important to keep in mind that what countries that are grouped together have in common is the conditional distribution of their growth rates. In other words, it is a characteristic that is difficult to observe directly. The covariates, which are observable, are providing additional information that enhances our ability to group countries.

Even though the countries are grouped by a latent characteristic, it is informative to look at the observable characteristics of these countries. Table 7 provides information on the regional composition of each class as well as the average levels of member regressors and covariates. We continue to find little support for classifications based on regions. For example, all four classes contain members from Latin America and Sub-Saharan Africa. However, our results suggest that a country's level of development does play a role in structuring its growth process. All of the developed countries are in either class 1 or 2, though developing countries make up close to half the membership of both groups. As shown in Table 7, class averages for each regressor are the most similar for classes 1 and 2. Although there is significant variation within each class, these classes have the highest average initial incomes, the largest enrollment rates and the lowest population growth rates of around 1 percent. Class 3 and class 4 are composed entirely of developing countries. These classes have average initial incomes of less than $2,700, enrollment rates of around 35 percent, and population growth rates of over 2 percent. In spite of the similarities of their initial conditions and factor accumulation, the poor countries exhibit remarkably different growth rates, with class 3 countries experiencing the fastest average growth over the period and class 4 countries experiencing the lowest.

Our results lend some support to the common practice of treating rich and poor countries separately, but they also suggest that this practice is far from perfect. The common practice of controlling for the influence of relative backwardness on growth by using separate samples of rich and poor countries fails to take into account significant heterogeneity among countries at similar levels of development. Developed countries are members of both class 1 and class 2, which are governed by very different growth processes. Less developed countries are members of all four classes. Such an approach also ignores significant similarities of experience among countries at different levels of development. While prior development clearly matters for growth, there are also significant differences in parameter values among rich countries and among poor countries.

As before, our results suggest that the use of standard cross-country growth regressions generates results that may be misleading with respect to growth process in any particular country. Note that there is nothing subtle about the predictions of the standard regression: the coefficients in the first column of Table 5 are all significant at the 1 percent level, and they all have the signs consistent with the neoclassical growth model. In the four-class model, however, each regressor is insignificant for at least one class, and the values of significant coefficients vary widely across classes as well. For example, the standard regression suggests a mildly positive relationship between education and economic growth and a mildly negative relationship between population growth and economic growth. In contrast, the four class model suggests education matters a great deal to the countries in class 1, and much less to other countries. Similarly, population growth has a much stronger negative relationship with growth for class 3 countries than is predicted by the standard regression, but it is otherwise statistically insignificant.

Calculations in Table 8 compare the effects of the coefficients from the four-class model with those from a standard cross-country growth regression. The last four columns of Table 8 show the difference in the predicted growth effects of a one-standard deviation increase in each regressor for the four-class and one-class model. Not only do these effects vary greatly across the four classes, but the differences in average annual growth rates are large enough to be economically significant. Thus, knowing the "average" results for the one-class model may not be very informative for describing the growth process in many countries.

4.2 Discussion

We turn now to interpreting the growth processes of particular classes. Although all the countries in classes 1 and 2 would not be considered to be developed countries, we note that all the developed countries are in one of these two classes and dominate these two groupings. Therefore, it is useful to first discuss class 1 in relation to class 2 and then to compare results for classes 3 and 4.

Growth in More Developed Countries

Class 1 and class 2 countries experience a noticeable difference in predicted growth rates. The average growth rate for class 1 countries was 2.36 percent, compared to 1.52 percent for class 2 countries. In addition, a good deal of this difference is due to the difference in growth process: if class 1 countries had followed the class 2 growth process, they would have achieved an average annual growth rate of 1.83 percent. In other words, roughly two-thirds of the difference in growth rates is due to the different growth process rather than differences in the level of regressors.

