

**Economic Growth,
Convergence and the
HIV/AIDS Epidemic: A
Cross-Country Panel Data
Analysis**

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Declaration

I declare that this thesis was composed by myself and that the work contained therein is my own, except where explicitly stated otherwise in the text.

(Joel Smith)

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To Nicki, Auchen and Bren

Abstract

This thesis presents an analysis of the dynamic process of economic growth, national welfare and the HIV/AIDS epidemic. An assessment of the methodological designs of applied growth research is undertaken in order to polarise the limitations associated with cross-sectional growth regressions. The cross-country cross-sectional methodology that has been the dominant feature of empirical growth analysis may suffer from an endogeneity and omitted variable bias. A panel data approach is adopted in order to address the econometric issues associated with cross-sectional study designs. To highlight the discrepancies between theory and empirics, a rudimentary description of the Solow model is offered. Extensions of the Solow paradigm are also discussed and form the basis of the theoretical foundations of the research.

The relationship between health and economic growth within the existing literature has considered the consequences of poor population health in determining national income levels. Disease-specific effects have been included in growth regressions to capture the output losses associated with the widespread reduction in human capabilities. This thesis contributes to the existing literature by testing the empirical relationship between economic growth and the HIV/AIDS epidemic for a broad cross-section of countries. Previous empirical studies have not presented a unified account of the epidemic's effects in determining cross-country productivity differentials. The way in which the epidemic might impede economic prosperity is considered by drawing upon the existing literature. The

strengths and limitations of previous study estimates are considered in relation to the study design. A more robust empirical estimator for growth regressions is proposed in the form of a system Generalised Method of Moments estimator. The research extends on previous study estimates by considering the epidemic's effect across the conditional quantiles of the growth distribution.

A central prediction of the neoclassical growth paradigm relates to the convergence hypothesis in which poorer economies are considered to achieve faster growth rates. By drawing upon the distributional changes in national income over time for the entire cross-section of countries, this thesis will assess the potential barriers that may violate the theoretical predictions of the convergence hypothesis. An empirical assessment of the role of convergence clubs, mortality and poverty traps will be presented through an analysis of the changes in health and income inequality over time. The distributional shifts that have occurred over the period under analysis consider the consequences of growth as a measure of national welfare.

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Chapter 1

Introduction

The threat and spread of HIV/AIDS throughout the world has resulted in the overwhelming loss of life and individual autonomy. By its very nature, the virus has decimated the structural foundations of familial ties, further negating the prospect of human agency and sustained economic development. HIV/AIDS has maintained its position as one of the leading causes of death globally (WHO, 2008). This case is particularly evident within Sub-Saharan Africa which accounted for 71% of all new HIV infections in 2008 (UNAIDS, 2009). The current situation within the region highlights the imperative need for a priority setting of effective health care in order to quell this prevalence. Indeed, the region boasts the sombre classification of homing almost two-thirds of all people living with HIV, despite being home to less than 10 per cent of the world's population (UNAIDS/WHO, 2004). Since the initial outbreak of the disease it is estimated that over 20 million Africans have died from HIV/AIDS, with over 2 million mortalities in 2006 alone (UNAIDS/WHO, 2006). Despite substantial investment from international aid initiatives to reverse the trend, the pandemic continues with increased vigour. This situation is polarised with the infection rate of new cases rising to 2.8 million for 2006 - a figure higher than all other regions combined (UNAIDS/WHO, 2007).

The multifaceted mechanisms through which the HIV/AIDS epidemic impedes

a country's autonomy extends beyond microeconomic considerations. Instead, the societal costs of the epidemic may be equally damaging for countries worst affected by rising HIV prevalence rates. Although individuals and households largely burden the costs of health care treatments and the psychological consequences of increased mortality and morbidity, the accumulation of such microeconomic forces may result in important negative effects for national prosperity. There has been an increased appreciation of the role of population health in determining national welfare in the policy arena due to several recent seminal contributions (WHO, 2001; Sachs and Malaney, 2002; Bloom et al., 2004). As a consequence, the role of maintaining a good level of population health has been identified as a central feature of the pursuit for economic growth and development. A primary motivation for health's role in the growth process relates to the direct impact on labour productivity. Indeed, the mechanism can be considered as increasing both the quantity and quality of labour within an economy. An increase in labour supply is derived from the reduction in incapacity, sickness absence and premature death following health improvements. Furthermore, the stock of labour is also enhanced with healthier workers considered more productive leading to a greater marginal product of labour. The mechanisms through which health contributes to increased economic growth can, therefore, be broadly defined as improving nutrition and productivity, reducing sickness absence as well as deriving gains in longevity.

An alternative viewpoint of the importance of health as a determinant of economic growth is to consider the consequences of health deteriorations at the aggregate level. In this setting, poor population health can be viewed as an impediment to national economic growth rates. A country's propensity to invest in population health is determined by a myriad of social, economic and political factors. Nonetheless, external mechanisms also exist that may have significant consequences for the health of a country's citizens. This situation is exemplified

in the case of the HIV/AIDS epidemic. Notwithstanding the substantial negative effects of the epidemic at the individual level, countries with high HIV prevalence rates may also be further penalised through a reduction in the quality and quantity of labour supplied within the economy. The corresponding reduction in national productivity may be further compounded if it also deters foreign direct investment due to the presupposition of an uncompetitive environment. It is clear that the pursuit of economic growth may alter the distribution of poverty and inequality within society through the direct impact on mean income. The nature and capacity for countries to address rising HIV prevalence rates differs across countries and level of economic development. A country's response to the HIV/AIDS epidemic may, therefore, have a profound impact on economic growth, poverty reduction and income inequality within society.

A unifying theme throughout this thesis concerns the dynamic process of economic growth and its role in determining national welfare. National accounts data are commonly used to construct estimates regarding the prosperity and vitality of an economy over time. The logarithmic change in real GDP per capita can be considered the dominant empirical measure of economic growth. This measure of the change in national income can be used to draw inferences on aggregate welfare across countries. The derivation of economic growth may also uncover distributional shifts in national income over time. Poverty and inequality can be considered essential features of the growth process demonstrating sensitivity to changes in national income. An assessment of the factors that polarise cross-country productivity differentials offers a greater understanding into the interdependent relationship between growth, poverty and inequality.

Real GDP per capita is assumed to be a crude measure of aggregate welfare. For some, a more inclusive measure would account for differences in human capabilities (Sen, 1999). Proponents of income as a measure of welfare consider real GDP per capita to encompass all the necessary individual opportunities that de-

termine welfare (Ray, 1998). At the aggregate level, national income is positively associated with a number of alternative welfare indicators. Education, health and democracy are all higher in countries reporting greater levels of income. Nonetheless, a number of barriers exist that may restrict a country's prosperity. Physical characteristics, such as geography and climate, have been proposed as notable factors leading to increased growth differentials across countries. In this setting, investment in human capability welfare indicators in isolation may still lead to reduced income levels. The thesis aims to present an assessment of the determinants of economic growth. Theoretical motivations are aligned to the neoclassical growth paradigm associated with Solow and the more recent developments by Mankiw, Romer and Weil (1992). The theoretical narrative will be complemented by an empirical assessment of the underlying predictions for a panel of countries. By offering an assessment of the growth process, the primary aim of this account is to establish the dyadic relationship between national income and the investment in productivity.

The capabilities approach of welfare acknowledges the productive properties of both education and health in determining income levels. An implicit assumption of the public health literature postulates that income is a core determinant of health. Standard economic models consider the causality to flow in the opposite direction. That is, from health to income. The rationale for this premise is directly related to the productive features associated with improved health. Indeed, causality from income to health still leaves unanswered the question of the accumulation of income in the absence of good health. By identifying and drawing upon the determinants of economic growth, this research will consider the impact on income growth from adverse health outcomes. More specifically, whether the HIV/AIDS epidemic has had a negative effect on national income. An assessment of this relationship seems logical given the accepted viewpoint of the AIDS epidemic as a disease of the poor. Advocates of this line of reasoning

point to the observed income and health differentials in sub-Saharan Africa. In particular, the region can be considered the worlds poorest and the worst affected by the AIDS epidemic.

Using modern econometric methods, the thesis aims to address three central research questions. By drawing upon current applied models of economic growth, a fundamental research question concerns the impact of the HIV/AIDS epidemic as a determinant of economic growth. In particular, the thesis aims to estimate whether the HIV/AIDS epidemic has been a barrier to economic growth for a broad heterogeneous sample of countries. To address this research question, a system generalised method of moments estimator is adopted as the preferred method to account for the dynamic nature of panel data growth regressions as well as the endogeneity of regressors. A complementary aim of the thesis is to build upon the initial research question by estimating the effect of the HIV/AIDS epidemic across the conditional growth distribution. This complementary research question aims to estimate whether there is evidence of a differential impact of the HIV/AIDS epidemic for high and low growth performing economies. The use of quantile regressions with fixed effects offers a means of incorporating parameter heterogeneity within the growth regression model and forms the basis of the estimation routine. A unifying theme throughout the thesis concerns the dynamic process of economic growth and its role in determining national welfare. As a result, the final research question aims to analyse the evolving distribution of income and health across countries by exploiting the time-series nature of the data sources. In this setting, the research question aims to estimate the world distributional dynamics of income and health in relation to poverty reduction and the associated consequences for global inequalities in income and health.

1.1 Description of Data Sources

To address the research questions, a synthesis of cross-country data sources are utilised. The latest round of the Penn World Tables (PWT) represents the most comprehensive set of time-series estimates for a number of economic variables focusing upon national accounts data. PWT 6.2 offers data on 24 variables for 188 countries over the period 1950-2004. Although the dataset is primarily restricted to economic variables, this limitation is also its strength. Indeed, the methodology used to create PWT 6.2 has resulted in more robust measures of the economic variables across both time and countries (Heston et al., 2006). The World Bank World Development Indicator Database (WDI) provides annual aggregate data for 208 economies for a range of socio-economic, demographic and health measures from 1960-2006. WDI is a possible alternative to PWT 6.2 due to the comprehensiveness of the dataset, however, the variables of interest in this data source lie solely in its welfare and demographic indicators, such as nutrition, life expectancy and population growth. Estimates of human capital come from the Barro-Lee dataset that is commonly used in applied economic analysis (Barro and Lee, 2001). A full sample of 112 countries are included within a panel data design over the period 1960-2004. In order to remove short-term economic fluctuations of the variables of interest, the panel data framework is specified among 5 year intervals, resulting in 9 data points over the period. The origin of 1960 is specified due to the limited availability of data for a broad cross-section of countries prior to this time point.

The recently released UNAIDS HIV prevalence estimates (UNAIDS/WHO, 2008) have greatly rectified the paucity of cross-country prevalence data currently available within the public domain. This fruitful development is also reflected within the quality of the data produced. A re-assessment of previous prevalence estimates based on more recent data has yielded greater insights into the global HIV epidemic. Previous prevalence rates in Botswana, in particular,

were considered inconsistent in light of more recent national level data. This re-evaluation has seen the national prevalence rate for Botswana fall by 33 per cent from the level previously reported and commonly used in applied research. A major shortcoming of the UNAIDS data relates to the limited time period covered. Cross-country prevalence estimates prior to 1990 remain scarce. Furthermore, the consistency of data prior to 1990 is an additional challenge due to the reliance on, now considered, over-inflated estimates.

The UNAIDS prevalence estimates are used as the primary data source of HIV prevalence for the final 3 waves of the panel. A zero HIV prevalence rate was explicitly assumed for the initial 3 wave period, 1960-1970. In order to construct prevalence estimates for the intermittent period of 1971-1989, existing HIV data was utilised in addition to the more recently revised prevalence estimates. The estimates for national HIV prevalence rates during the period 1971-1989 were calculated from the UNAIDS Estimation and Projection Package (EPP) (The UNAIDS Reference Group on Estimates and Projections, 2002). EPP utilises country-specific HIV prevalence data in order to construct a national HIV prevalence rate. An intuitive appeal of EPP relates to its ease in incorporating the complexity of the HIV/AIDS epidemic as a feature of group sub-epidemics. For example, it is clear that HIV prevalence rates are higher among certain members of society but the specific populations of interest differ across countries and level of economic development. Two alternative models are used within EPP in order to obtain robust national estimates of adult HIV prevalence. By classifying countries based on the level of prevalence in specific sub-populations, EPP constructs estimates for countries with a generalised and concentrated epidemic through the use of fitted epidemic curves. Ghys et al. (2004) defines generalised epidemics as occurring when HIV prevalence is established within the general population. Although generalised epidemics are considered to be a substantial public health concern for the general population, specific sub-populations within

a country may continue to contribute disproportionately to the HIV epidemic. Conversely, concentrated epidemics occur when certain groups of society experience a rapid increase in the rate of HIV prevalence, despite the spread of HIV remaining low in the general population.

In order to derive national HIV prevalence rates over the period 1971-1989, prior assumptions were made regarding the classification of countries in terms of their HIV epidemic. A prevalence rate greater than 1% in antenatal clinics was used as a benchmark in which to classify countries as experiencing a generalised epidemic. In contrast, concentrated epidemics were viewed to occur when some other sub-population experienced a prevalence rate greater than 5%. Such sub-populations analysed for concentrated epidemics were injecting drug users, commercial sex workers and men engaging in homosexual activities. The dichotomous framework for classifying countries as experiencing a generalised or concentrated epidemic follows the recommendations of The UNAIDS Reference Group on Estimates and Projections (2002).

The key data requirements for constructing national HIV prevalence estimates within EPP are HIV surveillance data as well as the population estimates for the defined sub-epidemics. A country experiencing a generalised HIV epidemic can be considered to be experiencing the accumulation of two sub-epidemics within the urban and rural populations. In this setting, EPP would require population estimates for both the urban and rural populations in order to derive sub-epidemic prevalence estimates. The flexibility of EPP also allows greater weight to be attached to specific HIV surveillance data providing there is a clear rationale. This situation is exemplified if surveillance data is derived from large urban antenatal clinics in which a significant percentage of the population resides (Ghys et al., 2004).

In order to derive national HIV prevalence estimates, EPP incorporates four epidemiological parameters within the least squares model specification. The

four parameters that can be adjusted within EPP depending on each country's experience are:

1. t_0 = The start year of the epidemic
2. f_0 = The fraction of the population deemed at risk of infection in the initial period of the HIV outbreak.
3. r = The growth rate of the HIV epidemic
4. φ = A behavioural parameter characterising the populations response to the epidemic.

The behavioural parameter, φ , also captures the increased exposure for the previously unaffected population as the epidemic intensifies. As Ghys et al. (2004) notes, φ can be considered to be a function of geographic and social barriers that might erode as the epidemic progresses. By adjusting the four parameters, EPP fits epidemic curves for each sub-epidemic as well as for estimating national HIV prevalence rates.

EPP incorporates uncertainty by randomly generating a pre-specified number of epidemic curves based on the four epidemiological parameters. A lower threshold of 50,000 epidemic curves were specified for countries with a paucity of HIV data due to the limited number of antenatal surveillance sites used in the model fit. When sufficient HIV surveillance data were available for both urban and rural populations, 200,000 epidemic curves were generated to estimate national prevalence rates. An example of the Bayesian Melding fitted epidemic curves for Botswana is presented in Appendix B. EPP relies on maximum likelihood as a measure of the goodness of fit in which to compare the generated epidemic curves to the HIV parameter data. The aim of this process is to identify epidemic curves which provide both a good and poor fit to the data based on their likelihood. By excluding epidemic curves with very small likelihoods, EPP resamples with replacement based on 3,000 curves from the initial set of epidemic curves of either

50,000 or 200,000. The resampling process attaches greater weight to epidemic curves with higher likelihoods in order to ensure that curves which provide a good fit to the data are selected more often. In this setting, the probability of selection for each epidemic curve is proportional to its likelihood (Brown et al., 2008). The process of Bayesian melding incorporated with EPP explicitly accounts for the uncertainty in deriving national HIV prevalence estimates. A number of unique epidemic curves are generated from the sampling process. It is clear that the number of unique curves generated will be substantial smaller than the 3,000 curves used in the resampling process due to the weighting mechanism for curves with a high likelihood. It is from the small number of unique epidemic curves that EPP selects a best-fit curve which can be defined as the maximum a posteriori trajectory (Alkema et al., 2008).

The variation in prevalence rates across waves over this period was minimal for concentrated epidemic countries. Conversely, this period defines the epidemics infancy through to its prominent state in 1989 in which rates were considerable for countries experiencing a generalised epidemic. It was imperative, therefore, to limit the number of fitted curves for concentrated epidemics based on the updated UNAIDS prevalence data from 1990-2004. That is, the fitted curves restricted the path of the national prevalence rates over time by conditioning on the outcome post-1990. The method of Bayesian Melding in EPP was used to obtain robust prevalence rates using the conditioning parameter of the UNAIDS data points, as well as behavioural and policy response indicators. Backward extrapolation of the original UNAIDS/WHO (2008) HIV prevalence estimates was also undertaken in order to assess the differential methods in constructing national time-series HIV point estimates.

PWT 6.2 assigns a measure of quality of the constructed estimates for each individual country on a four point scale. Countries that are assigned the lowest value in terms of data quality were excluded from the full sample analysis. Fur-

thermore, small and oil producing economies were also excluded as income levels for these countries are more sensitive to economic fluctuations. This situation is polarised in the superficially high levels of income reported for the oil producing economies. Indeed, income levels for major oil producing economies can be viewed as being dictated by oil price fluctuations. As aggregate income levels capture the value added to the economy, countries in which oil production represents a major share of GDP are limited in this regard. Instead, the value added to the economy is marginal, if not negative, for oil production as any increase in income is derived from the extraction of scarce natural resources.

The Penn World Tables are largely constructed by the method of extrapolation derived from the national accounts data for selected benchmark countries. There is, therefore, a degree of uncertainty in the estimated values of the variable of interest. In particular, this level of uncertainty is increased for countries with limited data points due to poor national account records. Such countries fall under the category of low income and former centrally planned economies. Countries of the former Soviet Union were excluded due to the unreliability of estimates and the limited data points in which to construct estimates of long-run economic growth. A number of low income countries recorded missing data for the key variables of interest for the initial waves of the panel. Nonetheless, the countries were included in the study design due to the greater number of data points available and the potential concern over a sample selection bias. For example, it is clear that the quality of data is higher among richer economies which have a greater capacity for routinely recording national accounts data. Nonetheless, a cut-off time threshold of the year 1975 was implemented for countries to be included in the sample. This year was selected on the grounds that it represented the minimum time-period required in which to analyse the dynamics of long-run economic growth. An unbalanced panel of 112 countries were included in the 9 wave panel design.

1.2 Summary of Chapters

Chapter 2 presents a selective review of the literature on economic growth, starting with an assessment of the theoretical motivations. A rudimentary description of the Solow model is offered in order to highlight the discrepancies between theory and empirics. Extensions of the Solow paradigm are also discussed and form the basis of the theoretical foundations of the research. This discussion focuses upon the cross-country cross-sectional methodology that has been the dominant feature of applied growth research. An analysis of the econometric issues associated with applied growth research will be undertaken in order to polarise the limitations of the cross-sectional methodological design. The concern of model uncertainty inherent in growth regressions will be acknowledged through a critique of the salient determinants considered in growth analysis. An exhaustive list of the determinants included in growth regressions is beyond the scope of the thesis. Instead, the partial list of determinants outlined is motivated by the study design by noting that some regressors can be considered time-invariant. A number of empirical issues relating to cross-sectional growth regressions have been identified leading to the adoption of a more fruitful study design in which to offer more robust estimates. By exploiting the variation within countries, panel data growth regressions may uncover salient features of the growth process in which to complement the existing applied and theoretical literature. The advantages associated with a panel data design from the existing literature propose the use of an estimator that can suitably control for country fixed effects. An evaluation of the alternative estimators used in panel data studies to address the econometric issues inherent in growth regressions concludes this chapter.