Class 1 countries exhibit accumulation-driven growth. This class has the largest coefficients on both physical and human capital. If we interpret these coefficients as reflecting how efficiently these factors are allocated, then their magnitudes suggest well-developed and flexible factor markets. Because efficient factor markets also allocate resources to their most productive uses first, they give rise to sharply diminishing returns, a finding that is consistent with the large negative coefficient on initial income. These results suggest that the growth process in class 1 might be consistent with the neoclassical model, however, the pattern of coefficients is not fully consistent with any of the models reviewed in section 3. The coefficient on population growth is not statistically significantly negative. This could reflect scale effects in levels, as suggested by some lines of endogenous growth theory, or the influence of some other factor, such as openness to international capital flows, that reduces the constraints on equipping new workers. A final possibility is that population growth rates do not vary enough among class 1 countries to estimate their effect with any confidence. However, that does not seem to be the case in this group of countries, with log of the population growth rate having a standard deviation of .84 (compared to the average of .03). Nonetheless, while the pattern of coefficients we find for class 1 countries is sufficient to reject the neoclassical model, it is broadly consistent with many of its predictions.

Class 2 countries exhibit education-driven, endogenous growth. The coefficient on education is positive and the other coefficients are not statistically significant, a pattern of coefficients that is consistent with the predictions of Lucas (1988). The slightly positive and insignificant coefficient on initial income suggests the absence of convergence dynamics and is consistent with the endogenous growth models considered above. In addition, the insignificant coefficient on investment suggests that physical capital accumulation plays at most a supporting role in economic growth, complementing the accumulation of human capital. As with class 1 countries, population growth does not appear to play an important role in the growth of class 2 countries.

What accounts for the observed differences in these growth processes? Theory only provides partial guidance in addressing this question, since we lack theories mapping combinations of covariates onto competing growth models. That said, our results are consistent with a number of hypotheses. First, as shown in Table 5, these classes of countries differ in terms of their identifying institutional structure. While class 1 countries have highly democratic political institutions, class membership reflects their adherence to the rule of law, as the negative coefficient on law and order in Table 5 suggests that higher values of law and order reduce the probability of class 2 membership relative to class 1. This supports the idea that well-developed property rights generate clear incentives and facilitate the efficient allocation of resources. In contrast, class 2 countries are characterized by the coexistence of democratic politics and lower levels of the rule of law. The absence of a significant role for investment in this group's growth process is thus consistent with the contention that an emphasis on political rights over property rights may give rise to populist or special interest politics that tend to blunt incentives. In contrast, macroeconomic policy does not seem to be sorting countries between groups 1 and 2, as evidenced by the insignificant coefficient on inflation and government consumption in column 3 of Table 5. It is possible that some of the effects of macroeconomic policy are being absorbed by the coefficient on the black market premium. This interpretation may be particularly likely, given that higher volume of trade is associated with lower class membership in class 2, but a lower black market premium is associated with higher membership. In other words, once the volume of trade is controlled for, the black market premium may be picking up broader macroeconomic distortions.

Growth in Less Developed Countries

The two classes of less developed countries have dramatically different outcomes with respect to their average growth rates. Of the four classes, class 3 countries grow the fastest with an average growth rate of 2.7 percent and class 4 countries grow the slowest with an average growth rate close to zero. If class 4 countries followed the same growth process as class 3 countries, their average growth rate would be 1.4 percent per year. Thus, as above, the differences in growth processes have a significant impact on growth rates, accounting for about half the difference between the fastest and slowest growing groups.

Class 3 includes many of the Newly Industrializing Countries (NICs), such as China, Egypt, Hong Kong, India, Indonesia, and South Korea. Our results support this interpretation in that the experience of the class 3 countries is consistent with Rebelo's (1991) model of capital-driven endogenous growth. The coefficients reported in Table 5 show that growth is increasing in the rate of physical capital investment. In contrast, the coefficient on education is not significant. Thus, while investment in education may serve to accommodate increases in the capital intensity of production, it does not appear to constitute an independent source of growth. Growth is also sharply decreasing in the rate of population growth, suggesting faster population growth increases the difficulty of equipping new workers. The magnitude of this coefficient is greater than would be expected from Rebelo's model, a finding that may suggest the influence of omitted variables. Finally, we do not find evidence that growth is related to initial income, suggesting a lack of conditional convergence.