Descriptive statistics of the correlates of growth are presented in Chapter 3 in order to gain a rudimentary insight into the dynamic process of growth. An empirical assessment of the textbook Solow model's predictions is undertaken in which to guide the subsequent empirical design. It is postulated that the speed

of convergence is sensitive to the estimator used in the growth regressions. The rationale for the advocacy of the system GMM estimator for growth regressions is outlined and forms the basis of the regression analysis of chapter 4. An assessment of the relationship between health and economic growth also determines the direction of the research questions undertaken in subsequent chapters. In particular, the descriptive statistics outline empirical issues that need to be addressed when considering causal inferences between growth and health.

The aim of Chapter 4 is to test the empirical relationship between economic growth and the HIV/AIDS epidemic. Previous empirical studies have not presented a unified account of the epidemics effects in determining cross-country productivity differentials. The way in which the epidemic might impede economic prosperity is considered by drawing upon the existing literature. Using a larger sample of countries and more recently revised data on adult HIV prevalence, a central aim of this chapter is to reconcile previous study estimates in order to elucidate the epidemics effect. The strengths and limitations of previous study estimates are considered in relation to the study design. A more robust empirical estimator for the growth regressions is proposed in the form of a system GMM estimator.

Chapter 5 extends on the empirical estimates derived in Chapter 4 concerning the growth process and the HIV/AIDS epidemic. By considering the estimated impact of regressors across the conditional growth distribution, a central aim of this chapter is to introduce parameter heterogeneity into the growth regression framework. Using a quantile regression approach within the panel data design, the results offer a greater insight into the growth process beyond estimates based on the conditional mean. The central tenets of convergence and the estimated impact of the HIV/AIDS epidemic on economic growth are explicitly analysed in order to capture the degree of parameter heterogeneity.

By drawing upon the distributional changes in national income over time for

a broad cross-section of countries, Chapter 6 assesses the potential barriers that violate the theoretical predictions of the convergence hypothesis. An empirical assessment of the role of convergence clubs, mortality and poverty traps is presented through an analysis of the changes in health and income inequality over time. The distributional shifts that have occurred over the previous 40 year period are discussed in relation to the changing level of welfare across countries. The chapter incorporates the growth nexus of poverty and inequality in order to capture the dynamics of the growth process as well as encapsulating the unifying theme throughout the thesis.

The main concepts of the thesis are summarised in the final chapter. By considering the underlying premise of the thesis and the methodologies adopted throughout the course of this research, this chapter acknowledges the possible limitations of the thesis. Chapter 7 concludes by suggesting directions of future research and possible extensions of the current research programme.

Chapter 2

Literature Review on the Economics of Growth

2.1 Introduction

The literature review will outline the theoretical and empirical advancements in the area of economic growth. This discussion will be motivated by the identification of salient growth determinants and the role of convergence. These two strands are the key areas of modern empirical and theoretical growth research. The starting point of this section will offer an overview of the textbook Solow model. Following on from this will be a critique of the Solow model in empirical research in relation to theoretical and empirical advancements. In particular, focus will be placed on the current interest in the role of panel data designs in growth analysis. This section will not present an exhaustive account of the advantages associated with a panel data approach. Instead, the focus will be limited to the pertinent strengths and challenges associated with a panel data methodology. The theoretical prediction of convergence will be discussed and analysed in relation to the competing empirical designs. Finally, this section concludes with a review of the methods and summary of the identification of growth determinants.

2.2 The Solow Growth Model

In order to elucidate the recent theoretical and empirical advancements in the area, a description of the rudimentary components of the general growth model is necessary. The Solow (1956) model of economic growth and its extensions form the basis of the work presented in this thesis. Solow's model takes the rates of saving, population growth and technological progress as exogenous. There are two inputs, capital and labour, which are paid their marginal products. A Cobb-Douglas production function is used to specify the relationship, whereby production at time t is given by

$$Y(t) = K(t)^\alpha (A(t)L(t))^{1-\alpha} \quad 0 < \alpha < 1 \quad (2.1)$$

The notation is of a standard form so that Y is output, K is capital, L labour, and A the level of technology. L and A are assumed to grow exogenously at rates n and g :

$$\begin{aligned} L(t) &= L(0)e^{nt} \\ A(t) &= A(0)e^{gt} \end{aligned} \quad (2.2)$$

The number of effective units of labour, $A(t)L(t)$, grows at the rate $n + g$.

The model assumes a constant fraction of output, s , is invested. Defining k as the stock of capital per effective unit of labour, $k = K/AL$, and y as the level of output per effective unit of labour, $y = Y/AL$, the accumulation of k is determined by

$$\dot{k}(t) = sy(t) - (n + g + \delta)k(t)$$

$$= sk(t)^\alpha - (n + g + \delta)k(t), \quad (2.3)$$

where δ is the rate of depreciation. Equation (2.3) implies that k converges to a steady-state value k^* defined by $sk^{*\alpha} = (n+g+\delta)k^*$, or

$$k^* = \left[\frac{s}{(n + g + \delta)} \right]^{1/(1-\alpha)} \quad (2.4)$$

The steady-state capital-labour ratio is related positively to the rate of saving and negatively to the rate of population growth.

$$\ln \frac{Y(t)}{L(t)} = \ln A(0) + gt + \frac{\alpha}{1-\alpha} \ln(s) - \frac{\alpha}{1-\alpha} \ln(n + g + \delta) \quad (2.5)$$

2.3 The Solow Model in Applied Research

The general theoretical framework of the Solow growth model offers fruitful insights into the dynamic process of growth. Although theoretical advancements modelling the complexity of the growth process have been proposed, their origins can be considered extensions of the general Solow framework ¹. The plethora of applied research empirically testing the neoclassical growth model can be viewed as a direct consequence of the flexibility of the Solow model. This longevity has generated a number of econometric advancements concerning the Solow model in applied research. The flexibility and longevity of the Solow model in applied research can be viewed directly from the number of empirical papers generated. This situation is particularly true within the field of growth econometrics. By outlining the early empirical methods and results of cross-country growth regressions, this section will explore the transition from cross-sectional to panel data

¹See, for example, the 'new growth theory' of Romer (1986, 1990) in which technological progress is considered endogenous to the model

designs.

The seminal contribution of Mankiw, Romer and Weil (1992) can be considered one of the earliest empirical papers to empirically test the predictions of the textbook Solow model. Using a cross-section of 98 countries, the key variables of national output, investment and population growth were averaged over the period 1960-1985 in order to model the growth relationship. To estimate the relationship between economic growth and its determinants, the cross-sectional growth regression specification can be stated:

$$y_i = \alpha + \beta_1 x_i + \beta_2 z_i + \beta_3 g_i + u_i \quad (2.6)$$

where y_i is the average growth rate of real GDP per capita calculated over the entire time period; x_i is the corresponding national level of real GDP per capita in the initial year. The average growth rate of investment and population growth over the entire time period are denoted by z_i and g_i , respectively.

A central feature of the textbook paradigm is the embedded assumption that factors are paid their marginal products. In this setting, robustness checks could be implemented to test the models predictions regarding the signs and also the magnitudes of the coefficients on investment and population growth. The estimated results of Mankiw et al. (1992) provided a reasonable fit, with the coefficients being similar in magnitude but opposite in sign, as predicted by the Solow model. Indeed, the two model parameters of investment and population growth alone were reported to explain over 50% of the cross-country variation in current income. Capital's share of income, however, was noted to be substantially higher than that assumed *a priori*. A common assumption made within the empirical literature on the elasticity of output with respect to capital, α , is that of a constant value across countries of roughly one-third, half the estimated value obtained by Mankiw et al. (1992). This anomaly led Mankiw, Romer and Weil to question the robustness of the textbook Solow model. More specifically,

it was felt that the higher capital elasticity was, in part, driven by an omitted variable bias. Instead, it was postulated that human capital should be included as an additional explanatory variable in order to correct for such a bias. This augmentation of the Solow model was based on the need for a broader notion of capital within the production function. The inclusion of human capital within the Solow model provided an improved fit and also led to more credible estimates of α .

The early econometric approaches addressing the cross-country variation in growth were almost exclusively restricted to cross-sectional study designs. A natural starting point for a critique of the cross-section regression framework in empirical growth research is the work of Robert Barro. In an early empirical paper, Barro (1991) outlined what he considered to be the key determinants of economic growth. Using a cross-section of 98 countries over the period 1960-1985, Barro included a number of alternative growth determinants to help explain the cross-country variation in growth. The growth determinants considered extended beyond those outlined theoretically to include measures of human capital, demographic variables, as well as indicators on a country's political stability. By drawing upon the weak predictive capacity of the growth theories in empirical research, the additional explanatory variables were included for two fundamental reasons. Whilst this theoretical limitation provided a prosperous environment for theoretical advancements, Barro sought an empirical resolution to the theoretical shortcomings. The inclusion of the additional key determinants of growth aimed to improve the predictive capabilities of the model by correcting the potential bias induced by omitted variables. Furthermore, by conditioning on a country's initial conditions beyond those dictated by theory, a key research objective was to provide a more robust estimate of the convergence process. Prior to the inclusion of the conditioning variables, the empirical results of convergence in initial GDP per capita ran counter-intuitively to the theoretical predictions. That is, rather

than a process of catch-up, the empirical results reported greater divergence in which the initially richer economies achieved faster relative growth.

The seminal contribution of Barro's insights into the cross-country variation in growth is typified by the plethora of empirical papers that have been subsequently generated. Modern empirical advancements in growth analysis can trace their origins to the early work of Barro. It is, perhaps, this rationale that has seen the dominant econometric technique of growth analysis been colloquially termed as 'Barro-regressions'. Durlauf, Johnson and Temple (2005) regard this regression based approach as the 'workhorse' of applied growth research.

2.4 Determinants of Economic Growth

The number of determinants identified within the empirical literature in which to explain the variation in growth rates across countries raises important methodological concerns. It is clear that not all the determinants considered will be robust. Nonetheless, their inclusion has been justified on the grounds of model uncertainty. It is beyond the scope of this thesis to present an exhaustive account of the determinants considered within growth regressions. The aim of this section is to present a review of the salient growth determinants and offer a critique into the mechanisms between growth and the inputs into the process.

Human Capital:

The augmentation of the neoclassical growth model by Mankiw, Romer and Weil (1992) can be considered to be motivated by the primacy of human capital in microeconomic studies of wage equations. Defining human capital broadly in terms of individual capabilities, education and training offer a means in which individuals can increase their stock of human capital. At a microeconomic theoretical level, individuals with a higher stock of human capital are assumed to

have a greater rate of return on their investment (Becker, 1964; Mincer, 1974). This rationale explicitly acknowledges the productive features derived from the investment in human capabilities in terms of increased wage rates. For example, higher educated individuals are rewarded with higher salaries due to the presupposition of a greater marginal productivity. An individual's decision to invest in human capital, therefore, is based on an assessment of both the costs and future benefits. At the aggregate level, the mechanisms through which education is observed to lead to higher income levels is directly aligned to the microeconomic studies focusing upon individual wages.

The textbook Solow model considers physical capital and labour to be the two key inputs into the production function. By augmenting the theoretical model, Mankiw, Romer and Weil (1992) further identified education as an additional input into national productivity. The role of human capital within the growth process is assumed to be analogous to any other capital good. Nonetheless, Becker (1993) notes a fundamental difference between physical and human capital. The non-transferability of human capabilities renders human capital as a purely private investment. By focusing on the social rates of return from human capital investments, the economic growth literature represents a departure from an individual assessment of the returns to education. Although decisions concerning human capital investment may be made at the individual level, a number of externalities exist that may contribute to a country's level of national productivity. Measures of education are highly correlated with a number of other determinants of economic growth. Investments in education may exhibit positive externalities between factors such as population growth through fertility decisions, health and measures of social cohesion. Endogenous growth theory also stresses the importance of human capital investments through an assessment of the diffusion of technological progress. Within this paradigm, a population with a higher stock of human capital is not only considered more productive but also more efficient

in generating, implementing and adopting new technologies to stimulate growth activity (Benhabib and Spiegel, 1994). In contrast to neoclassical growth theory, the research and development approach of human capital investment associated with endogenous growth theory offers a more robust explanation for the persistently high rates of growth experienced by some economies. For example, the success of the Southeast Asian Tiger economies is difficult to reconcile with the neoclassical growth paradigm in which diminishing returns are assumed for the factor inputs of economic growth.

A number of alternative measures of human capital have been proposed within the growth literature. Education remains the most widely accepted proxy for human capital used within growth regressions. A central empirical question, therefore, relates to the level of education needed to stimulate growth activity. The low levels of educational attainment, literacy and expenditure on education in many LDCs have been cited as a means to justify primary schooling as the appropriate level to explain cross-country growth disparities (Krueger and Lindahl, 2001). Proponents of the use of primary education within growth regressions argue that the investment equips the labour force with rudimentary but essential skills in promoting economic growth. The role of primary education should not be disparaged with Sala-i Martin (1997) noting primary schooling to be the best performing measure of human capital within his sensitivity analysis of growth determinants. In contrast, some have argued that secondary schooling not only promotes growth but also reinforces the process in the long-run (Romer, 1990; Barro, 1991; Bils and Klenow, 2000). Within this setting, investment in secondary education stimulates growth but also offers a greater capacity for innovation and the assimilation of new technologies. Pritchett (2001) acknowledges an additional clause in which economies require the institutional capabilities in order to absorb the benefits of human capital through the diffusion of technology.

Papageorgiou (2003) undertakes an assessment of the differential roles of both

primary and secondary education within the growth process. Primary education was measured as a country's mean number of completed years of primary education. Secondary education was defined as post-primary schooling and measured as the sum of the mean number of completed years of secondary and tertiary education. The empirical results support the differential roles associated with primary and post-primary education within the growth process. Papageorgiou (2003) concludes that the value attached to primary schooling is mainly through the production of goods. The results for post-primary education support the viewpoint of secondary education as a technological efficiency input through a research and development framework. For example, Papageorgiou (2003) notes that post-primary schooling enters the production function through a greater innovation and adoption of technology.

The notion of secondary education as a technological efficiency input into the growth process has resulted in a greater emphasis and adoption of the measure within growth regressions. Barro (2002) estimated that the average years of secondary and higher levels of school attainment for males aged 25 years had a positive effect on the growth rate of per capita income. The economic significance of the relationship was also sizable with an additional year of schooling resulting in a 0.44 percent increase in the annual growth rate. A primary reason for the proliferation of empirical papers estimating the returns to human capital on aggregate productivity can be attributable to the endeavours of Robert Barro and Jong-Wha Lee. By compiling cross-country estimates on educational attainment and years of completed schooling over time, Barro and Lee (1993, 2001) greatly enhanced the quality and quantity of human capital estimates. In addition, the publicly available dataset further reinforced the reproducibility of regression results within the field of economic growth. An innovative contribution of the dataset relates to the flexible approach adopted by accounting for both cross-sectional and panel data designs within the cross-country estimates.

The proxy measures of human capital discussed have focused upon the educational output derived from increased investment. For example, years of completed schooling, educational attainment and adult literacy rates all associate human capital as a purely consequential commodity. That is, the productive features of human capital have been confined to output measures of education. An alternative viewpoint of the role of human capital within the growth process is to acknowledge input measures of education. Expenditure on primary and secondary education represents the two most widely used measures of educational input within growth regressions. Nonetheless, the difference between measures of human capital used in growth regressions has little effect in diluting the strong positive association between education and economic growth². An empirical question is whether output measures of education capture both the quantity and quality of the national stock of human capital. Jones and Schneider (2006) conduct a sensitivity analysis of competing measures of human capital used in growth regressions. A primary motivation for the research was to assess whether standard measures of human capital, such as years of schooling, were appropriate in capturing the quality of human capital. By utilising secondary data sources on national intelligence quotient (IQ) scores, Jones and Schneider (2006) empirically tested the robustness of cognitive measures of human capital relative to standard proxies. In contrast to the earlier sensitivity analysis results of Sala-i-Martin (1997), primary education was no longer identified as the most robust measure of human capital. Instead, Jones and Schneider (2006) estimate IQ to be statistically significant in 1327 of the 1330 growth regressions using the full sample of countries. IQ was observed to be the most robust measure of human capital estimated, outperforming standard measures such as years of schooling, enrolment and expenditure.

The results of Jones and Schneider (2006) show that IQ outperforms other

²See Temple (2001) for a review of the literature on education and economic growth

measures of human capital used in growth regressions. A primary limitation of the sensitivity analysis relates to the applicability of measures of human capital for panel data designs. At present, there is a paucity of cross-country IQ data scores over sufficiently long time periods in which to analyse the variation within countries needed for panel data studies. In this setting, cognitive measures of human capital are largely confined to cross-sectional study designs. The IQ data sources used by Jones and Schneider (2006) were restricted to one or two time points in which to construct national estimates. Although panel data designs for growth analysis utilise standard measures of human capital, the empirical results are not as uniform as reported in cross-sectional studies. It is not uncommon for the panel data growth regression results to exhibit a negative coefficient on measures of education. Taken at face value, the results would imply that increases in education have a negative effect on economic growth. This result is neither theoretically nor empirically appealing. In their analysis of the economic costs of the AIDS epidemic, McDonald and Roberts (2006) conclude that the negative coefficient on years of schooling may be attributed to the quality-quantity paradox over human capital investment. Islam (1995) considers the inconsistent finding of education within panel data growth regression to be a manifestation of the underlying estimation process.

Health Human Capital:

It is only in recent years that health has been identified as determinant of economic growth. Early empirical papers accounted for the role of health through a broader concept of human capital. The seminal paper by Mankiw, Romer and Weil (1992) considered health and nutrition as essential components of human capital. This viewpoint was also supported theoretically with Becker (1993) defining human capital as encompassing education, health and nutrition. It is clear that health can be considered an essential feature of the concept of human

capital. This rationale reflects the notion that improved health is associated with greater productivity, a reduction in sickness absence as well as gains in longevity. Despite the complementary productive properties between human capital and health, it is also important to acknowledge the differing roles between each input into the growth process. The absence of an established theoretical paradigm on the determinants of health at the aggregate level has resulted in a reliance on microeconomic theory within applied growth research. For example, McDonald and Roberts (2006) offer a synthesis between the neoclassical growth paradigm and the household production function of health capital originally presented by Grossman (1972). An intuitive appeal of this approach relates to the ability to estimate the effect of health within an established growth framework.

Knowles and Owen (1995), Barro (1996b), Strauss and Thomas (1998) and Bhargava et al. (2001) offered the early contributions to the literature estimating the relationship between health and economic prosperity. The acknowledgement of health as a determinant, as a separate entity from human capital, was further endorsed by Doppelhofer et al. (2004). Life expectancy was estimated to be one of the key determinants of economic growth following the sensitivity analysis identifying the robust determinants of growth. The mechanisms through which health contributes to increased national wealth offers similarities to the relationship between growth and education. A primary motivation for health's role in the growth process relates to the direct impact on labour productivity. Indeed, the mechanism can be considered as increasing both the quantity and quality of labour within an economy. An increase in labour supply is derived from the reduction in incapacity, sickness absence and premature death following health improvements. Furthermore, the stock of labour is also enhanced with healthier workers considered more productive leading to a greater marginal product of labour. Positive externalities also exist from health improvements regarding school achievement. In this setting, the benefits are not immediately realised but

are invested in the future stock of labour.