Class 4 is the slowest growing class. None of the regressors enter the estimation significantly, though education is borderline significant with a p-value of .11. Clearly, in this group, additional resources are not producing faster growth, suggesting that countries in this group are not allocating resources efficiently. Perhaps more revealing is the lack of predictability of growth in this class of countries. Unlike the other three classes, none of the class 4 coefficients is estimated to be statistically significant, and the R-squared indicates that the standard growth model explains only 24 percent of the observed variation in these countries' growth rates. This compares unfavorably to the fit of the other three classes, each of which have an R-squared of .95 or better. The theory most consistent with the experience of these countries is that suggested by Easterly et al. (1993): growth is a function of random shocks.

An examination of the covariates of these classes suggests several factors that could account for their difference in growth experience. One important difference lies in their institutions. Membership in both class 3 and class 4 is characterized by the lack of democratic politics, but the probability of class 4 membership is strongly decreasing in the rule of law. Thus, class 3 countries may be characterized as authoritarian and law abiding, whereas class 4 may be more closely associated with despotism. If the absence of enforceable property rights results in a distorted allocation of physical capital, this might partially explain why the coefficient on investment is not significant for class 4 countries. Differences in economic policy may also play a role, with a higher share of government spending being associated with being in class 4. Interestingly, more trade is also associated with a higher probability of being in class 4 relative to class 1, but recall also that higher trade is associated with a higher probability of being in class 1 relative to class 2. One interpretation of this is that greater integration into the world market subjects countries to more shocks that, without appropriate institutions, lower growth rates. Class 1 countries may be able to absorb these shocks with less difficulty because of the different institutional environment. (See, for example, Rodrik, 1999.)

Policy Implications

Although so far our analysis has mainly been descriptive, if we were to infer a causal role for either the covariates or the regressors in the growth process, the policy conclusions would come at two levels. First, one type of policy conclusion would address the question: Given the growth process in a particular country (i.e., the class the country is in), what should be the focus of growth enhancing policy? For example, investment in education might be recommended for countries in class 1 and 2, but countries in class 3, might be better off focusing on limiting population growth and increasing physical capital investment. Similarly physical capital investment may be particularly productive for countries in classes 1 and 3, but not necessarily for countries in classes 2 and 4.[11]

The second level at which this type of analysis might suggest policy solutions would be to answer the question, what should a country do to move to a different group? While it is obvious that a country would want to move out of the poor-performing class 4, it is also the case that class 2 countries would grow faster if they moved to class 1. The results in Table 5 suggest that to move out of group 4, increasing law and order, increasing democracy, lowering government consumption, and (at least temporarily) reducing trade may be beneficial policy goals.

4.3 Comparison to standard methods

In the model we presented above, policy, institutions, and openness were used as covariates to help predict the growth regime to which a country belongs. This is in contrast to a standard treatment of variables like this in which they are entered separately as regressors in a one-class model. Before concluding, we also present these standard results and demonstrate that our methods not only fit the data better, but provide results that have a richer interpretation.

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[11] Interestingly, we note that lack of productivity for physical capital investment may be explained by more than one reason, even for countries in the same group. For example, in some countries physical capital investment may not be productive because markets are not efficient in allocating this investment or it may not be as productive because a country is on the frontier and human capital investment drives growth rather than physical capital accumulation. This type of explanation may be responsible for a somewhat unexpected grouping of countries in Class 3.

The results in Table 9 corroborate those found by many others-- a negative and significant coefficient on initial income and a positive and significant coefficient on investment and schooling. Also consistent with the lack of robustness for many of our covariates that is typically found, we do not find strong significance for any of the policy, institution, or openness variables. The coefficient on law and order is weakly significant with a p-value near .10. Yet, in our earlier results, we find that many of these variables play an important role in sorting countries into growth regimes. Further comparison of these standard results to the 4 class model also shows that the 4 class model fits the data better in terms of having a lower AIC3, allowing us to confidently reject this standard approach in favor of the four class model.

5 Conclusion

This paper presents a novel application of finite mixture models for estimating growth equations. While much of the analysis is necessarily descriptive, it does strongly suggest that there are several different growth processes and a universal policy recommendation for future growth does not exist. Interestingly, regression results for the full sample do not correspond to those for any of the four classes that we identify. Thus, while cross-country regressions may provide insight into the behavior of a hypothetical average country, we do not find that this average country is representative of any of the groups we identify. One-size-fit-all policy prescriptions based on the standard, one-class results would not be the right medicine for any country.