A number of measures of health have been defined to capture the link between national prosperity and population health. Weil (2007) defines the measures as amounting to an assessment to capture the effects of health inputs and outcomes of health. It is beyond the scope of this section to provide an exhaustive account of the measures of population health used in growth regressions. Instead, a description of the salient proxies for health will be briefly outlined. Although life expectancy, infant mortality and nutrition represent the dominant measures used in growth regressions to capture the role of health, a range of alternative measures have also been proposed within the literature. The positive correlation between nutrition and height has been used to estimate the negative effects of malnutrition. Schultz (2002) considers height to be a latent measure of lifetime health status precisely due to the consequences of malnutrition in reducing the average height of the population.

Bhargava et al. (2001) adopt a panel data design in order to model the effects of health on economic growth. By focusing on the adult survival rate as a measure of population health, the estimated results reinforce the positive role of health in the growth process. This situation was particularly evident among the poorest economies with a 1% increase in the adult survival rate corresponding to a 0.05% increase in the growth rate. Acemoglu et al. (2003) introduces settler mortality as a means of capturing health within an institutional paradigm by emphasising the underlying growth process to be partly determined by a country's own institutional framework beyond that defined by modern economic growth.

A number of disease-specific effects have been included in growth regressions in order to capture the consequences associated with poor population health. Sachs (2003) includes measures for malaria ecology and the percentage of the population at risk of malaria transmission in order to highlight the geographic obstacles faced by many of the world's poorest economies. Dixon et al. (2001b,

2002) discusses the relationship between economic growth and the HIV/AIDS epidemic as well as subsequent papers estimating the impact of the epidemic within a panel data design (Dixon et al., 2001a; McDonald and Roberts, 2006).

Policy and Institutions:

The institutional environment in the pursuit of economic prosperity can be considered a fundamental determinant of economic growth. Globally, the consequences of poor governance, mismanagement and corruption have all been considered contributory factors to the limited growth experiences of many fragile economies. The current situation in Zimbabwe captures the essence of this argument with devastating effect. Despite previously representing one of the richest economies in Africa, Zimbabwe is now synonymous with hyperinflation, segregation and the general collapse of its social, economic and public health infrastructures. Indeed, Zimbabwe's real GDP per capita has been estimated to have declined by over 25% over the 10 year period from 1993-2003 (PWT6.2). Life expectancy has also been halved over a ten year period largely attributable to negative political involvement. It is perhaps not surprising therefore, that Zimbabwe has been used as a caveat to emphasize the negative impact on economic prosperity accruing from poor governance, ineffective legal frameworks and weak infrastructure.

Although poor governance acts as a constraint on economic prosperity, a central empirical question is whether the opposite relationship holds. That is, whether good institutions reinforce and promote economic growth. Acemoglu et al. (2001) has persuasively argued the importance of institutional arrangements on economic growth. By including composite measures of institutional quality within a cross-country growth equation, Acemoglu et al. (2001) reports a significant partial effect of institutions on economic growth.

A central feature of the institutional paradigm of economic growth of Ace-

moglu et al. (2001) relates to the premise that the establishment of institutions occurs slowly over the long-run time period. More pertinently, much of the current disparities in growth rates across countries are considered to be simply manifestations of institutional arrangements prior to the 20th century. In this setting, the current growth trajectories of many former colonial nations are partially determined by the implemented institutions of the sovereign country. To empirically test this hypothesis, Acemoglu, Johnson and Robinson (2003) draw upon the variation in settler mortality to assess the fortunes of former colonial nations.

Natural Resource Base:

The institutional paradigm of economic growth has some resonance with the paradox concerning prosperity and a country's natural resource endowment. Rather than presenting unique growth opportunities, a large natural resource base is associated with lower growth output (Sachs, 1997). Although supported empirically, this result appears rather puzzling in the sense that countries are penalised simply for benefiting from the increased access to a scarce limited resource. For Collier (2007), this phenomenon is tantamount to a "resource curse". Within the growth and development economics literature, countries affected by this negative relationship are said to be experiencing the 'Dutch Disease'. This term is derived from historical accounts noting the negative effects of North Sea gas on the Dutch economy. The significant negative relationship between a country's initial natural resource base and national output within growth regressions may uncover an important facet of the growth process.

A natural starting point in empirical estimates of the 'Dutch Disease' concerns the structure of incentives for the diversification of an economy. More pertinently, whether adequate incentives exist for future investment in the manufacturing sector and labour force in the presence of an abundant natural resource base. The restriction on the division of labour may be further compounded at the micro

level. Indeed, if individuals perceive the lack of diversification of the economy and limited employment opportunities outside the extraction of natural resources then incentives for human capital may also be reduced. This characterisation of a cyclical process of sectoral dominance and unskilled labour has been proposed as a possible explanation for the Dutch Disease. The consequences of this approach will ultimately result in a surplus of natural resource exports.

Sachs (1999) includes the initial share of natural resource exports in Gross National Product as a determinant of economic growth for a sample of 79 countries from 1965-1990. The estimated coefficient confirms the negative association between natural resource endowments and economic growth. Even after controlling for a country's institutional quality and geographic environment, natural resource exports are associated with a non-trivial reduction in growth of 0.39 per cent per annum. Although resource rich countries may concentrate activities on natural resource exports, there are a number of other potential confounders linked to the 'Dutch Disease' process. Political manifestations, in particular, may intensify the negative association. Collier (2007) has noted the tendency for 'rent seeking' behaviour of less scrupulous governments when presented with a large natural resource base. In this setting, the surplus from natural resource exports can be viewed as offering a fertile environment in which to maintain political positions.

This proclivity for political corruption within resource-rich economies may be further compounded if such activities lead to a desire for forceful political change. This characterisation of coups and military interventions in the pursuit of natural resource control is a common feature of many of the world's poorest resource-rich economies. Bannon and Collier (2003) argue that an increase in natural resource endowments within low income countries also increases the risk of civil war, particularly for oil exporting economies. It should be noted that oil producing economies are often excluded from cross-country growth regressions due to their national output being largely determined by the stochastic nature of

oil prices. Nonetheless, the negative impact of natural resource endowments on national output may provide additional barriers to economic growth.

Geography and Climate:

A country's physical environment has also been considered a proximate determinant of national economic activity. Although this viewpoint is not necessarily incompatible with the institutional environment paradigm, it is often perceived as a competing hypothesis (Durlauf, Johnson and Temple, 2005). The deviation in focus from social and economic structures towards fixed physical characteristics has recently been warmly received in the policy arena due to several seminal contributions. Most notably, Jeffrey Sachs (1997, 1999, 2003); Faye et al. (2004) has played a pivotal role in the policy debate by considering a number of geographic variables within a cross-country growth regression framework. A central premise for the focus on a country's physical environment relates to the geographical advantage associated with more prosperous economies. Similarly, the physical geography of many of the world's poorest economies represents a natural disadvantage in the pursuit of economic growth. For Sachs and other proponents of the physical environment hypothesis, such countries are in a geographic poverty trap.

Bloom et al. (1998); Sachs (1997, 2003) represent a small number of the empirical papers that have included dummy variables within the cross-country growth regressions to capture the differential growth experiences between tropical, landlocked and coastal economies. The growth experiences of landlocked economies are statistically lower than coastal economies. That is, landlocked countries are observed to have a reduction in their annual rate of growth even after controlling for other geographic features and sources for slow growth. Landlocked countries face additional obstacles in the terms of trade than those experienced by coastal economies. Transportation costs due to border tariffs and custom duties will in-

evitably be greater for landlocked countries. The consequences of this increased burden will, ultimately, raise the cost of imports and reduce the competitiveness of exports for many of the world's landlocked economies.

Gallup et al. (1999) implement a number of geographic, demographic and institutional quality variables to assess the relationship between geography and economic growth. The inclusion of institutional control variables offers additional insights into the dynamic relationship between geography, policies and economic prosperity. In particular, the cross-country regression results support the premise of spatial disadvantages but also that geographic factors contribute to national economic policy choices. Gallup et al. (1999) draw upon the previous empirical insights between trade activity and national output in order to draw inferences for the geographical effects on economic policies.

Social Cohesion, Conflict and Religion:

There has been a resurgent interest in the empirical relationship between social and economic cohesion on sustained economic growth. The early contribution by Max Weber (1930) attributed the observed productivity differentials to religious attitudes on the accumulation of wealth. That is, the practice of faith was more prosperous for some religions than others. Indeed, Weber noted the greater productivity gains for Protestant faith practitioners as opposed to Catholics. More recently, researchers have attempted to test the predictions of Weber's hypothesis of the disparities in growth from religious practice. A number of measures to capture State religion have been included in growth regressions to estimate the impact of religious practice on national output. By including variables for a country's religious affiliation, the empirical evidence has generated interesting but diverse results regarding religions impact on economic growth.

Barro (1996a) included a measure of State religion by estimating the fraction of the population affiliated to religious groups over the period 1960-1990 for

a panel of nearly 100 countries. Using this measure, growth output was positive and significantly higher for Buddhist, Confucian, Protestant and Muslim economies. Likewise, Masters and Sachs (2001) include the percentage of the population that is Muslim, Catholic or Protestant as a proxy for social history. The regression results confirm the positive effects of religion on national output. In particular, the growth rates of Christian countries were estimated to be significantly higher than more secular economies. For Masters and Sachs (2001), this conclusion supported the premise of positive influences on growth from Northern and Southern Europe as represented by the Protestant and Catholic measures.

The sensitivity analysis of Sala-i-Martin (1997) has posited an alternative viewpoint regarding the uniform association between religion and economic growth. Using the same measure of religious affiliation as Barro (1996a), both Protestant and Catholic countries were noted to have a significantly lower level of growth in over 95 per cent of regressions. In contrast, Muslim religious affiliation was estimated to have a significant and positive effect on economic growth over the same criteria in the regression specifications.

Barro and McCleary (2003) draw upon a number of survey data sources in order to construct two additional measures of a country's religious affiliation. The various data sources were used to measure country level averages of both church attendance and religious belief. A primary research focus upon the two new measures reflected the recent theoretical emphasis of religion within the development economics literature. More specifically, the theoretical developments considered religious belief to be inversely related to a county's level of economic development. In order to test this secularisation hypothesis, Barro and McCleary reflected on the limitation of previous measures of religious affiliation used in empirical analyses. Instead, focus was placed on the mechanisms in which the new proposed measures could influence economic growth. Church attendance was considered to be a religious input with religious belief representing the analogous output.

The characterisation of the two measures as the means of religious production allowed Barro and McCleary (2003) to hypothesise on the direction of each influence individually. After controlling for religious belief, greater church attendance was considered to have a negative effect on economic prosperity. This rationale reflected the greater resource costs of consumption from religious inputs as opposed to outputs. The estimated regression results support this initial hypothesis with both measures reporting significant but opposing effects on economic growth. Barro and McCleary (2003) astutely consider the contrasting measures as evidence of the growth process depending more on belief than belonging.

The main focus on religion as a determinant of economic growth reflects its role in influencing individual traits, such as "thrift, work ethic, honesty and openness to strangers" (Barro and McCleary, 2003; pg. 23). A broader interpretation of religion's role as a growth determinant, therefore, concerns its effect in shaping a shared identity. That is, members affiliated to a particular religion can be considered as sharing certain core values. A number of alternative measures to capture influences on individual traits have been included within cross-country growth regressions. The most prominent advocated within the growth literature is language. Like religion, it is clear that language creates a shared identity. The variation in identity within and between countries has been a central empirical motivation of cross-country growth regressions including measures of language. More pertinently, empirical studies have attempted to address whether more homogenous identities are beneficial for economic growth. Easterly and Levine (1997) propose a measure of ethnic diversity to establish the relationship between ethnically homogenous country populations and economic growth. To test the hypothesis that diverse economies also have slower growth output, ethnolinguistic fractionalisation was used as a measure of a country's ethnic diversity. Using a cross-section of African countries, growth rates were estimated to be statistically lower for more ethnically heterogeneous economies. Indeed, ethnic

diversity was estimated to lead to a reduction in growth of over 2 per cent per annum. It is perhaps not surprising therefore, that ethno-linguistic fractionalisation has been considered an important determinant in a number of subsequent cross-sectional growth regressions (see for example, Hall and Jones 1999 and Brock and Durlauf 2001). For more recent alternative proposed measures of ethnic-linguistic fractionalisation see Alesina et al. (2003), Fearon (2003) and Posner (2004).

The results of Barro (1996), Sala-i-Martin (1997), Masters and Sachs (2001) and Barro and McCleary (2003) all provide insightful estimates of the partial correlation between measures of religion and economic growth. Nonetheless, a number of econometric issues are left unanswered due to difficulties in estimating causal relationships. Indeed, the presence of reverse causality is problematic for many analyses of cultural features on economic growth.

2.5 Dyanmic Panel Data Designs of Economic Growth

Islam (1995), Caselli et al. (1996), Nerlove (1999) and Lee et al. (1997) have all estimated panel data variants of the growth regression noted in equation 2.6. In contrast to cross-sectional studies which average over the entire period, economic growth, y , is often specified as the average growth rate over a much shorter time frame within panel data studies. The existing panel data growth literature has commonly constructed y as the average growth rate over 5 year periods. In addition, the independent variables also represent averages or initial levels over 5 year periods within panel data designs. Although alternative time frames have been implemented, $t=5$ has been considered the most appropriate time frame in which to assess the dynamics of growth. This rationale reflects the premise that a period of 5 years removes economic fluctuations without any loss of information in which to capture the within-country variation of the key growth variables. Panel

data variants of equation 2.6 can be defined as:

$$y_{it} = \alpha + \beta_1 x_{i,t-1} + \beta_2 z_{it} + \beta_3 g_{it} + \eta_i + v_{it} \quad (2.7)$$

where y_{it} is calculated as the logarithmic difference in GDP per capita over 5 year periods. Equation 2.7 can be considered a dynamic panel data model due to the presence of the level GDP per capita, $x_{i,t-1}$, as an explanatory variable within the regression specification.

2.5.1 Extensions of the Solow Growth Model

The regression equation estimated by Mankiw et al. (1992) to test the predictions of the Solow model has generated an increasing number of cross-section empirical studies. More recently, alternative modelling specifications have been proposed in the form of panel data designs in order to explain the persistence of cross-country income differentials. Islam (1995) draws upon a potential weakness in the cross-section regression equation, in order to polarise the differing modelling strategies. In addition to the parameters of investment and population growth, the equation also includes the term $[\ln A(0) + gt]$. The additive suffix, gt , is simply a constant term. This is derived from the assumption that the exogenous rate of technological progress, g , is uniform across all countries and the time variable, t , can be considered to be a fixed number within a cross-section analysis. Instead, an element of ambiguity emerges not simply upon the role of $A(0)$ but also around its internal dynamics. For Mankiw et al. (1992), $A(0)$ extends beyond the confines of technological endowments to capture country-specific factors, such as climate and institutions. In this setting, the relationship can be stated as:

$$\ln A(0) = a + e \quad (2.8)$$

where a corresponds to the constant term, gt , and e represents a country-

specific shock term. Substituting this equation into the cross-section regression equation above gives the specification:

$$\ln \frac{Y(t)}{L(t)} = a + \frac{\alpha}{1-\alpha} \ln(s) - \frac{\alpha}{1-\alpha} \ln(n+g+\delta) + \epsilon \quad (2.9)$$

Mankiw et al. (1992) explicitly assumed that the country-specific shock term was independent of investment and population growth. This assumption was an econometric necessity under which Mankiw et al. (1992) could proceed with OLS estimation. However, this assumption can also be considered too restrictive and difficult to justify. Indeed, it is likely that ϵ is correlated with investment and population growth. Islam (1995) draws upon this argument to state the need to account for this correlation within the modelling specification. By questioning the assumption of independence, Islam (1995) postulates the use of instrumental variables as a possible alternative estimation approach. More pertinently, it was argued that in light of the difficulty in obtaining suitable instruments for $A(0)$, a panel data approach provides a more robust alternative to OLS and 2SLS estimates.

Cross-sectional study designs need to explicitly account for the growth differentials that are derived from a country's physical environment. A number of innovative measures have been included in empirical estimates of equation 2.6 in order to capture the consequences associated with a number of geographical features. This is evident from the various proxy measures included in cross-sectional growth regressions, such as indicators for coastal, equatorial and resource-rich economies. Panel data studies represent a departure from this empirical design. Instead, panel data estimates of equation 2.7 do not explicitly include such variables within the regression specification. The decomposition of the cross-sectional regression error term, e_{it} , into η_i and v_{it} within equation 2.7 is a central feature of this differing design. A country's physical characteristics, in particular, can

be considered time-invariant. That is, over the period of analysis such factors are assumed to be fixed. Panel data methods that can suitably eliminate country fixed effects may offer more robust estimates of cross-country growth differentials.

An additional motivation for the deviation away from cross-sectional growth regressions relates to the role of unobservable country-specific heterogeneity. In this setting, panel data studies seek to purge the individual effects contained in the parameter $A(0)$. OLS estimates of equation 2.6 may suffer from an endogeneity bias due to the implicit assumption of a constant initial level of efficiency across countries. The rationale for the assumption of a constant level of $A(0)$ is directly related to the restriction imposed by data limitations on observed national levels of efficiency. Nonetheless, it is not unfeasible to assume a differing rate of technological progress across countries. This situation is particularly evident in the presence of positive externalities from technological diffusion. For example, the violation of pharmaceutical patents on HIV treatments has resulted in the manufacturing of generic drugs in some low income countries. This process of the imitation of technological advancements between high and low income countries may contribute to the convergence in income levels over time. By treating $A(0)$ as a nuisance parameter, panel data models aim to offer more robust estimates of the dynamic growth relationship than cross-sectional studies. In particular, initial efficiency can be considered to be removed from the cross-sectional error term and explicitly modelled within u_{it} within equation 2.7.

The within-groups estimator can be considered a natural starting point for panel data estimates of equation 2.7. Islam (1995) and Caselli, Esquivel and Lefort (1996) have adopted this empirical design as a means for correcting the endogeneity bias inherent in cross-sectional growth regressions. A salient modification applied to the within-groups estimator relates to parameter homogeneity. By accounting for unobserved country-specific effects, the within-groups estimator allows for the possibility of unique intercepts for each country. Although

classified as a constant in the cross-sectional growth specification, β_0 is comprised of two factors within the panel data model. That is,

$$\beta_0 = u_j + k_j \tag{2.10}$$

Where u_j and k_j represent country-specific and time-specific effects, respectively.

Inherent empirical problems associated with the analyses of economic growth are the constraints imposed by a finite number of countries as well as data limitations. More recently, improvements in data quality have resulted in a greater cross-section of countries used in growth regressions. Although data are available for periods in excess of 40 years, large cross-country panel data studies based on 5 year averages are largely limited to a 9 wave design. In this setting, panel data designs of economic growth can be considered to be of the form large N, small T. That is, a large number of countries over relatively short time-periods. At a methodological level, the econometric design also needs to take account of the dynamic nature of equation 2.7. This dynamic specification arises from the inclusion of initial income as an explanatory variable for the change in income across countries.

Nickell (1981) has previously questioned the validity of the within-groups estimator for short dynamic panel data models. As a consequence, many panel data studies of economic growth have relied upon alternative estimation techniques. The first-difference GMM estimator has been considered a more robust alternative to the within-groups estimator for short dynamic panel data growth designs. Caselli, Esquivel and Lefort (1996) use the first-difference GMM estimator for a panel of countries over the period 1960-1985 in order to test the predictions of the convergence hypothesis. In particular, they advocate the first-difference GMM estimator as a means of correcting for the large N, small T bias noted for the within-groups estimator. The advantage in terms of specification is that it also

retains the desirable econometric properties associated with the within-groups estimator. In this setting, the first-difference GMM estimator can be considered as an alternative means for dealing with endogeneous regressors and country-specific fixed effects.