The regional and income variables commonly used to control for heterogeneity in growth are not in fact strongly correlated with group membership. There are two groups with high incomes and all four groups contain less developed countries and countries from nearly every region for which we have data. In contrast, we find that economic and political institutions play an important role in shaping the environment for growth and find that the effect of openness may be context dependent. We find only limited evidence that macroeconomic policy has similar importance in shaping the growth process.

Overall, our results support the idea that existing theories of growth are complementary and not competing. We find evidence that the augmented neoclassical model is a reasonable description of the growth process in about one-third of our sample. The growth process in the remaining countries may be more in line with a physical-capital driven growth model, a human-capital driven growth model or a random shock model. The technique we use is well suited to dealing with this type of heterogeneity.

That said, there are limitations of our analysis. Importantly, the technique we use is data driven, and the small sample we are able to construct limits the extent to which we can explore additional covariates, implement more sophisticated specifications, or even identify additional groupings of countries. Although more data will eventually become available, there are some additional issues that can be addressed more immediately. Future work will explore two issues. First, although much empirical work on long-run growth is plagued by issues of endogeneity, our work is too and consideration of the endogeneity of both the regressors and the covariates should be addressed to strengthen the usefulness of this technique for policy makers. Second, in our analysis, we have required a country to maintain membership in the same group throughout the 30 year time period. This may be too strict of a requirement, especially for countries that have made important institutional or policy changes over the 30 year period. In future work, we intend to address both of these issues. Nonetheless, this work advances a new way of thinking about the growth process that has important implications for policy and theory.

Table 1: Parameter Restrictions for Various Growth Models

	Augmented Neoclassical Model	Endogenous Growth Models	
		Human Capital Driven Growth	Physical Capital Driven Growth
β_y	-	0	0
β_K	+	0	+
β_H	+	+	0
β_L	-	0	-n

Table 2: Descriptive Statistics

Variable	Obs.	Mean	SD	Description	Data Source
GROWTH	79	.0184	.0173	30 year average annual growth rate of real GDP	PWT 6.2
Ln(gdp70)	79	8.258	1.009	Natural log of real 1970 GDP per capita	PWT 6.2
Ln(inv)	79	3.108	.2502	Ln(30 year average of I/GDP)	PWT 6.2
Ln(seced)	79	3.811	.7569	Ln(30 year average of gross secondary school enrollment rate)	Barro and Lee data set
Ln(popgrow)	79	.4012	.7809	Ln(30 year average annual population growth rate)	PWT 6.2
Law and Order	69	0	1	Standardized index of law and order	ICRG
Democracy	69	0	1	Standardized index of democracy	ICRG
BMP	69	0	1	Ln(1+black market premium), standardized	World Bank's Global Development Network Growth Database
Trade	69	0	1	(Imports+exports)/GDP, standardized	World Development Indicators
Inflation	69	0	1	30 year average inflation rate, standardized	World Development Indicators
Government Consumption	69	0	1	Government Consumption/GDP	PWT 6.2

Table 3: Fit Statistics

Model	Log likelihood	AIC3	Classification Error	R^2
1-Class Regression	239.9491	-461.8983	0.0000	0.5453
2-Class Regression	253.2004	-467.4007	0.1900	0.8829
3-Class Regression	264.9826	-469.9652	0.2435	0.9413
4-Class Regression	**276.0811**	**-471.1623**	**0.2883**	**0.9696**
5-Class Regression	281.7533	-461.5067	0.3309	0.9866