The origins of the first-difference GMM (FD-GMM) estimator can be traced to Holtz-Eakin et al. (1988), as well as the subsequent specification tests proposed by Arellano and Bond (1991). As the name suggests, the FD-GMM approach proceeds with a first difference transformation of equation 2.7 in order to purge the country-specific effects. To address the endogeneity issues inherent in growth regressions as well as the dynamic specification of panel designs, the instrument set for the first differenced regressors is derived from the regressors in levels lagged two periods or more. A fundamental assumption underpinning the GMM approach of growth regressions, therefore, relates to the presence of serial correlation. For example, the first-differenced transformation of equation 2.7 can be considered to be of the form:

$$(y_{it} - y_{i,t-1}) = b_0(y_{i,t-1} - y_{i,t-2}) + c_0(x_{it} - x_{i,t-1}) + (v_{it} - v_{i,t-1}) \quad (2.11)$$

It is clear that the differenced lagged dependent variable of initial income, y_{it} , in equation 2.11 will be correlated with the first-differenced error term. In terms of the 'textbook' Solow model, therefore, OLS estimates will yield inconsistent results relating to the predictions of convergence. By imposing the assumption that the idiosyncratic error term is not serially correlated, Arellano and Bond (1991) illustrate the conditions under which valid instruments for Δy_{it} can be derived. More formally, providing

$$E(v_{it}v_{is}) = 0 \text{ for } s \neq t \quad (2.12)$$

and

$$E(y_{i1}v_{it}) = 0 \text{ for } t \geq 2 \quad (2.13)$$

are satisfied then y_{it} lagged two periods or more can be used as instruments in equation 2.11. The rationale for this assumption relates to the premise that although $y_{i,t-2}$ and earlier can be considered correlated with the change in $y_{i,t-1}$, they remain independent of the change in v_{it} (Bond, Hoeffler and Temple, 2001). In this setting, following a 5-year average dynamic panel data design, GDP_{2000} is assumed to be correlated only with the error term for 1995 and earlier. Although the first-differenced GMM estimator may suitably address a number of econometric challenges, there still remain a number of design features that may limit its application for panel data growth regressions. In particular, the FD-GMM estimator has been noted to be biased in short dynamic panel data models (Blundell and Bond, 1998). The persistence of series such as real GDP per capita may further compound the application of the FD-GMM estimator in growth analysis. In particular, the simulation results of Blundell and Bond (1998) illustrate that the FD-GMM estimator can result in weak instrument biases when $y_{i,t-1}$ is close to a random walk. As Roodman (2009) acknowledges, the consequence of weak instruments suggests that $y_{i,t-2}$ may yield little information regarding the $\Delta y_{i,t-1}$. In light of this potential limitation for dynamic panel data growth models, the system GMM estimator of Blundell and Bond (1998) has been proposed as an alternative. The system GMM approach can be considered as augmenting the instrument set by including lagged levels as well as first differences as instruments.

Although the FD-GMM and SYS-GMM estimators are both suited for small N, large T panels, the system GMM estimator has been the preferred method of estimation in recent years (See for example, Bond, 2001; Hoeffler, 2002). As Blundell and Bond (1998) acknowledge, the system GMM explicitly includes an additional assumption:

$$E(\eta_i \Delta y_{i2}) = 0 \text{ for } i = 1, \dots, N \quad (2.14)$$

The central feature of the assumption captured within equation 2.14 is that although the mean of the y_{it} series may differ across countries they remain constant over time for each country.

Roodman (2009) offers a practical guide to estimating the first-difference and system GMM models. In light of the increased number of instruments used within the system GMM approach, Roodman (2009a) also notes the caution needed when adopting the system GMM estimator. Chapter 3 addresses whether the system GMM estimator is suitable for growth analysis in light of the econometric frailties associated with the first-difference GMM estimator. By offering a comparison of competing estimators for growth regressions, Chapter 3 highlights the robustness of the system GMM for growth analysis.

2.6 Econometric Issues

The analysis of long-run economic growth using a cross-section methodological design is severely constrained by data limitations. A fundamental shortcoming reflects the small number of countries available in which to analyse the growth process. It is clear that limitations regarding the fixed number of countries in the world, as well as available data, are not confined to cross-sectional studies. However, such data limitations are inherent in the design of cross-sectional growth analyses. By collapsing dynamics across countries, cross-sectional studies are constrained by a lack of variation in the key growth variables. More recently, researchers have adopted alternative empirical designs in the form of panel data to address such limitations. The time-series component of a panel data design allows greater analysis of the within-country variation in which to augment the number of observations. Dynamic panel data models are often constructed on

an interval of five years, providing greater variation in the key variables across waves. Within this setting, panel data designs offer a resolution to the lack of cross-country variation within growth analysis. The intrinsic advantage of a panel data design is not confined to such considerations. By outlining the strengths and weaknesses of this methodology, this section will address the rationale for adopting a panel data design in the context of growth analysis.

There has been an exponential growth in panel data analyses, which can be directly attributable to the increased availability of data. The increase in the quality, time period and availability of economic data has resulted in a greater interest in panel data studies at both the micro and macro level. The use of panel data was largely confined to microeconomic studies, focusing upon individuals, households and firms as the unit of analysis. More recently, researchers have pooled individual time-series data in which to simultaneously analyse in the form of a panel data design. This situation is particularly evident within the field of economic growth. The opportunity created by combining the individual time-series cross-country data has resulted in a movement away from a cross-sectional to a panel data methodology. This transition can be viewed as a manifestation of factors beyond simply improvements in data availability. Indeed, the use of panel data represents a more fruitful design in which to uncover salient characteristics of the growth process that are beyond the scope of cross-sectional designs.

Although panel data designs are firmly grounded in microeconomic theory, the adoption of such an approach to address questions at the aggregate level are no less suitable or feasible. Hsiao et al. (2005) consider the prediction of macroeconomic outcomes using aggregate data to be less accurate than the predictions based on micro-equations. In this setting, the adoption of a panel data design in the context of economic growth may yield more productive policy conclusions than cross-sectional or time-series approaches. The embedded micro-equation form of a panel data methodology also offers greater capacity for modelling the

complexity of the dynamic process of growth. Despite such advantages and opportunities, Durlauf, Johnson and Temple (2005) make a cautionary observation concerning the perception of panel data designs as a panacea for growth econometrics. In particular, they note the misuse of panel data methods by cavalier researchers unfamiliar with the time-series component of the data structure. This expectation of an instantaneous change within panel data models has led to the careless rejection of important growth determinants derived from cross-sectional growth literature. A more robust empirical design would allow for a more contemporaneous effect through the use of lag and lead variables to assess the dynamic relationship between growth and its determinants. Notwithstanding such misplaced advocacy of panel data estimates of economic growth, there are a number of other general econometric issues that need to be considered.

2.6.1 Omitted Variable Bias

The cross-sectional growth regression approach associated with Barro (1991) and Mankiw, Romer and Weil (1992) can still be considered the dominant empirical method of applied growth research. Despite the more recent econometric advancements in the field, there still remains a wealth of empirical analyses dedicated to cross-sectional growth regressions. An intuitive appeal attached to the OLS estimator used in cross-sectional studies relates to its ease in implementation and interpretation. This appeal, however, may also be a direct consequence of potential misspecification bias and model uncertainty. Although researchers have questioned and become less sanguine about the validity of some growth determinants, the augmenting list may partially reflect attempts by researchers to address a fundamental weakness of the cross-sectional regression framework.

The inclusion of a measure of human capital to the textbook Solow model by Mankiw, Romer and Weil (1992) attempted to reconcile theory with empirics. This modification, resulting in the augmented-Solow model, was not only intu-

itively appealing but also partially addressed a key area of econometric frailty of OLS estimates of economic growth. The frailty of cross-sectional studies, in this setting, relates to the bias induced by omitting an important determinant of economic growth. By accounting for the effects of education on national income, Mankiw Romer and Weil (1992) ensured that human capital was removed from the error term and explicitly included in the regression model. However, the OLS estimator for growth regressions may also suffer from an additional source of omitted variable bias. More formally, the cross-sectional augmented-Solow model presented in equation 2.6 can be stated as:

$$y_i = \alpha + \beta X_i + c_i + e_i \quad (2.15)$$

That is, the cross-country variation in income is specified as a function of growth determinants, X , unobserved factors, c , and an error term denoted e . The additional parameter, c , to the standard specification noted in equation 2.6 poses important empirical concerns due to the difficulty in measuring the factors contained in c . An essential facet of the growth literature is concerned with the convergence hypothesis. The extent to which countries converge in terms of real GDP per capita is determined by the direction and magnitude of the coefficient on initial income. It is clear, however, that the degree in which countries achieve convergence in income levels is also determined by the efficiency in which inputs are transformed into outputs. In this setting, initial efficiency represents an important unobserved factor contained in c . Mankiw, Romer and Weil (1992) acknowledge the limitation imposed by assuming a common initial level of efficiency across countries. Indeed, initial efficiency can be considered one of the constituent parts of $A(0)$ of the cross-sectional growth regression framework. It is clear, therefore, that OLS estimates of economic growth may suffer from an omitted variable bias. As will be discussed in Section 5, more robust alternative econometric methods can be adopted in order to control for unobserved hetero-

geneity by treating initial efficiency as a time-invariant factor.

2.6.2 Model Uncertainty

The concern over misspecification from an omitted variable bias can be considered to be partly attributable to the general issue of model uncertainty in growth regressions. The large number of possible growth determinants considered in cross-sectional studies is a manifestation of this problem. Indeed, this problem can be considered a theoretical shortcoming of the Solow model. Mankiw, Romer and Weil (1992) have illustrated the need to augment the list of growth determinants. Other researchers have adopted a similar approach by specifying growth regressions that are not constrained by theoretical restrictions. This ultimately limits the theoretical interpretation of coefficient but can also provide valuable insights into the relationship between a number of factors that contribute to changes in national income.

Model specification can be considered to be a central feature of regression analysis. The identification of key determinants of economic growth is compounded by model uncertainty. An exhaustive recourse to theory has identified a number of key variables for the inclusion in growth regressions. The implementation of salient growth determinants beyond those dictated by theory is largely at the discretion of the researcher. Consequently, the upshot of this approach has led to a plethora of possible determinants for consideration. As Sala-i Martin et al. (2004) acknowledge, the number of potential determinants in which to explain the variation in growth rates across countries outnumbers the list of countries in which there is available data on economic growth. Among this augmenting list of determinants, it is clear that greater weight should be attached to certain variables for the inclusion in the growth analysis. Recent econometric advancements have created an avenue of increased optimism regarding model specification and parameter estimates.

Levine and Renelt (1992) can be considered one of the earliest attempts to address the model uncertainty inherent in growth regressions. By adopting the extreme-bounds test advocated by Leamer (1983), Levine and Renelt (1992) were concerned with the identification of robust growth determinants. Starting with a vector of growth correlates, the extreme-bounds test methodology aims to assess the robustness of each determinant within the growth regression. That is, by pooling the list of growth determinants commonly used in empirical analyses, Levine and Renelt (1992) were able to demarcate each variable as "robust" or "nonrobust". In order to implement this classification, OLS cross-sectional growth regressions were analysed of the form:

$$\gamma = \alpha_j + \beta_{y_j}y + \beta_{z_j}z + \beta_{x_j}x_j + \epsilon \quad (2.16)$$

Where y represents a vector of variables that are included in every regression combination. For Levine and Renelt (1992), y was specified as the variables of interest within the augmented-Solow model. In this setting y is equal to initial income, the average investment rate, population growth and the rate of school of enrolment. The variable of interest, z , is included in the regression along with three additional variables contained in x from the full vector of potential determinants available. The demarcation of each determinant is obtained by running each possible combination of equation 2.16 using the exhaustive list of growth correlates represented by N . A corresponding parameter estimate, β_{z_j} , and standard deviation, σ_{z_j} , is obtained for each model j . The testing of the extreme-bounds can be defined as:

$$Lower = \beta_{z_j} - 2\sigma_{z_j} \quad Upper = \beta_{z_j} + 2\sigma_{z_j} \quad (2.17)$$

To pass the extreme-bounds test, the upper and lower bounds of variable z must maintain the same directional sign. That is, if the sign of β_z changes in a

single regression then the variable is not considered robust (Sala-i Martin, 1997). This rigid methodological design led Levine and Renelt (1992) to conclude that very few variables passed the test to be considered robust. The significance of this methodological design does not relate to the overall conclusion, but rather the future insights generated to address the model uncertainty in growth analysis. Indeed, Sala-i Martin (1997) adopted a similar dichotomous framework to test the robustness of the key correlates of growth using a more conservative procedural test.

In contrast to Levine and Renelt (1992), Sala-i Martin (1997) observed a number of variables to be significantly correlated to growth. Starting with a pool of 59 variables, 22 were estimated to be robustly significant in over 90 per cent of regressions using the more conservative test. Nearly half of all the 22 robust variables were dummy indicators controlling for country-specific characteristics, such as geographic and religious proxies ³. Nonetheless, the sanguine outlook posited by Sala-i Martin (1997) is embedded in the premise that the method of extreme-bounds estimation represented a test too strong for any variable to pass it. By relaxing the demarcation criteria for robust variables, Sala-i Martin (1997) adopted a hybrid approach between Bayesian Model Averaging and a classical statistical interpretation. That is, the Pseudo-Bayesian implementation provided increased ease and accessibility to a wider audience for both Bayesian and Frequentist researchers.

2.6.3 Endogeneity

The empirical estimation of growth regressions are often constrained by the endogeneity of right hand side variables. Although not confined to growth regressions, the presence of endogenous regressors raises questions regarding the robustness of OLS estimates of economic growth. The assumption that the determinants

³A full list of the estimated robust determinants of economic growth identified by Sala-i Martin (1997) are included in the appendices by rank order.

of economic growth are exogenous can be considered a central implicit feature of cross-sectional study estimates. That is, the regressors are assumed to be uncorrelated with the error term, u_i . The violation of this assumption is not uncommon in many economic applications and can, therefore, be suitably addressed with reasonable ease. Nonetheless, the consequence of endogenous right hand side variables results in biased and inconsistent OLS estimates if not appropriately addressed. More formally, the presence of endogeneity can be decomposed as arising from three sources. In addition to the omitted variable problem discussed in 2.6.1, Wooldridge (2002) notes that endogeneity may also arise from measurement error and simultaneity.

To see the possibility of the presence of measurement error in growth regressions, consider the calculation of y_i in the standard growth regression model reported in equation 2.6. Cross-country estimates of economic growth are derived from national accounts data. A source of measurement error may arise, therefore, if the cross-country estimates of reported national income do not equal actual national income. The residual between reported and actual values does not necessarily lead to biased and inconsistent estimates. It is likely that any discrepancy will be mitigated provided the reported levels are a good indicator of actual income levels. This condition, however, contains an additional clause. Instead, the measurement error would also need to be uncorrelated with the growth determinants contained in X_i in order for any error bias to be fully purged. If there is no association between the measurement error and regressors then OLS estimates of equation 2.6 are valid despite the presence of measurement error.

It is clear that the quality of national accounts data is greater in high income countries. The data constraints in poor economies are largely driven by limited infrastructural and resource arrangements to support routine reporting of aggregate statistics. Furthermore, the greater reliance on informal markets within low income countries may lead to under-reporting of national income levels due to

the difficulty associated with quantifying 'hidden' trade activity. It is unclear whether countries would benefit from under-reporting or inflating income levels. Nonetheless, the standard econometric tool to deal with measurement error is through the use of instrumental variables. As Durlauf, Johnson and Temple (2005) postulate, the methods commonly employed to address measurement error may be limited in the context of cross-sectional growth regressions. This rationale explicitly acknowledges the small sample sizes available to researchers estimating cross-sectional growth regressions. In this setting, panel data estimates that exploit the variation within countries may provide a robust methodological design in which to address the measurement error in growth analysis.

Simultaneity is an additional facet of the endogeneity problem inherent in growth regressions. McDonald and Roberts (2006) estimate the significant negative effect of HIV prevalence on national output for a panel of 112 countries over the period 1960-1998. Over the past 40 years, Botswana has achieved growth rates similar in magnitude of other high growth performing economies of Southeast Asia, such as Singapore, South Korea and Taiwan. This achievement is all the more remarkable given Botswana's geographical obstacles as a landlocked, resource-rich, sub-Saharan African country, factors considered detrimental to sustained growth. More pertinently, the growth achievement has been realised despite Botswana experiencing one of the world's worst AIDS epidemics. At its peak, the country's HIV prevalence rate among the working-age population was estimated to be over 30 per cent. This characterisation of high rates of both growth and HIV prevalence provides a pertinent example of potential simultaneity in the estimated regression results presented in Chapter 4. A central empirical concern, therefore, relates to the presence of reverse causality. That is, have growth rates in Botswana been diluted due to the AIDS epidemic or equally has the growth process actually intensified the epidemic. The presence of simultaneity, therefore, would imply that HIV prevalence rates are partly determined

by growth and consequently correlated with the error term.

2.6.4 Parameter Heterogeneity

The interpretation of growth regression estimates are commonly based on inferences that assume a uniform effect across the growth distribution. At both a theoretical and empirical level, this assumption would require that the marginal effects of policy changes are the same for high and low growth economies. It is clear that this premise is neither a theoretical nor empirical regularity. Instead, the key drivers of economic growth are likely to exhibit differing returns to scale for countries in opposing positions in the pursuit of growth. This situation is polarised for policy prescriptions based on the investment in human capabilities. For example, investments in education are likely to exhibit diminishing returns once a country reaches a threshold level of educational achievement. It has been previously discussed earlier in this chapter on human capital as a determinant that the percentage of citizens completing secondary schooling offers greater rewards for LDCs than if the countries concentrated investment in tertiary education. A population with a basic level of educational achievement is more desirable for national welfare than a few highly educated elite among an illiterate population. Nonetheless, the educational achievement of a country can be considered to be linear function of its stage of economic development. The returns to life expectancy are also likely to exhibit the same relationship so that the marginal benefits for poorer economies far exceed those in more affluent countries. This premise is an essential feature of the Preston Curve which has been adopted by some to argue that income has a negative effect on health after some threshold level is achieved ⁴.

Durlauf, Johnson and Temple (2005) consider parameter heterogeneity to be a dominant feature of future growth research. This advocacy is based on the

⁴The negative effect is considered to be driven not by income levels but the negative effects arising from income inequality

assumption that there may be an implicit limitation in policy prescriptions based on conditional mean estimates. The adoption of sub-samples in which to uncover differential growth experiences may also be constrained by the use of mean regression techniques. Mean regression estimates of growth regressions, such as OLS, offer insights into the relationship for the average economy within each sub-sample. In this setting, conditional mean estimates may disguise the large degree of heterogeneity within sub-samples. Quantile regression techniques provide a means in which to address the issue of parameter heterogeneity and, presently, represent an under-utilised estimation procedure for growth analysis.

2.7 Convergence Hypothesis

A central tenet of neoclassical growth theory concerns the diminishing effect of initial conditions in determining a country's long-run growth. This theoretical prediction has motivated the direction of modern growth analysis in the form of the Convergence Hypothesis. A principle feature of the convergence paradigm is the notion of a catching-up process of real GDP per capita across countries. Early analytical insights into the convergence process explicitly interpreted the neoclassical models predictions from the viewpoint of a temporary effect. That is, income differentials were simply transitory. The weak empirical results in terms of the theoretical predictions from a broad cross-section of countries questioned the validity of a temporary effect. More recently, empirical research has focused upon the role of structural heterogeneity in the form of initial conditions in determining the persistence of growth differentials. A wealth of empirical analysis has derived estimates of the extent of temporary and persistent effects across various economic units. Absolute convergence has been reported for homogeneous sample populations supporting the premise of reduced income differentials over time (Barro and Sala-i Martin, 1991, 2004) Conversely, conditional convergence has been estimated for heterogeneous population samples only after taking ac-

count of their differing structural possibilities (Barro and Sala-i Martin, 1992). By outlining the key theoretical and empirical developments of the convergence literature, this section will elucidate the differing properties associated with Absolute and Conditional β -convergence. A critique of this demarcation will be presented in relation to the interpretation of parameter estimates and the sensitivity of results to model specification and data structure.