Table 4: Class Membership, Model without Covariates

Class 1	Probability of Class 1 Membership	Class 2	Probability of Class 2 Membership	Class 3	Probability of Class 3 Membership	Class 4	Probability of Class 4 Membership
Austria	0.55	Australia	0.38	Burkina Faso	0.38	Argentina	0.67
Belgium	0.55	Canada	0.4	Costa Rica	0.6	Bolivia	0.49
Brazil	0.78	Algeria	0.52	Finland	0.72	Switzerland	0.78
Botswana	≈ 1	Ghana	0.39	United Kingdom	0.53	Korea, Rep.	0.71
Chile	0.51	Honduras	0.75	Guinea-Bissau	0.67	Nigeria	0.93
China	≈ 1	Ireland	0.86	Greece	0.86	Nicaragua	0.99
Cote dä Ivoire	0.9	Iran, Islamic Rep.	0.51	Guatemala	0.67	New Zealand	0.53
Colombia	0.78	Jordan	0.66	Jamaica	≈ 1	Uruguay	0.77
Cyprus	0.4	Kenya	0.98	Japan	0.86		
Denmark	0.83	Lesotho	0.55	Luxemburg	0.63		
Dominican Republic	≈ 1	Philippines	≈ 1	Mauritania	0.53		
Ecuador	0.42	Uganda	0.95	Peru	≈ 1		
Egypt	0.89	Venezuela	≈ 1	Trinidad and Tobago	0.47		
Spain	0.92	Zimbabwe	0.64	United States	0.53		
France	0.51			Zambia	0.57		
Hong Kong, China	≈ 1						
Indonesia	0.71						
India	0.54						
Israel	0.86						
Italy	0.74						
Sri Lanka	0.58						
Madagascar	0.6						
Mexico	0.65						
Mali	0.81						
Mauritius	≈ 1						
Malaysia	≈ 1						
Niger	0.58						
Netherlands	0.53						
Norway	0.51						
Nepal	0.37						
Oman	≈ 1						
Papua New Guinea	0.59						
Portugal	0.59						
Paraguay	0.99						
Rwanda	0.55						
Senegal	0.47						
Singapore	≈ 1						
El Salvador	0.36						
Sweden	0.73						
Thailand	≈ 1						
Tunisia	≈ 1						
Turkey	0.95						

Countries are placed in classes using empirical Bayes modal estimation.

Table 5: Regression Results for model with covariates, real per capita GDP growth, 1970-2000

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	One Class Model (OLS)	Class 1	Class 2	Class 3	Class 4	p-value for Wald statistic for equality of coefficients across all 4 classes
Ln(gdp70)	-0.0141*** (.0022)	-.0267*** (.0012)	.0011 (.0016)	-.0029 (.0021)	-.0084 (.0075)	.00
Ln(inv)	0.0329*** (.0070)	.0348*** (.0038)	-.0008 (.0042)	.0505*** (.0054)	-.0015 (.0136)	.00
Ln(seced)	0.0127*** (.0022)	.0407*** (.0035)	.0100*** (.0018)	.0010 (.0021)	.0108 (.0067)	.00
Ln(popgrow)	-0.0081*** (.0033)	.0005 (.0012)	.0001 (.0008)	-.0377*** (.0087)	-.0018 (.0037)	.00
Constant	-.0135 (.024)	-.0221 (.016)	-.0314** (.014)	-.084*** (.008)	.033 (.027)	.01
Covariates						
Law and Order			-9.134*** (1.867)	-3.269*** (1.232)	-4.823*** (1.370)	
Democracy			1.890 (1.717)	-2.583** (1.111)	-3.626*** (1.373)	
BMP			-10.915*** (2.526)	-2.194 (1.413)	1.282 (1.226)	
Inflation			-4.147 (6.841)	-11.080 (8.138)	0.265 (0.641)	
Government Consumption			-.0667 (0.845)	0.627 (.792)	1.656** (.720)	
Trade			-3.441** (1.465)	-0.880 (0.678)	1.616** (0.781)	
R^2	.5884	.9705	.9464	.9718	.2420	
AIC3	-409	-431				
Class Size (% of observations)	1.00	.32	.28	.25	.16	

All estimations include a constant. Robust standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%

Coefficients for covariates are reported relative to class 1.

Table 6: Class Membership for Model with Covariates

Class 1	Probability of Class Membership	Class 2	Probability of Class Membership	Class 3	Probability of Class Membership	Class 4	Probability of Class Membership
Argentina	.99	Australia	.82	China	≈ 1	Bolivia	≈ 1
Austria	.95	Canada	.60	Ecuador	.99	South Africa	.99
Belgium	.99	Ivory Coast	.97	Egypt	.99	Ghana	.99
Brazil	.99	Columbia	.99	Hong Kong	.99	Iran	≈ 1
Botswana	≈1	Spain	.96	Indonesia	.99	Jamaica	.99
Switzerland	.99	Finland	.99	India	.99	Jordan	.92
Chile	.99	France	.99	Kenya	.99	Nigera	≈ 1
Costa Rica	.98	Great Britain	.99	Korea	.99	Nicaragua	≈ 1
Cypress	≈ 1	Greece	.99	Sri Lanka	.99	Peru	≈ 1
Denmark	.97	Guatemala	.98	Madagascar	.80	Uganda	≈ 1
Dominican Rep.	.75	Honduras	.49	Mali	.99	Zambia	≈ 1
Ireland	.99	Italy	.99	Papua New Guinea	.99		
Israel	.99	Japan	.99	Paraguay	.98		
Malaysia	.99	Mexico	.99	El Salvador	.88		
Netherlands	.99	Niger	.98	Thailand	.90		
Norway	.99	Philippines	.99	Tunisia	.97		
New Zealand	.99	Senegal	.99	Zimbabwe	.53		
Portugal	≈ 1	Uruguay	.93				
Sweden	.98	USA	≈ 1				
Trinidad & Tobago	.99						
Turkey	.94						
Venezuela	.99						

Countries are placed in classes using empirical Bayes modal estimation.

Table 7: Description of Classes for Model with Standardized Covariates

Regions	**Class 1**	**Class 2**	**Class 3**	**Class 4**
Non-Developing	11	10	0	0
Latin America and Caribbean	7	5	3	4
Middle East and North Africa	1	0	2	3
Eastern Europe and Central Asia	1	0	0	0
Sub-Saharan Africa	1	3	4	4
East Asia and Pacific	1	1	6	0
South Asian Region	0	0	2	0
Total by Class	22	19	17	11
Regressor Averages	**Class 1**	**Class 2**	**Class 3**	**Class 4**
Initial Income	7549	5872	1830	2672
Investment	24	21	23	21
Education	71	54	35	37
Pop. Growth (%)	0.98	1.11	2.11	2.58
Income Growth (%)	2.36	1.52	2.66	-0.10
Standardized Covariate Averages	**Class 1**	**Class 2**	**Class 3**	**Class 4**
Law	0.70	0.16	-0.43	-1.00
Democracy	0.64	0.41	-0.66	-0.97
Trade	0.38	-0.49	0.08	-0.04
BMP	-0.30	-0.65	0.26	1.33
Inflation	-0.03	-0.26	-0.28	0.94
Government Consumption	-0.06	-0.55	0.05	1.00

Table 8: Comparing the One-Class and Four-Class Models

		Difference in Predicted Growth Rate, Percent Per Year			
Variable	Standard Deviation	Class1	Class2	Class3	Class4
ln(gdp70)	0.9525	-1.2027***	1.4452***	1.0642***	0.5213
ln(inv30yr)	0.2396	0.0420	-0.8111***	0.4254***	-0.8207*
ln(seced30yr)	0.6784	1.8966***	-0.1862	-0.7968***	-0.1251
ln(popgrow30yr)	0.8102	0.6928***	0.6604***	-2.3699***	0.5145

Asterisks indicate that the coefficients used to calculate the difference in predicted growth rates are significantly different than the point estimate from the one-class model. ***significant at 1%, **significant at 5%, *significant at 10%

Table 9: Standard Growth Regression

Variable	
Ln(gdp70)	-.0168*** (.0025)
Ln(inv)	.0255*** (.0067)
Ln(seced)	.0152*** (.0037)
Ln(popgrow)	-.0027 (.0023)
Law and Order	.0047* (.0028)
Democracy	-.0011 (.0029)
BMP	-.0033 (.0026)
Inflation	-.0015 (.0010)
Government Consumption	-.0011 (.0026)
Trade	.0010 (.0014)
AIC3	-410
R^2	.70
Class Size (% of observations)	1.00

All estimations include a constant. Robust standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%

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