The early empirical investigations into the convergence hypothesis considered the dynamic process as one of catch-up. The central feature of this notion of convergence explicitly viewed productivity as a public good. In this setting, growth investments for the leading economies also generated positive spillovers that benefited the growth of lagging economies. One source for the presence of positive externalities in the growth process can be directly attributable to the imitation and adoption of new technologies. Baumol (1986) utilised this interpretation for a cross-sectional analysis of 16 industrialised nations over the period 1870-1979. A primary research question was whether the poorer economies in 1870 achieved faster growth relative to the more affluent economies of the initial period. Using the data of Maddison (1982) covering a longer time period than modern growth analysis, Baumol (1986) ran the linear regression of the growth rate over the period 1870-1979 on the log of real GDP per work hour in 1870. Noting a negative association between growth and initial GDP, Baumol (1986) concluded that an historical trend was evident in which the poorer economies achieved faster growth than the more affluent economies in 1870. The long time period, exceeding a century in Baumol's (1986) analysis, also came at a cost. By offering an historical account, the extensive time dimension ultimately restricted the sample of countries considered for inclusion. The consequence of this approach limits the generalisability of results and, perhaps more importantly, suffers from sample selection bias. To conclude that absolute convergence occurred during the period 1870-1979 for the 16 industrialised countries offers limited insights into the

convergence process for a broad heterogeneous sample of countries. That is not to say the results from Baumol's (1986) study are not informative. Instead, the true value derived may not simply be attached to the results or time period analysed but rather the plethora of empirical research that was subsequently generated concerned with the analysis of sample homogeneity in convergence analysis.

The role of homogeneity in Baumol's (1986) sample of 16 industrialised countries raised important questions regarding the convergence process. For DeLong (1988), the presence of homogeneity was simply a manifestation of sample self-selection leading to spurious conclusions. The discord between absolute convergence and homogeneity may not represent two competing juxtapositions. To see this more clearly consider the cross-section analysis of Barro and Sala-i Martin (1991). By using national economic data over the period 1960-1985, Barro and Sala-i Martin (1991) estimated the degree of convergence among US States. That is, the variation in income across States was analysed with the aim of assessing the degree of cohesion in income levels over time. The results supported the general conclusion reached by Baumol (1986) in terms of a catching-up process of U.S. State income levels. Undertaking the same econometric procedure adopted by Baumol (1986), the data confirmed the presence of unconditional convergence among the 50 US States. The finding of unconditional convergence was further strengthened in subsequent analysis using a broader set of homogeneous samples. Sala-i Martin (1996b,a), for example, reported absolute convergence for both Japanese Prefectures and Canadian Provinces. Barro and Sala-i-Martin (1992) further observed the unconditional convergence process across OECD countries.

The regression based approach of convergence analysis for a broad cross-section of countries resulted in a discrepancy between theoretical and empirical outcomes. Researchers analysing a large heterogeneous sample of countries observed a process of divergence in income levels over time. This conclusion represented a departure from the theoretical prediction of poorer economies achieving

faster relative growth. In order to reconcile this disparity between theory and empirical results, emphasis was placed upon the role of structural heterogeneity. At an empirical level, this required augmenting the convergence regression model to hold fixed the factors that may determine a country's steady-state path. Structural heterogeneity, therefore, was viewed as a constituent part of the convergence process. By conditioning on the growth possibilities of countries, the multivariate regression results allowed greater insights into the steady-state convergence for a heterogeneous sample of countries. This modification for a broad cross-section of countries supported the convergence hypothesis, albeit a process of conditional convergence.

The discussion in this section has focused upon the regression based approach of convergence analysis. Chapter 6 extends on the β -convergence interpretation by formulating the convergence hypothesis within a distributional approach. In this setting, the convergence hypothesis is not concerned with the catching-up process in terms of income levels but rather assesses whether there is evidence of a narrowing of the world distribution of income over time. This distributional approach to convergence analysis has been termed σ -convergence and is particularly associated with seminal contributions by Quah (1993, 1996).

Chapter 3

Economic Growth and Health

Capital

3.1 Introduction

The observed differences in cross-country income levels can be viewed as a direct consequence of differential growth experiences. In this setting, marginal growth rates sustained over a long-period of time can lead to substantial improvements in national standards of living. A natural consequence of this process is that there are inevitable winners and losers associated with economic growth. It is clear that a country's ability to increase national productivity is determined by a number of complex factors. There is plethora of literature focusing upon the determinants of economic growth which has produced a wealth of theoretical and empirical advancements in which to aid understanding of cross-country income differentials. The aim of this chapter is to present an overview of the differential growth experiences observed for the full sample of countries. Descriptive statistics are used to highlight the winners and losers within the growth process, as well as offering an insight into the relationship among growth and its determinants. The relationship between health and national productivity is introduced in order

to highlight the direction of growth analysis in subsequent chapters. Indeed, the recent synthesis of health capital and economic growth models represents a central theme throughout this thesis. By drawing upon the recent analytical and empirical developments in the field, this section also introduces the prominent methods used to explain the differential growth experiences across countries for the textbook Solow model.

3.2 Disparities in the Growth Process

Historical perspectives on cross-country productivity argue that the growth experiences currently achieved are a phenomenon of the last two centuries. Mokyr (1990), and supported by Acemoglu (2009), consider the origins of modern economic growth to have occurred during the time of the industrial revolution. The industrial revolution provided the impetus for many Western nations to achieve growth rates previously considered unattainable. Ultimately, this success was detrimental to the development of the world's poorest countries. The availability of national accounts data over the past 40 years has provided the opportunity to fully scrutinise the extent and consequences of this inequality. Table 3.1 provides a comparison of the disparities in real GDP per worker across countries. The table is constructed to measure the inequality in GDP per worker relative to the United States for the years 1960 and 2000. Countries were included if their population was greater than 50 million in the year 2000. Overall, this restriction has the benefit of accounting for over 4 billion people. A number of countries improved on their relative position over the 40 year period. Most notably, China, Japan, Indonesia and Mexico achieved substantial productivity gains. Conversely, table 3.1 provides evidence of increased productivity differentials over the period. This case is polarised for the position in the year 2000 of African nations relative to the United States. The salient feature of Table 3.1 can be encapsulated by the viewpoint of growth as a dichotomous outcome in which there are both winners

and losers. Indeed, the adage of 'prosper or perish' is a particularly pertinent description of this growth outcome.

Table 3.1: Disparities in Real GDP per Capita

Country	Population Million, 2000	Relative GDP, 1960	Relative GDP, 2000
Brazil	174	0.20	0.21
China	1263	0.03	0.12
Dem. Rep. Congo	50		0.10
Egypt	67	0.14	0.13
Ethiopia	64	0.03	0.02
France	59	0.66	0.73
India	1016	0.07	0.08
Indonesia	206	0.05	0.11
Iran	64	0.24	0.18
Italy	57	0.55	0.65
Japan	127	0.36	0.70
Mexico	98	0.29	0.44
Nigeria	118	0.08	0.03
Pakistan	138	0.06	0.07
Philippines	76	0.16	0.11
Thailand	61	0.09	0.19
Turkey	67	0.18	0.17
United Kingdom	60	0.77	0.72
United States	282	1	1
Total	4047		
Mean		0.28	0.30
Median		0.17	0.17

Table 3.2 ranks the biggest growth winners and losers since 1960 across the full sample of countries in terms per capita GDP growth rates per annum. The large disparities in growth rates across countries illustrate that the growth process is not an inevitability that countries experience after a finite period. Instead, a large number of factors have been proposed as possible determinants of growth. To what extent, however, is growth itself a determinant? More formally, once the mechanisms of growth are in place, then is the process an inevitability? This rationale is fully conditional on the extent to which past growth is a predictor of future growth rates.

Table 3.2: Growth Miracles and Disasters

Country	Growth Miracles 1960-2000
Botswana	6.38
Rep of Korea	5.85
China	5.80
Thailand	4.74
Vietnam	4.58
Cyprus	4.48
Ghana	4.27
Japan	4.20
Ireland	3.99
Portugal	3.74

Country	Growth Disasters 1960-2000
Nicaragua	-0.41
Senegal	-0.43
Central African Republic	-0.55
Niger	-0.64
Malawi	-1.12
Sierra Leone	-1.72
Somalia	-1.73
Afghanistan	-2.22
Congo, Dem. Rep.	-3.09
Liberia	-3.16

Table 3.3 elucidates this point through a correlation matrix of growth rates by decade. The poor association of growth rates across decades highlights the volatility of the growth process. Across the full sample of countries, the correlation between the growth rate of 1960-1980 and 1980-2000 is a meagre 0.23. Past growth, therefore, can be considered to be a poor indicator of future growth rates. At an empirical level, the absence of a deterministic trend in the rates of growth does not reflect a negative outcome. Instead, this viewpoint reflects the focus upon income growth rather than levels of income within empirical models. Income levels are highly correlated with previous levels of income even over several time periods. That is, the accumulation of wealth could be largely explained by the inclusion of lagged income. Although providing a good predictor of future income levels, it also negates any understanding of the mechanisms of wealth accumulation and productivity. The absence of this autocorrelation for income growth provides an opportunity for a greater insight into the process of growth.

Table 3.3: Correlation Matrix of Growth Rates across Decades

	1960-1969	1970-1979	1980-1989	1990-1999
Growth 1960-1969	1.00			
Growth 1970-1979	0.14	1.00		
Growth 1980-1989	0.08	0.18	1.00	
Growth 1990-1999	0.14	0.21	0.17	1.00

3.3 Key variables: Correlates of Growth

The variables of interest in which to explain the cross-country variation in income growth rates are dictated by economic growth theory, as well as important determinants previously identified in empirical applications. The broad class of variables can be separated into economic variables of interest and demographic and health variables. Following the Solow growth model, real GDP per capita and the investment share of GDP are two variables that would fall under the former category. Real GDP per capita is measured in constant prices based on

the chain index approach derived from PWT 6.2. The growth rate of real GDP per capita is calculated from the difference between the natural logarithm of real GDP in the final and initial years for the panel data design. Average investment is calculated as a percentage share of real GDP per capita over five year intervals derived from PWT 6.2. A measure of institutional quality is captured by the degree of openness within countries. This variable is defined in constant prices as the total value of exports plus imports divided by real GDP per capita. In terms of the demographic and health variables of interest, population growth is measured as the average percentage growth over five year intervals. A measure of human capital is defined as the average years of schooling completed in the working age population over five year intervals. National estimates of the stock of health capital are derived from life expectancy at birth in the base year. The impact of the AIDS epidemic is measured by adult HIV prevalence, calculated as the percentage rate at each initial 5 year period.

Table 3.4: Descriptive Statistics for the Full Sample

	N	Mean	Min	Max	Std.Dev.
Economic Growth	945	0.23	-5.57	3.24	0.47
(ln) Initial GDP	942	8.34	5.14	10.44	1.07
Investment (%)	946	2.54	-0.06	4.51	0.66
Population Growth (%)	896	2.40	-4.78	12.31	1.58
Education (Years)	782	5.13	0.12	12.05	2.80
Life Expectancy (Years)	985	61.60	26.68	81.57	11.93
HIV Prevalence (%)	826	0.67	0	28.35	2.77
(ln) Openness	940	3.95	0.70	6.89	0.78

Table 3.4 presents the descriptive statistics for the key variables across the full sample of countries. A definition of each variable, as well as the corresponding data source, is presented in Table A.1 in the Appendices. To complement Table 3.4, Table A.2 in the Appendices presents descriptive statistics for the full sample of countries for each wave of the panel data study. As reported in Table 3.4, the average rate of growth experienced over the 40 year period for the full sample is almost a quarter of a percentage point per annum. There is a large degree

of variation relative to the sample mean, reflecting the inevitable winners and losers within the growth process. This is supported by the summary statistics of real GDP per capita which polarise the disparities in income levels across the world. For example, the lowest level of real GDP per capita reported is \$170 for Liberia compared to \$34,000 observed for the USA. The aim of Table 3.4 is to summarise the information for the key variables over the 40 year period. In this setting, the highest and lowest values may simply reflect underlying economic conditions in which the lowest values correspond to the earliest time point due to limited technological advancements relative to the modern era. Nonetheless, the disparities in income levels observed for Liberia and the USA are not over the entire 40 year period but instead correspond to a meagre 5 years from 1995 to 2000. A similar situation is reported for life expectancy with a difference of almost 55 years between the healthiest country and the country experiencing the lowest level of life expectancy. Again, this difference is not due to the technological advancements in health care over the 40 years. Instead, the outliers in terms of health achievement relative to the sample mean of 61.6 years correspond to 81.6 years for Japan in 2000 and 26.6 for Rwanda in 1990.

The correlation matrix of Table 3.5 presents the association between income growth and factors that may lead to productivity differences across countries. A measure of the national stock of human capital is estimated by the average years of schooling completed in the working age population. The positive relationship between education and economic growth reflects the productivity gains derived from investments in a trained and educated labour force. As illustrated for the descriptive statistics of the key variables in Table 3.4, the measure of human capital ranges from 0.12 years through to a maximum number of 12 years of completed schooling. To gain an insight into the quantitative impact of the returns to education, it is possible to estimate the magnitude of income differentials accruing from increased investment in education. That is, differences in the income levels

of the two countries at the extremes of the education spectrum can be estimated by:

$$\frac{\alpha}{1 - \alpha - \beta} (\ln Education_{max} - \ln Education_{min}) \quad (3.1)$$

By calculating the fraction prefix, $\frac{\alpha}{1 - \alpha - \beta}$, as 0.66 in line with the assumed theoretical values, equation 3.1 can be fully calculated as $0.66 * (\ln 12 - \ln 0.12) \approx 3.04$. The implication from this estimated value highlights the substantial returns to education in terms of increased income. Indeed, holding constant other determinants of economic growth, the value suggests that countries with 12 years of completed schooling will be $\exp(3.04) - 1 \approx 20$ times richer than countries with less than one year of completed schooling.

Table 3.5: Correlation Matrix of Growth Determinants

	Economic Growth	Investment	Education	Life Expectancy
Investment	0.59			
Education	0.47	0.58		
Life Expectancy	0.51	0.67	0.74	
HIV Prevalence	-0.27	-0.42	-0.35	-0.56

The coefficients of life expectancy and HIV prevalence within Table 3.5 highlight the importance of good health on economic prosperity. Health improvements have a direct impact on the average life expectancy within society. If individuals perceive this improvement then there is a greater incentive to save for retirement. The current situation within sub-Saharan Africa ensures that any potential savings are eroded by unexpected events, such as health shocks. Furthermore, the high fertility rates observed in sub-Saharan Africa creates an additional burden on household resource allocations. That is, the greater the number of children within a family, the lower the investment in each child's health, nutrition and education. Positive externalities exist between increased longevity and national fertility rates. For example, Becker and Barro (1988) postulate that high birth

rates can be partly attributable to the expectation that their children will not reach adulthood. In this setting, the greater number of children per household increases the probability of one child reaching adulthood. The lag between mortality and fertility creates a 'baby boom' generation, which ensures a greater pool of labour stock for subsequent job creation upon reaching working age. Bloom and Williamson (1998) term this relationship a 'demographic dividend' and estimate that as much as one third of the economic success of the East Asian "tiger" economies can be attributed to this changing demographic structure. The sustained presence of HIV/AIDS among the world's poorest nations has negated the prospect of benefiting from this demographic dividend.

Table 3.6 shows the changing rates of HIV prevalence across regions. The average prevalence rate in sub-Saharan Africa more than doubled during the period 1990-2000. The current HIV/AIDS epidemic can be viewed as reducing national labour supply as the epidemic is more prevalent among the working-age population. An important policy question, therefore, is whether focus should be directed towards individuals of working age. This question is even more pertinent given the reliance on labour-intensive agricultural forms of employment among the poor in sub-Saharan Africa. The vicious cycle of poor health and reduced labour supply is perhaps, less obvious but equally damaging at the aggregate level. Indeed, observed poor levels of productivity and population health will likely deter direct foreign investment. Consequently, reduced domestic productivity will result in a greater reliance on imports. The direct impact on the national balance of payments will reduce the capacity for countries to combat the HIV/AIDS epidemic. Bloom et al. (2005), for example, note an historical trend within the treasury departments of LDCs in an unwillingness to allocate increased resources to promote public health due to previous poor performance.

Notwithstanding the substantial increases in sub-Saharan Africa, both the Latin America and OECD samples have also experienced increases in their preva-

Table 3.6: Changing Rate of HIV Prevalence Across Regions

		1990	1995	2000	2005
World	Average	1.57	2.56	2.8	2.7
	Std. Dev.	3.29	5.22	5.71	5.45
	Max	20.12	28.34	26.32	26.4
Asia	Average	0.47	0.59	0.57	0.55
	Std. Dev.	0.6	0.72	0.51	0.44
	Max	1.68	2.02	1.62	1.5
Latin America	Average	0.4	0.6	0.69	0.7
	Std. Dev.	0.47	0.55	0.54	0.53
	Max	1.72	2.18	2.2	2.2
OECD	Average	0.19	0.23	0.25	0.26
	Std. Dev.	0.16	0.17	0.18	0.17
	Max	0.58	0.6	0.6	0.6
Sub-Saharan Africa	Average	3.32	6.02	6.71	6.49
	Std. Dev.	4.55	7.17	7.9	7.55
	Max	20.12	28.34	26.32	26.4

lence rates at every time interval. The rates experienced within the OECD sample can be considered to be of the magnitude defined for a concentrated epidemic within certain high risk sub-populations. Despite this, the raising rates from 1990-2005 will be of an increasing concern to public health practitioners within the region. Latin America is currently on the periphery of the epidemic categorisation, with the region being home to countries of both concentrated and generalised epidemics. National responses to combat the generalised epidemics currently occurring will largely determine the extent to which the region as a whole will follow the path of sub-Saharan Africa. Lessons from sub-Saharan Africa highlight the consequences of inactivity in eradicating HIV/AIDS within particular countries. For example, the consequences extend beyond national boundaries to the detriment of neighbouring countries. This relationship can be illustrated more clearly through a focus on the spatial distribution of HIV prevalence rates within the region.

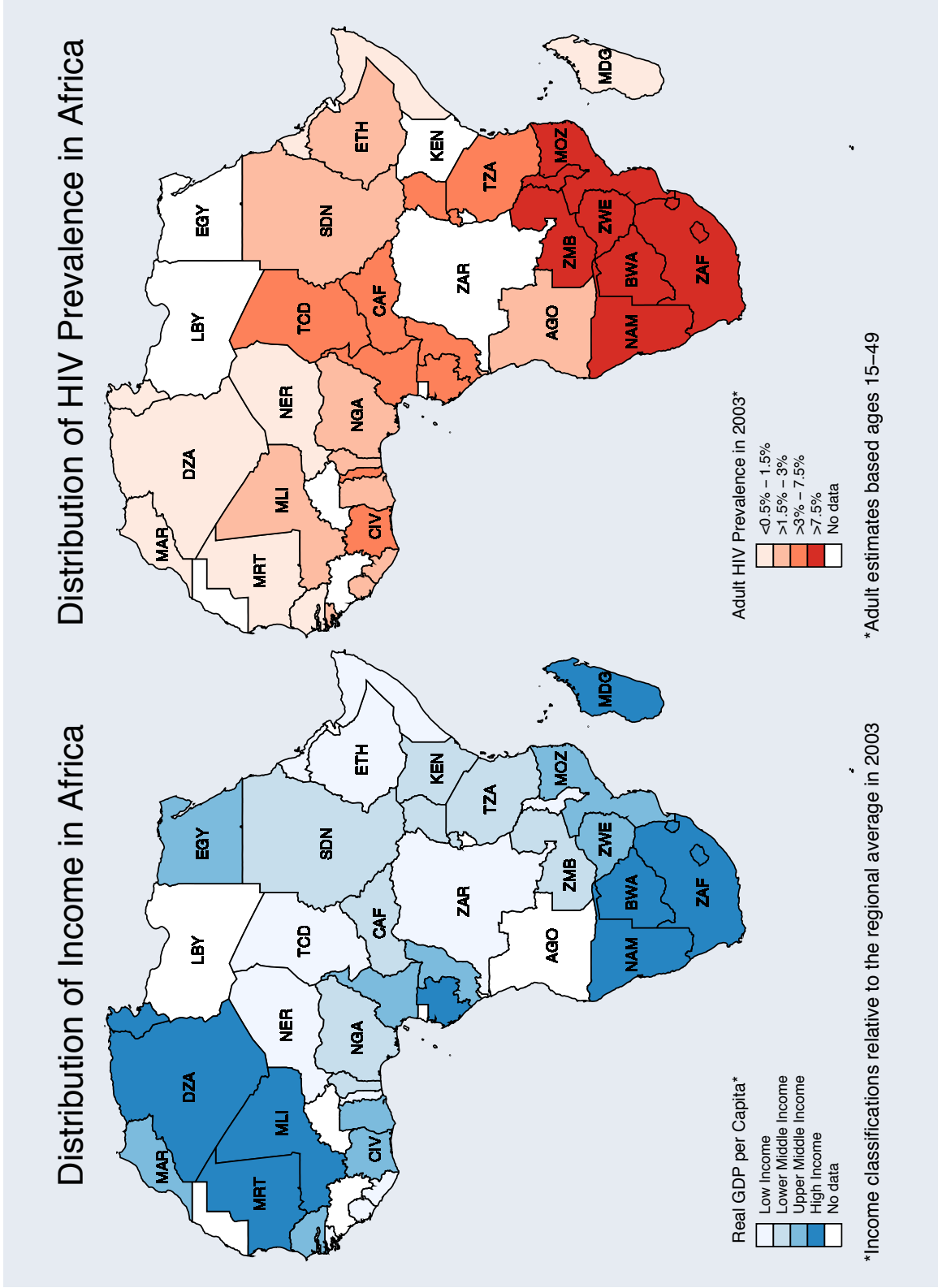


Figure 3.1: Spatial Distribution of Income and HIV Prevalence within Africa

The incidence of HIV has often been considered an epidemic of the poor. This rationale can be considered to be a manifestation of the current situation in sub-Saharan Africa, which is disproportionately affected by the epidemic. With nearly 70 percent of AIDS cases concentrated within the region, researchers have postulated a link between HIV and poverty (Krueger et al., 1990; Whiteside, 2002). It is clear that ill health is more prosperous under conditions of abject poverty but the dynamics of the disease have been noted to be more complex than a simple linear association (See for example, Gregson, Waddell and Chandiwana, 2001). Taking one facet of poor health in isolation, the high incidence of infant mortality may provide additional incentives to engage in greater sexual activity. For HIV, the consequence of such actions creates an environment detrimental to reducing HIV infections. Household and facility level studies analysing the impact of the AIDS epidemic have highlighted a potential anomaly with this line of reasoning. In contrast to economic theory, some studies have reported a positive correlation between an individual's level of education and the prevalence of HIV. Gregson et al. (2001) note that the higher educated are initially more at risk of HIV infection but may also have a greater capacity to mitigate the effects through behavioural changes. A potential rationale for studies noting a positive association between education and HIV infection may relate to an underlying income effect. This situation is polarised in societies whereby increased levels of education correspond to an improved position in society, maintaining a place among the country's elite. It is clear that education has a positive effect on individual wage levels. If sex is explicitly considered to be a normal good then increased levels of educational attainment may act as a stimulus for the higher risk of HIV infection. In light of this microeconomic evidence, at the aggregate level HIV prevalence should be inversely related to a country's level of income. Figure 3.1 illustrates the spatial distribution of real GDP per capita and the adult HIV prevalence rate for sub-Saharan Africa. The figure is produced using the `spmap`

package for Stata 9.2 developed by Pisati (2007). As the levels of prevalence and income are relative to the region as a whole, Figure 3.1 highlights the substantial variation across countries within sub-Saharan Africa. The visual pattern of this spatial distribution elucidates the clustering of countries that share similar levels of income and prevalence rates. That is, the mechanisms that determine the growth of both income and HIV can be considered to extend beyond national boundaries. Figure 3.1 postulates the presence of a geographic dependence across both variables. At an empirical level, the interpretation of this relationship is one of simultaneity. National economic prosperity, therefore, can be viewed as fully conditional on the economic environment of bordering countries.

The underlying paradox of Figure 3.1 is defined in terms of the positive association between income and the prevalence of HIV. Countries hampered by high HIV prevalence rates also experience higher average income levels for the region. This conclusion runs counter intuitively to the predictions of economic theory. The productive benefits of improved health status may provide the necessary impetus to achieve economic growth. Yet this theoretical depiction remains pertinent if consideration is placed beyond the level of income as used in Figure 3.1. A distinction is needed between income levels, income growth and income inequality. Although income levels provide an overview of the spatial pattern in sub-Saharan Africa in Figure 3.1, it does not account for the effects of growth and inequality in the underlying relationship. An insight into this relationship is presented in Figure 3.2 which plots the association between income inequality and HIV prevalence across African countries. A measure of income inequality for each country is obtained by averaging the national Gini coefficient over the time period. The general upward trend from the linear regression line in Figure 3.2 supports the premise of a positive association between income inequality and HIV prevalence. A higher Gini coefficient denotes increased income inequality within the country and is bound by zero and one as illustrated on the x-axis of

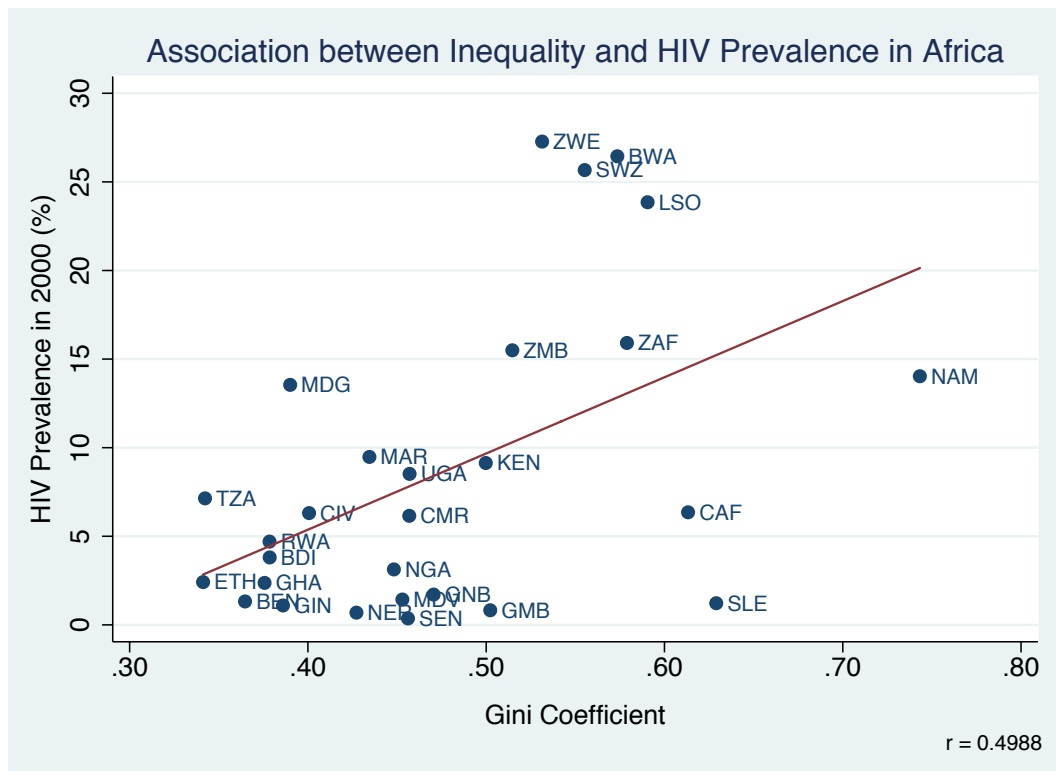


Figure 3.2: Scatterplot of Income Inequality and HIV Prevalence

Figure 3.2. There is a moderate association between income inequality and HIV prevalence among African countries as denoted by the correlation coefficient in Figure 3.2.

3.4 Health Human Capital, HIV and Policy

There has been a long-standing appreciation of the role of human capital within the policy arena. This appreciation is precisely due to its productive nature in the development process. The promotion of universal education as part of the Millennium Development Goals relates to the direct impact of productivity increases and positive externalities associated with human capital investments in which to achieve economic prosperity. More recently, the role of 'good health' has been considered a central feature of the pursuit for economic growth and development. In this setting, poor population health can be viewed as an impediment to national growth. This case is polarised in sub-Saharan Africa, in which the

region represents the world's poorest as well as experiencing the lowest levels of population health. A vicious cycle of poverty, poor health and institutional barriers can all be considered obstacles to improvements in living standards within the region. However, the negative relationship between poor health status and economic growth are not always immediately apparent. Indeed, the consequence of poor population health is more than simply a public health concern and affects all spheres of the economy.

Life expectancy at birth is used as general measure of aggregate health in order to draw cross-country comparisons. There is a high degree of association between life expectancy and real GDP per capita. In terms of any causation, however, the direction between the two variables can be modelled within a health human capital context. In this setting, health investments lead to improved employment longevity, as well as potential productivity benefits. The accumulation of both lifetime earning potential and productivity enhancements can be viewed as improving individual levels of wealth. This causality running from health to income represents an important policy consideration. In particular, causality running in the opposite direction would imply that the HIV/AIDS epidemic is simply a manifestation of poverty. Any attempts to combat the HIV/AIDS epidemic, therefore, must also focus upon poverty reduction initiatives. Conversely, if poor health acts as a barrier to future income then this mechanism should be reflected in reduced rates of economic growth. Within sub-Saharan Africa, there is a paradox in terms of HIV prevalence rates and levels of income. Prevalence rates are higher within the relatively richer countries of the region as illustrated in Figure 3.1. The phenomenal growth rate of real GDP per capita experienced by Botswana since 1960 has been achieved in the backdrop of one of the world's worst HIV epidemics. It could be argued that the growth rate achieved in Botswana since 1960 was an inevitability that simply would have occurred even in the absence of the AIDS epidemic. Instead, the epidemic may have restricted the countries

full growth potential. Alternatively, the epidemic may be a consequence of the growth transition. The movement along the development path leads to greater urbanisation, infrastructure and subsequent migration that could cultivate the epidemics vigour. The research outlined in this thesis aims to address these two fundamental questions. Firstly, the research will estimate whether the epidemic has impeded economic prosperity. By controlling for any potential feedback from growth to HIV, as well as key determinants of economic growth, the research also draws upon country specific characteristics to test whether the epidemic is simply a manifestation of such factors. More specifically, policies, institutional frameworks and geographical climate will form the basis of potential factors that may distort national incentives to promote growth and welfare. Of particular interest, is whether there is a degree of homogeneity across countries in their means of increasing population health?

Although an empirical question, the existing literature on national health policies points to the rejection of this test of homogeneity across countries. For example, Bloom et al. (2004) identify the potential presence of political obstacles to health improvement. In particular, the polarisation between the long-term strategies needed to combat the AIDS epidemic and the short-term tenure of health ministers was noted. The manifestation of this relationship leads to an emphasis on short-term policy goals in order to ensure and preserve political support. South Africa's unorthodox policy stance on the subject of HIV/AIDS is particularly pertinent. Matthews (2004) highlights the unconventional approach through a statement by the South African Health Minister in 2003. Rather than implement an antiretroviral therapy programme to ensure improvements in the quality of life of HIV patients, the Minister argued that sufferers should, instead, eat garlic, onions, olive oil and African potatoes to boost their immune system (Matthews, 2004: pg, 80). Paradoxically, Skordis and Natrass (2002) have estimated that the costs of non-intervention, reflected by early South African

governmental policy, are greater than the costs involved of a national treatment programme for the prevention of mother-to-child transmission. The rationale for non-uptake and the decisions under-pinning the timing of uptake are central to the research. At a theoretical level, the contrasting governmental actions in response to HIV signify the differing levels of priority placed upon the disease. By utilising the time dimension of the panel data, the research will analyse the consequences associated with this prioritisation in terms of reduced growth.

Figure 3.3 draws upon Preston's (1975) analysis of the relationship between population health and national output. The figure plots life expectancy against real GDP per capita in line with the original Preston Curve. A weight of population size is used in the construction of the figure so that the size of the hollow circle is proportional to the country's population. Deaton (2003) and, more recently, Cutler et al. (2006) have outlined the importance of the Preston (1975) curve in which to aid understanding of global health inequalities. The quadrant in Figure 3.3 represents individual Preston curves across decades to capture the relationship over time. The concave relationship between life expectancy and income remains constant across the time periods. Marginal increases in income can be viewed as achieving substantial increases in population health. This case is exemplified from the identifiable largest population countries of India and China. The greater weight placed upon these two countries, representing nearly one-third of the world's population, presents a means in which to identify their upward mobility along the 45 degree line. Undoubtedly, China reports one of the largest relative gains with a 60 percent increase in life expectancy over the 40 year period.

The Evolution of the Preston Curve

Life Expectancy versus Real GDP per Capita

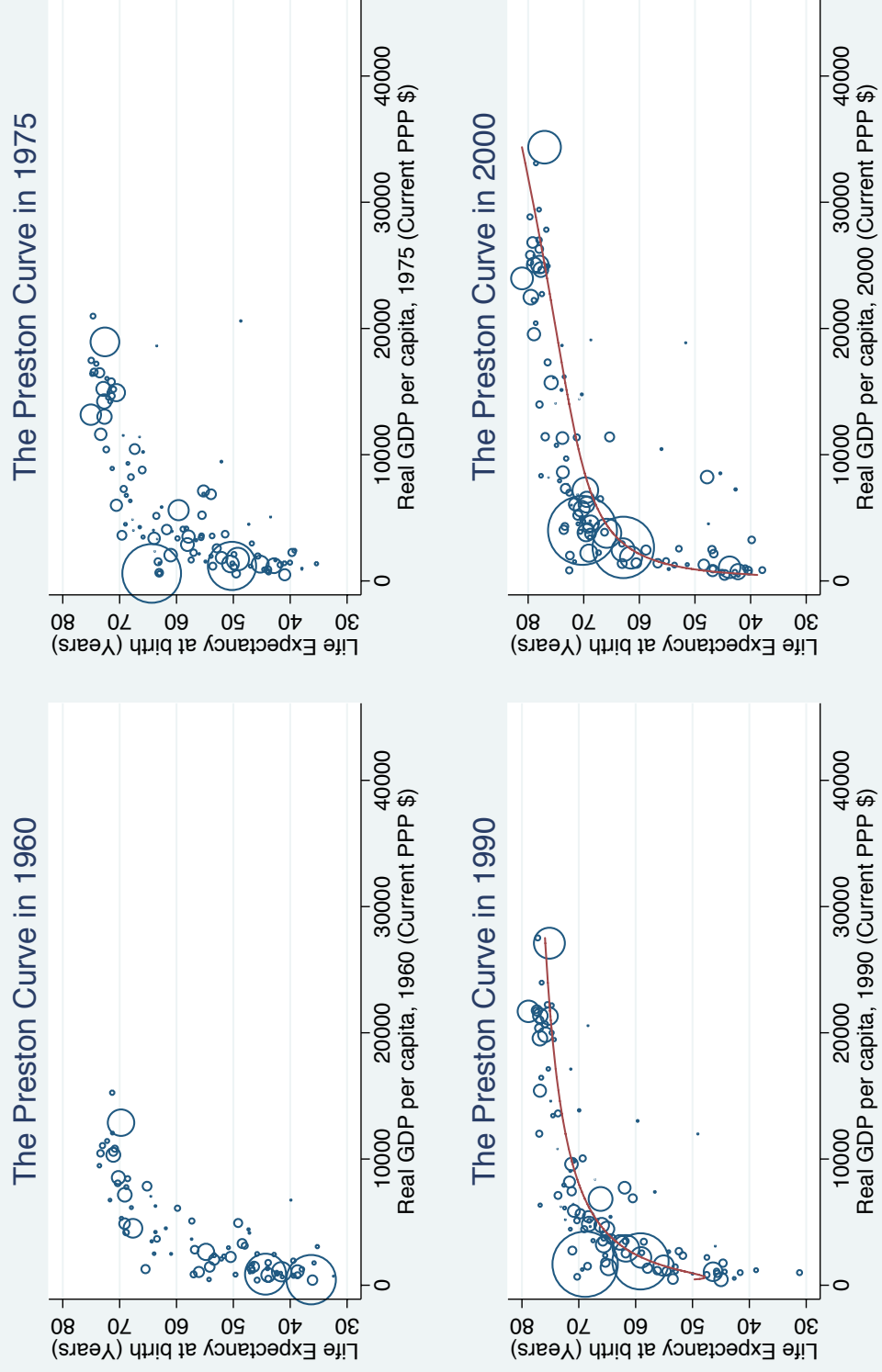


Figure 3.3: The Preston Curve by Decade

Countries constrained by low income and poor health status, reflected in the lower left corner of Figure 3.3, also achieved gains from 1960 through to the panel in 1990. A reversal of this upward trend post-1990 is difficult to reconcile with this general relationship. Instead, a number of external factors have been proposed in which to explain this setback. Deaton (2007) acknowledges both the collapse of the centrally planned economies of the Soviet Union and the HIV epidemic as probable causes. As the former Soviet countries fall beyond the sample of the research due to data limitations, emphasis is placed upon the significance of HIV/AIDS within this context. To isolate such factors in which to conclude causality from HIV/AIDS in this process is problematic but nontrivial. Indeed, the HIV epidemic amongst the world's poorest can also be considered to weaken both social and economic structures that are also detrimental to population health and income. Before modelling the impact of the HIV/AIDS on economic growth in Chapter 4, the remainder of this current chapter is concerned with empirically testing the predictions of the textbook Solow model. In particular, the following section aims to outline the adopted methodological stance for estimating growth regressions.

3.5 Solow Model Predictions

This section will present the adopted study design by explicitly drawing upon the estimation issues outlined in Chapter 2.6. By offering a critique of the alternative estimation models of the textbook Solow paradigm, this section will consider the consequences of the estimated results in terms of the theoretical predictions and subsequent study design. A central feature of this discussion is entwined with the issue of unobserved heterogeneity and the endogeneity of regressors. In particular, the results highlight the need for an estimator that can suitably eliminate the country-level fixed effects. More pertinently, the results appear sensitive to the specification among such estimators particularly in relation to the convergence

hypothesis. This is in line with the current convergence literature which fails to present a coherent unified rate of convergence from panel data studies.

The central predictions of the textbook Solow model concern the impact of savings and population growth on national income. The model is specified within a closed economy framework. In this setting, savings and investment are equalised in order to exhaust output possibilities. It is possible to test the general predictions of the Solow model in its attempts to explain disparities in national income levels. Figures 3.4 and 3.5 provide a scatterplot of the relationship between investment and population growth against real GDP per worker.

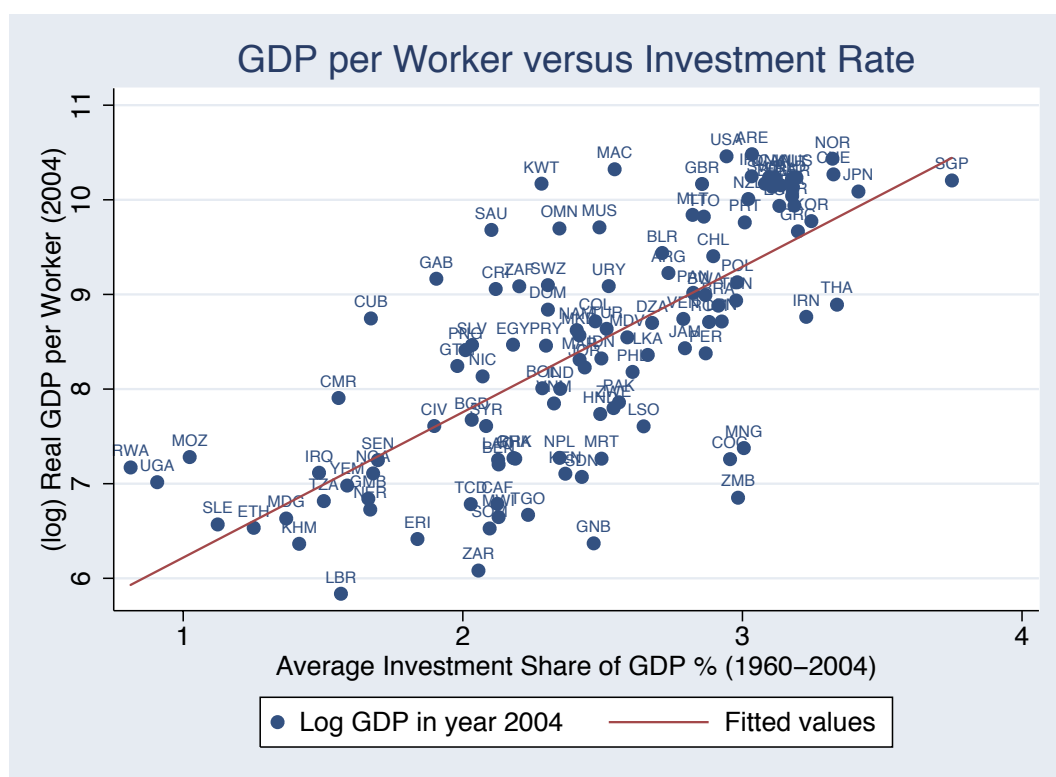


Figure 3.4: Scatterplot of Investment and National Income

Both figures provide support for the general predictions of the Solow model. As illustrated in Figure 3.4, countries with higher rates of investment also tend to enjoy higher income levels. This relationship is specified within the Solow model through the notion that higher investment levels lead to greater capital accumulation, which in turn creates increased income per capita. In contrast,

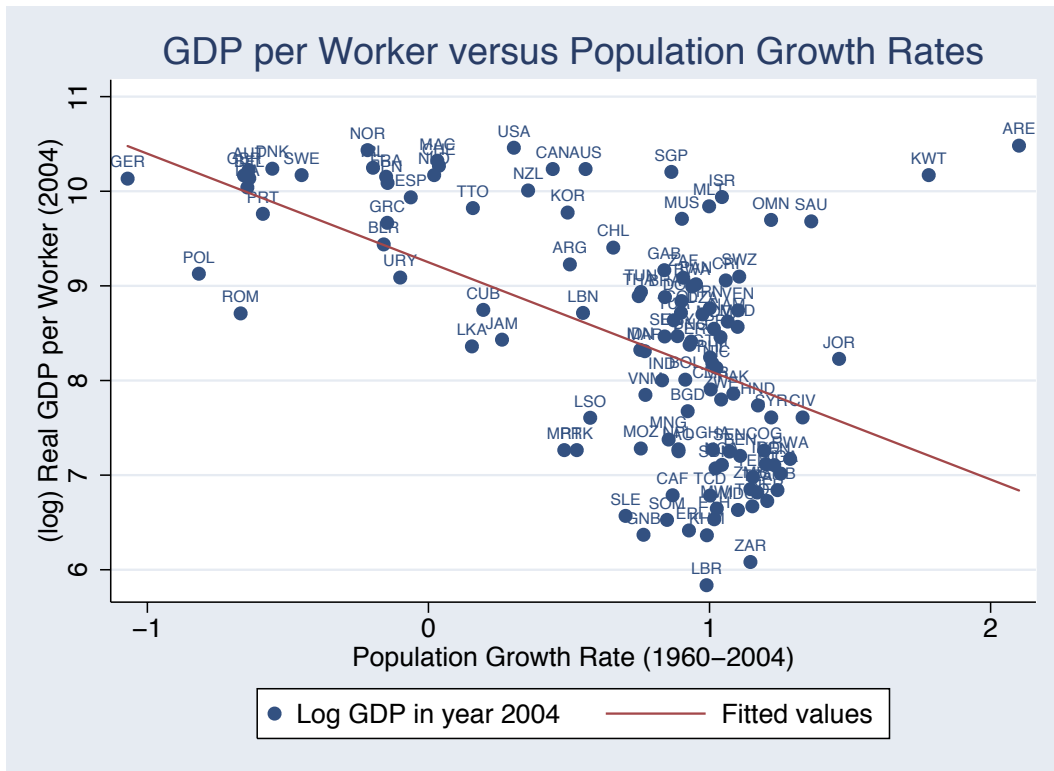


Figure 3.5: Scatterplot of Population Growth and National Income

high population growth rates limit output as any increases in investment can be viewed as simply replacing the capital-labour ratio to its initial level. This negative relationship is illustrated from the downward sloping regression line in figure 3.5.

3.5.1 Regression Estimates for the Textbook Solow Model

Table 3.7 considers the predictions of the textbook Solow model by comparing the regression results across competing specifications. The baseline specification is a pooled OLS model defined by Column (1). Column (2) accounts for the panel data design and the country-level fixed effects by adopting a within-groups estimator for the growth model. Columns (3) and (4) correspond to the first-differenced GMM (FD-GMM) and system GMM (SYS-GMM) estimators that are more suitable for short dynamic panel data models. The dependent variable across all specifications is the logarithmic difference in real GDP per capita across

5-year periods. As well as initial income, investment and population growth, the regression results also include a number of time dummy variables in order to control for time-specific shocks to economic growth. The central theoretical determinants of investment and population growth have the expected signs predicted by the Solow model. It is interesting to note that the economic significance on the coefficient for investment in Column (4) is higher in magnitude than the levels observed for the OLS, within-groups and FD-GMM estimators. A possible explanation relates to the improvement of the system GMM approach in terms of addressing unobserved heterogeneity as well as the potential endogeneity associated with investment. The time dummy variables also highlight the significant reduction in productivity during the 1980s and early 1990s arising from worldwide shocks to economic growth.

$m1$ and $m2$ report the first and second-order tests for serial correlation for the FD-GMM and SYS-GMM estimators. A fundamental assumption relating to both estimation methods relates to the absence of serial correlation for series lagged two periods or more. The significant negative first-order serial correlation reported in $m1$ for both estimators confirms the presence of autocorrelation and highlights the need for higher order lags as instruments. Furthermore, the absence of second-order serial correlation for the FD-GMM and SYS-GMM estimators from the test statistics reported in $m2$ in Columns(3) and (4) support the underlying assumptions regarding the need for lags of two periods or more. The corresponding Sargan test presents the p-values for the null hypothesis that the idiosyncratic error term is uncorrelated with the instruments. For the SYS-GMM estimator, the exogeneity of the instruments is confirmed with a non-significant p-value (0.28) and therefore fails to reject the null hypothesis. In contrast, the FD-GMM estimates of Column (3) reject the null hypothesis questioning the validity of the first-differenced instrument set.

Table 3.7: Panel Data Estimates for the Textbook Solow Model

	(1)	(2)	(3)	(4)
	OLS	Within-Groups	FD-GMM	SYS-GMM
GDP in base year	-0.097*** (0.015)	-0.339*** (0.060)	-0.389 (0.278)	-0.196*** (0.066)
Average Investment	0.241*** (0.023)	0.270*** (0.051)	0.166 (0.225)	0.326*** (0.102)
Population Growth	-0.016 (0.018)	-0.060*** (0.002)	-0.179* (0.089)	-0.117** (0.046)
Dummy, 1965-70	0.051 (0.058)	0.001 (0.071)	-0.035 (0.245)	0.108** (0.055)
Dummy, 1970-75	0.078 (0.055)	0.100 (0.064)	0.035 (0.190)	0.147** (0.058)
Dummy, 1975-80	-0.031 (0.055)	0.019 (0.061)	-0.017 (0.137)	0.050 (0.051)
Dummy, 1980-85	-0.207*** (0.055)	-0.124** (0.058)	-0.158 (0.111)	-0.113** (0.046)
Dummy, 1985-90	-0.119** (0.055)	-0.031 (0.057)	-0.031 (0.107)	0.027 (0.044)
Dummy, 1990-95	-0.153*** (0.056)	-0.155*** (0.056)	-0.071 (0.102)	-0.031 (0.057)
Dummy, 1995-2000	0.010 (0.055)	0.090 (0.056)	0.059 (0.048)	0.096*** (0.035)
N	859	859	747	747
λ	0.028	0.075	0.086	0.043
m1			-4.16	-3.28
m2			-0.73	-0.07
Sargan			0.03	0.28
Diff Sargan				0.21

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Speed of Convergence:

The speed of convergence represented by λ is derived from the coefficient on initial GDP per capita (GDP in base year within Table 3.7). More formally, the speed of convergence can be defined as:

$$\lambda = (1 - \exp^{-\lambda^*t})(\hat{\beta}_1) \quad (3.2)$$

Where λ is equal to 0.05 in line with the assumed theoretical values for the exogenous rate of technological change multiplied by the specified time period.

The results for λ illustrate that the speed of convergence differs greatly across each estimator. There is an almost three-fold increase in the OLS parameter estimate after accounting for country-specific effects within the first-differenced GMM estimator. The commonly reported 2% speed of convergence in cross-sectional studies is generally supported by the OLS result of 2.8% per annum in Column(1) of Table 3.7. In line with the current panel data literature on convergence, the within groups estimator reports a much higher speed of convergence of nearly 8% per annum. This finding is replicated using the first-differenced GMM estimator, although the speed of convergence increases to 9% within this specification. The finding is quantitatively similar to the reported speed of convergence by Caselli, Esquivel and Lefort (1996) of just over 10%.

Bond, Hoeffler and Temple (2001) argue that the coefficient on initial income can be used to capture the presence of finite sample biases for the adopted estimators in order to determine model specification. In particular, they argue that OLS estimates of $y_{i,t-1}$ will be biased upwards in the presence of country-specific effects. Conversely, Nickell (1981) and more recently Nerlove (1999) have noted that the within-groups estimator will be correspondingly biased downwards for autoregressive models that are characterised by a small number of time periods. In this setting, the short dynamic panel model estimates of $y_{i,t-1}$ in Columns (1)

and (2) in Table 3.7 can be considered biased in opposing directions. Bond, Hoefler and Temple (2001) conclude that a consistent estimate of $y_{i,t-1}$ and therefore, consequently by derivation, λ should be within the upper and lower bounds of the OLS and Within-groups estimates. More formally, Durlauf, Johnson and Temple (2005) state that a suitable estimate of $y_{i,t-1}$ should be of the form:

$$p \lim \hat{\beta}_{WG} < p \lim \hat{\beta} < p \lim \hat{\beta}_{OLS} \quad (3.3)$$

That is, a consistent estimate for $y_{i,t-1}$ should be higher than the within-groups estimate but lower than the corresponding OLS estimate.

To test the presence of a finite sample bias in the first-differenced GMM estimator, Bond et al. (2001) replicate the speed of convergence results of Caselli et al. (1996). Although the reported first-differenced estimate was within the desired range for the sample of countries used by Bond et al. (2001), it was noted to be higher than hypothesised. Instead, the first-differenced GMM estimator advocated by Caselli et al. (1996). reflected a similar downward bias as the within groups estimate. A comparison of convergence parameters in Table 3.7 illustrates the same relationship noted by Bond et al. (2001) with the first-differenced estimates being quantitatively similar to the within groups estimates. This result is perhaps not surprising given the similarity of convergence results in Table 3.7 with that of Caselli et al. (1996) for the first-differenced GMM estimator.

The first-differenced GMM estimate for λ is beyond the required range defined by equation 3.3. In this setting, the estimate for λ in Column (3) can be considered to be biased downwards in the same way as the Within-Groups estimator. Bond, Hoefler and Temple (2001) interpret this finding as evidence of weak instruments as the source for the biased estimates derived from the FD-GMM approach. The persistence of series such as real GDP per capita represents one of the contributory factors affecting the instrument set and reliability of the FD-GMM estimator for growth regressions. Instead, Bond et al. (2001) propose the

system-GMM approach of Blundell and Bond (1998) as a means for increasing efficiency and reliability of estimates in the presence of weak instruments. The use of first-differenced and levels of the series as instruments within the system-GMM approach for the estimate for λ polarises the presence of weak instruments within the FD-GMM estimator. In contrast to the estimates presented in Columns(1-3), the system-GMM estimate for λ can be considered to be within the desired range noted by equation 3.3. Indeed, the annual speed of convergence of 4.3% for the system-GMM estimator is well within the required range of 2.8%-7.5% derived from the OLS and Within-Groups estimates of λ in Table 3.7.

Cross-sectional Dependence

A discussion of the post-estimation results would be incomplete without considering the presence of cross-sectional dependence in the panel data models. The potential bias induced by cross-sectional dependence can be exposed with reference to the spatial distribution of income and HIV prevalence previously depicted in Figure 3.1. The map of Africa illuminated the clustering of neighbouring countries that shared similar distributional positions of both income and HIV prevalence. At an empirical level, this relationship questions the validity of whether the error terms are independent across observations within the panel data regressions. That is, the possibility of a geographic dependence in determining national levels of growth and HIV prevalence would lead to inconsistent standard errors if such factors were not explicitly controlled.

Improvements in the quality and availability of national accounts data has led to a steady increase in the number of cross-sectional units included in applied growth research. An increase in the number of countries under analysis, however, has not been combined with a greater number of time periods. Although covering in excess of 40 years for some countries, the number of time periods is greatly reduced within panel data designs in which data is commonly averaged over 5

year intervals. In this setting, panel data studies of economic growth are in the form of large N small T . This raises problems in terms of the implementation of more conventional test statistics, such as the Lagrange Multiplier, due to a restricted validity for small N and large T structural forms.

Pesaran (2004) proposes a test for the presence of spatial dependence suitable for large N small T , unbalanced panel designs. The correlation coefficient from this test statistic for the textbook Solow model in column (2) is 0.40 ($p < 0.001$), providing support for the presence of cross-sectional dependence in the growth regressions. Ultimately, this strong association between the error terms may yield inconsistent levels of significance for the key growth determinants. Nonetheless, the identification of the appropriate space is still an unresolved issue within growth regressions. Although cross-sectional dependence may be identified, the geographical boundaries underlying the growth relationship remain unclear. For example, shocks to growth may extend beyond simply neighbouring countries. As Durlauf, Johnson and Temple (2005) note, the USA can be considered more closely aligned to the UK in terms of trade, rather than neighbouring Mexico. In this setting, a movement away from neighbours as the appropriate spatial unit for cross-sectional dependence seems logical within the context of growth.

Conley and Ligon (2002) explicitly address this limitation by formulating the spatial covariance as a function of economic distance, country characteristics, unobserved factors and spillovers. The potential presence of cross-sectional dependence in the context of economic growth is particularly evident when considering international trade. By focusing upon economic distance, as opposed to geographical measures, Conley and Ligon (2002) attempted to capture the dependence arising from transportation costs of cross-country trade activity. The intuitive appeal of this approach relates to the consideration of spatial dependence beyond neighbouring countries. Despite the innovative methodology, the estimated regression results provide evidence of only trivial changes in the stan-

dard errors and inferences when capturing dependence in this way. Indeed, Conley and Ligon (2002) conclude that the existing Barro-style regression approach successfully accounts, albeit unintentionally, for the cross-sectional dependence in growth analysis.

3.6 Summary

This chapter has presented a rudimentary insight into the growth process and identified the differential growth experiences across countries in their pursuit of economic prosperity. The importance of health as a possible determinant in the growth process was considered by noting the positive association between life expectancy and a country's level of income. Although good health was acknowledged to be a salient feature of improved national productivity, the consequences of poor population health were also considered. In particular, the relationship between the HIV/AIDS epidemic and national income was explicitly assessed in order to offer an insight into the underlying process. By introducing the first-differenced GMM and system GMM estimators for growth regressions, this chapter was concerned with constructing robust estimates for the determinants of economic growth within a panel data design. The analysis undertaken in subsequent chapters builds upon these fruitful developments by estimating the impact of the HIV/AIDS epidemic on economic growth as well as capturing the dynamics between growth, poverty and inequality. Chapter 4 builds on the methodological stance adopted in this chapter by estimating the impact of the HIV/AIDS epidemic within a standard neoclassical growth model.

Chapter 4

Does the AIDS Epidemic Impede Economic Growth?

4.1 Introduction

The threat and spread of HIV/AIDS throughout the world has resulted in the overwhelming loss of life and individual autonomy. By its very nature, the virus has decimated the structural foundations of familial ties, further negating the prospect of human agency and sustained economic development. HIV/AIDS has maintained its position as one of the leading causes of death globally (WHO, 2008). This case is particularly evident within Sub-Saharan Africa which accounted for 71% of all new HIV infections in 2008 (UNAIDS, 2009). The current situation within the region highlights the imperative need for a priority setting of effective health care in order to quell this prevalence. Indeed, the region boasts the sombre classification of homing almost two-thirds of all people living with HIV, despite being home to less than 10 per cent of the world's population (UNAIDS/WHO, 2004). Since the initial outbreak of the disease it is estimated that over 20 million Africans have died from HIV/AIDS, with over 2 million mortalities in 2006 alone (UNAIDS/WHO, 2006). Despite substantial investment from

international aid initiatives to reverse the trend, the pandemic continues with increased vigour. This situation is polarised with the infection rate of new cases rising to 2.8 million for 2006 - a figure higher than all other regions combined (UNAIDS/WHO, 2007).

4.2 Literature Review on The Economics of AIDS

The early empirical literature estimating the impact of HIV/AIDS on economic growth was restricted by data limitations for the period of the epidemics infancy. In light of this, early studies adopted a design of forecasting the epidemics impact or focused analysis upon individual countries in which data was available. The seminal research by Over (1992) can be considered one of the earliest studies that generated future insights into this analytical approach of the macroeconomic impact of the HIV/AIDS epidemic. The growth trajectories of 30 countries over the period 1990-2005 were simulated under a scenario of an advanced AIDS epidemic and an alternative, hypothetical, situation of an absence of AIDS. Over (1992) estimated that the presence of AIDS within Africa had reduced the annual growth rate of GDP per capita by 0.15 percentage points per annum. However, there are reasons to assume that the results may overstate the epidemics impact. In particular, the simulated model results under an AIDS case scenario are based on assumptions that run counter to current empirical results. For example, the epidemic was assumed to be concentrated among the more highly educated. Although this assumption may appear feasible during the epidemics infancy, the general conclusion is in contrast to recent studies analysing individual knowledge of AIDS protection and risk-taking behaviour within Sub-Saharan Africa. Gregson et al. (2001) acknowledge that the highly educated are initially at more risk of HIV infection but that they also have a greater capacity for induced behavioural change. Using data from the Demographic and Health Surveys for Burkina Faso, Cameroon, Ghana, Kenya and Tanzania, Fortson (2008) offers support for Over's

(1992) prediction. Indeed, the results report a positive association between education and HIV prevalence, with the only exception for the most highly educated. The estimated impact of the education gradient in HIV infection was also estimated to be sizeable. For example, Fortson (2008) concludes that an individual with six years of schooling are as much as 3 percentage points more likely to be infected with HIV compared to individuals with no education. Over (1992) also assumed that half of all AIDS related medical care would be financed by reduced savings. The impact of this reduction in domestic savings is captured in reduced investment to generate future output. In this setting, if reduced consumption partly offsets medical costs in order to protect savings then growth possibilities will also be higher.

Cuddington (1993b) estimated the differing growth paths experienced by Tanzania under two AIDS case scenarios. The dichotomous framework simulated Tanzania's economic growth through an advanced AIDS epidemic and an alternative hypothetical scenario of an AIDS free Tanzania. A Solow-style growth model was developed to model the relationship between the key determinants of economic growth and the AIDS epidemic. In particular, the epidemic's impact on mortality and morbidity was focused upon in relation to labour productivity and domestic savings. Productivity differentials arising from the simulation results were attributed to a reduced labour force within the AIDS epidemic scenario. Furthermore, the quality of the labour force was also diminished as affected workers were replaced by less experienced and, therefore less productive, workers. By changing the age-cohort of workers, the impact of the AIDS epidemic can be considered to alter the mechanisms of labour demand and supply. If younger, less experienced, workers are required to fill the void created by the AIDS epidemic then incentives and opportunities for children to invest in education are also diminished.

An obvious drawback of the single-sector economy in which Cuddington (1993b)

formulates his model relates to the assumption of full-employment. In particular, the assumption holds that labour and capital are efficiently allocated, thereby ruling out the presence of market failures and resource misallocations. Critics of this approach argue that such assumptions do not hold for LDCs, in which economies operate below full capacity and are characterised by market failures and policies promoting the inefficient allocation of resources. If LDCs do operate below full capacity than the results derived from Cuddington (1993b) may overstate the true impact of the AIDS epidemic on economic growth. More specifically, the productivity differentials arising from the reduced stock of labour emphasised in the AIDS epidemic scenario may not be significant if workers can be easily replaced by surplus labour. Cuddington (1993a) responds to this criticism by extending upon his earlier work by formulating a dual labour market to assess the impact of AIDS on unemployment. The simulation results under this alternative framework reinforce the negative relationship between an advanced AIDS epidemic and economic growth. In this setting, whether the economy is at full employment is only partly addressing the question. Instead, what is important is the epidemic's impact in changing the composition of the labour force.

Despite its generalised framework, the estimated impact of the HIV epidemic was shown to be sizeable in impeding economic growth. For example, Cuddington (1993b) reports that GDP per capita would be 10 per cent higher in Tanzania in the absence of the AIDS epidemic from 1985-2000. The interaction between HIV/AIDS and economic prosperity within Cuddington's (1993b) framework focused solely on the epidemics role in reducing labour productivity within a Solow growth model. As has been discussed previously, HIV/AIDS may potentially be associated with a number of other proximate determinants of growth beyond simply its effects on increased mortality and morbidity.

The results derived from the simulation model analyses emphasise the negative relationship between HIV prevalence and economic prosperity. Despite this

compelling evidence of the impact of the epidemic, Bloom and Mahal (1997) observe a number of points of contention associated with the simulation model results. Four manifestations are identified within the simulation models that potentially could lead to biased estimates of the impact of the epidemic on economic growth. Notwithstanding Cuddington's (1993b) analysis from Tanzania, the absence of surplus labour within a wider country context may offset productivity losses. Furthermore, as the epidemic disproportionately affects the poor, failure to account for this relationship within the simulation model results may overstate the impact of the epidemic. Indeed, Bloom and Mahal (1997) argue that this link between HIV and poverty will reduce any output losses associated with the epidemic due to the low productivity, earnings and health care utilisation among the poor. In addition, the role of social networks and community initiatives may act as a potential source of support to mitigate the effects of the epidemic. This is particularly true for community-based education and treatment initiatives, as well as family support to cover monetary costs. Finally, Bloom and Mahal (1997) draw upon the life-cycle model of consumer behaviour to address the relationship between health care utilisation and personal savings. In this setting, health care expenditures will be met by reducing consumption and savings. This is in contrast to the assumption of domestic savings as the sole source of financing health care costs within the simulation model analyses.

To overcome the limitations of the existing simulation models, Bloom and Mahal (1997) contribute to the literature by directly estimating the impact of the AIDS epidemic from cross-country data on HIV prevalence and economic growth. By including HIV prevalence within an empirically established growth model, Bloom and Mahal (1997) provide the first systematic analysis of the epidemic from directly observable data. In contrast to the simulation models, the control variables included were not constrained by a theoretical paradigm. Instead, the additional explanatory variables were identified as important determinants of

economic growth from existing empirical literature, beyond those outlined within the neoclassical growth model. The nonlinear least squares regression results from the study show a significant negative relationship between the AIDS epidemic and economic growth. That is, income growth was lower in countries with larger increases in cumulative prevalence of AIDS. Indeed, each additional AIDS case per 1,000 adults per year was associated with a 0.86 percent reduction in the annual rate of per capita income growth. However, subsequent exploratory analysis that included control variables of income growth reduced the coefficient of AIDS substantially. Both the nonlinear least squares results and, more robust, nonlinear two-stage least squares estimates show that the impact of AIDS is insignificantly different from zero once these control variables are included. Bloom and Mahal (1997) conclude that the economies of those countries with higher prevalence rates of AIDS did not grow significantly slower during the period under analysis of 1980 to 1992. The results also signify the sensitivity of the AIDS epidemic estimates to the key determinants of economic growth within the regression results.

More recently, McDonald and Roberts (2006) offer the most comprehensive account to date of the impact of HIV/AIDS on economic growth. The adoption of the panel data study design represents a more fruitful basis in which to assess the mechanisms in which HIV/AIDS and economic growth interact. Indeed, the cross-country cross-section method typically employed within the growth literature negates any investigation into the internal workings between the epidemic and economic prosperity by collapsing dynamics across units. McDonald and Roberts (2006) estimate the impact of the epidemic within an augmented-Solow growth model for the period 1960-1998. They estimate the epidemic to have substantially reduced the growth rates experienced in sub-Saharan Africa. Indeed, the marginal impact on income growth was estimated to be as large as 0.59 percent within the region following a 1 percent increase in the regional prevalence rate.

This thesis aims to contribute to the literature by estimating the impact of

the HIV/AIDS epidemic on income growth using directly observable data from a more recent time period. Furthermore, by addressing potential explanations for the differing results outlined by Bloom and Mahal (1997) and McDonald and Roberts (2006), this thesis aims to elucidate, not only the estimated impact, but also the sensitivity of results to empirical specifications.

4.3 Growth Regression Models Beyond Solow

Chapter 3 outlined the strengths associated with the system GMM estimator for the textbook Solow model. This section introduces additional determinants of economic growth in light of the theoretical fragility of the textbook Solow model in empirical applications. It is clear that the factors that contribute to the growth differentials across countries extend beyond simply initial income, investment and population growth. By adopting a Barro-style growth regression approach, the additional determinants considered are not confined to a theoretical paradigm. Nonetheless, the core determinants presented are not simply piecemeal inclusions but instead aim to elucidate the differing approaches between cross-sectional and panel data designs. That is, the additional regressors included in OLS cross-sectional regressions are largely a manifestation of the need to control for country-level fixed effects through dummy variable indicators. Although the system GMM estimator was noted to be the preferred estimation approach, it is imperative to assess the relationship of the key determinants of growth at the baseline level as characterised by OLS.

The primary research objective is to quantify the impact of HIV/AIDS on economic prosperity. An essential facet of the research, therefore, is the analysis of the process of long-run economic growth. At an empirical level, the research structure can be considered to be representing two concurrent themes. Initially, the focus is on the study of the determinants of economic growth. This focus is extended by considering the structural relationship of HIV/AIDS on growth

and its determinants. Although this approach is not an empirical requirement, it does represent a preferential method. Indeed, the benefits derived from this approach are reflected in the greater understanding of each process in isolation. The differentiation reflects the change in focus from robust growth determinants to the empirical question of the role of HIV/AIDS within an established growth model. That is, the inclusion of a measure of HIV prevalence within a growth model should not be viewed as a means in which to augment the list of increasing growth determinants. Instead, the difficulty in overcoming the model uncertainty inherent within the study of growth dynamics is fully analysed under the description of 'core regressions'. This heading is used to elucidate the importance of establishing a robust growth model in which to construct and guide future analysis. Growth determinants are formalised within a Barro-style regression framework. In this setting, a synthesis of both theory and empirical research can be used in which to aid understanding of the growth process and its determinants.

The core regression results present the structural relationship between the key proximate determinants of growth. OLS estimates form the foundation in which to model this relationship. The development of subsequent model deviations away from this standard method are justified within the discussion of the core regression results. Indeed, the endogeneity of health variables may lead to biased OLS estimates. The opportunity to control for this relationship within an alternative specification provides greater scope in which to construct robust policy inferences. As previously discussed, model uncertainty represents a fundamental empirical concern within growth equations of the form of the core regression model. A synthesis of theory and previous empirical specifications provide a means in which to reduce such uncertainty. At a theoretical level, the augmented-Solow model identifies a number of salient variables that can be considered fundamental determinants of economic growth. The investment share of real GDP per capita is used as a proxy for physical capital. Population growth is measured as the

percentage change over each five year interval. The inclusion of a measure of national human capital reflects the positive relationship between education and productivity. However, difficulties remain in terms of an adequate measure of human capital. Total years of completed schooling is used as a measure of the quantity of aggregate human capital but may fail to account for the quality of education.

The notion of an income ceiling is a central premise embedded within the concept of a steady-state. Country-specific characteristics can be viewed as a direct consequence of heterogeneous national income ceilings. Geographical and policy factors have been identified as significant predictors of a country's long-run economic growth. Growth regression estimates have emphasised the constraint on economic prosperity derived from being landlocked and located in the tropics. Landlocked countries suffer higher transportation costs derived from trade activity. More recently, evidence has highlighted a further detriment to growth faced by landlocked nations. The growth experiences of landlocked countries have been shown to be partially dependent upon those of their bordering nations. In this setting, spillover effects from neighbouring countries may either restrict or promote economic prosperity. The direction of this spillover is ultimately determined by the process of achieving economic growth in the neighbouring country. Policy initiatives to promote economic reform, therefore, can be considered to extend beyond national boundaries. This conclusion is particularly pertinent for the case of HIV prevalence in landlocked nations. There are also negative effects of being located in the tropics. The ecology of tropical climates provides a prosperous environment for diseases such as malaria. Furthermore, the less fertile soil in tropical climates may further compound the productive capabilities of agricultural workers.

4.3.1 Core Regression: Determinants of Economic Growth

Table 4.1 presents the estimates for the determinants of growth for 9 consecutive five year periods over the years 1960-2004. Columns (1) and (2) report the results for the augmented-Solow model using the OLS and within-groups estimators. The results from a Barro-style growth specification are presented in Columns (3) and (4) for both OLS and the within-groups models. The determinants considered are fully representative of the growth literature with variables including initial income, education, investment, population growth as well as geographic and policy indicators. Column (1) reports the pooled OLS results for the baseline specification of the augmented-Solow model, with Column (2) including time indicator variables for the fixed effects panel data estimates.

The significant negative coefficient on initial GDP per capita supports the hypothesis of conditional convergence across all column specifications. Countries with lower income per capita at the start of each period, therefore, achieved faster growth after accounting for their infrastructural capabilities. The additional explanatory variables included in each specification are representative of such infrastructural factors that determine the steady-state income level. For Mankiw, Romer and Weil (1992), the half-life speed of convergence derived from the estimated coefficient on initial income was 35 years for their cross-section of 98 countries. The estimated half-life from the base OLS specification reported in Column (1) of Table 4.1 is 35 years. This estimate is greatly reduced to 12 years in Column (2), which controls for a country's physical environment through a within-groups estimator. The interpretation of the half-life estimate from Column (2), therefore, is that it would take an average of 12 years for poor economies to reduce half the gap in income differentials. More interestingly, however, is the sizeable reduction in the estimated half-life between the OLS estimates reported in Columns (1) and (3) and the fixed effects results reported in Columns (2) and (4) in Table 4.1. The importance of controlling for time invariant effects is

Table 4.1: Core Regression Results: OLS vs. Within-Groups

	(1)	(2)	(3)	(4)
	OLS	Within-Groups	OLS	Within-Groups
Constant	0.68 (0.23)	2.27 (0.61)	-2.44 (0.81)	-0.45 (1.76)
GDP in base year	-0.106*** (0.03)	-0.281*** (0.07)	-0.115*** (0.03)	-0.270*** (0.07)
Average Investment	0.272*** (0.04)	0.243*** (0.06)	0.147*** (0.04)	0.196** (0.08)
Population Growth	-0.056*** (0.01)	-0.070*** (0.02)	-0.053*** (0.01)	-0.084*** (0.02)
Schooling in base year	-0.090** (0.04)	-0.083 (0.09)	-0.148*** (0.05)	-0.075 (0.10)
Tropical	-0.024 (0.05)			
Landlocked	-0.009 (0.05)			
Africa	-0.044 (0.05)			
Southeast Asia	0.155* (0.09)			
Life Expectancy			0.821*** (0.22)	0.742* (0.42)
HIV Prevalence			0.009 (0.01)	-0.006 (0.01)
Openness			0.036 (0.03)	-0.015 (0.07)
Dummy, 1965-70		-0.007 (0.10)	0.189** (0.08)	0.074 (0.13)
Dummy, 1970-75		0.104 (0.09)	0.250*** (0.07)	0.130 (0.11)
Dummy, 1975-80		-0.009 (0.08)	0.104 (0.07)	0.003 (0.10)
Dummy, 1980-85		-0.144** (0.07)	-0.076 (0.09)	-0.145 (0.10)
Dummy, 1985-90		-0.064 (0.07)	-0.020 (0.08)	-0.081 (0.09)
Dummy, 1990-95		-0.173** (0.07)	-0.213*** (0.07)	-0.247*** (0.08)
Dummy, 1995-2000		0.101* (0.06)	0.098 (0.07)	0.053 (0.06)
N	682	682	564	564

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

reflected in the change in the estimated half-life between Columns (1) and (2). This effect is more astutely polarised between the panel data designs of columns (2) and (4) and the OLS analyses of columns (1) and (3). Using the estimated β coefficient on GDP per capita in the base year from Table 4.1 to derive the speed of convergence, the half-life, T , can be calculated as:

$$T = \frac{\log(2)}{\beta} \quad (4.1)$$

The half-life for the panel data fixed effects specification is estimated to be a meagre 12 years for columns (2) and (4). Although significantly smaller in magnitude than that reported by Mankiw et al. (1992), the estimate is consistent with the existing panel data literature investigating the convergence hypothesis. The five wave panel data analysis of Loayza (1994) reported a half-life of 14 years for a sample of 98 countries. As Loayza (1994) points out, however, this should not necessarily be interpreted as good news for poor economies as the half-life interpretation is confined to transitions towards a country's own steady state.

Investment and population growth have the expected signs and magnitude as predicted by the Solow model of economic growth. The overall significance level of investment is greatly reduced across columns as the specifications changes from OLS to fixed effects panel estimates. Although investment remains significant at the 5 % level, both the large economic and statistical significance obtained from the OLS models may be partly determined by country-specific characteristics beyond simply the geographic controls. The inclusion of geographic variables that may determine the steady-state level of income has received strong prominence within recent empirical research (See, for example, Gallup, Sachs and Mellinger, 1999). Dummy indicators were used to control for factors that may lead to differences in growth rates. The negative coefficients for both landlocked countries and nations located in the tropics highlight the importance of the physical environment in determining a country's rate of growth. Easterly and Levine (1997)

considers this as a manifestation of luck in the process of economic growth. That is, the fate of countries is pre-determined. This rationale embodies the premise that essential components of the growth process extend beyond the factors that can be controlled by conventional measures.

Column (1) reports the estimated results of the geographic variables for the pooled OLS model. Both the tropical dummy and landlocked indicator are not significant at any conventional level. Although both variables have the expected negative signs, the practical significance of each indicator should not be ignored. Landlocked countries can be viewed as achieving growth rates of nearly a third of a percentage point lower than their coastal neighbours. Tropical countries are further penalised by reduced growth rates of 1% over the period following a standard deviation change in the indicator. The policy indicator variable of openness to trade in Column (3) goes some way to correcting for these geographic obstacles. By capturing the quality of a country's institutions through the sum of imports and exports, this measure highlights the potential benefits derived from ensuring an environment suitable to trade. For example, a 10 percentage point increase in a country's level of openness is associated with an increase in GDP growth of a third after controlling for the standard determinants of growth.

Human capital is measured by the average years of secondary schooling in the adult population. Barro and Sala-i Martin (2004) and Bloom et al. (1999) have argued that it is secondary, as opposed to primary or tertiary education that encapsulates the essential properties of human capital. The significant negative finding on the coefficient of secondary schooling from the pooled OLS regressions is difficult to reconcile with this viewpoint. More pertinently, the negative coefficient runs counter intuitively to economic theory suggesting investments in education lead to productivity reductions. This conclusion from the OLS growth estimates appears difficult to justify. Further exploratory analysis using lagged education variables provides a potential explanation for this relationship. The

inclusion of education lagged one period changes the sign of the education coefficient from negative to positive. It is only when an additional lag is included that education achieves significance at the 5% level and retains the positive estimated coefficient. Estimates based on the within-groups estimator also highlight the incoherent finding of a negative coefficient for the measure of human capital. Nonetheless, the fixed effects panel data estimates using lagged education support the viewpoint of secondary schooling as an engine for economic growth. Although the results support the premise of a delayed diffusion of educational investments, the use of lagged levels of education severely reduce the number of observations available. The inclusion of education lagged two periods would result in a potential loss of two data points for each country, resulting in a 7 wave panel data design rather than the current 9 waves. For this reason, the thesis adopts a 9 wave study design in order to maximise the available data points. It is important, however, to interpret the education coefficients with caution due to the inference of an instantaneous return on their investment in the absence of lagged education variables. It should also be noted that the inclusion of education as an additional determinant of economic growth has had an impact on the magnitude of the coefficients of other regressors. The sole motivation for this effect reflects the loss of observations due to the limited number of data points available for cross-country estimates of human capital. Indeed, the difficulty in obtaining suitable time-series proxy measures of human capital has been previously outlined in the thesis. For example, Jones and Schneider (2006) outline the robustness of IQ as a proxy of human capital relative to standard measures within a Bayesian Model Averaging framework. The absence of national IQ data for a broad cross-section of countries limits the application for the current thesis and is further compounded by the need for time-series estimates.

Time and regional dummy indicators were also included as explanatory variables. All time dummies, with the exception of the period 1990-1995, were in-

significantly different from zero. This conclusion suggests that the reported results in column (4) are not sensitive to economic fluctuations arising from worldwide shocks to economic growth at each five-year interval. Regional dummies were included for countries in sub-Saharan Africa and Southeast Asia whose growth experiences are characterised by large deviations away from the sample mean. Given the structural characteristics that determine the steady-state level of income, Southeast Asia over-performed the rest of the world's economies by over 2 per cent per year. In contrast, growth in sub-Saharan Africa was estimated to be nearly half a percentage point lower than that explained by the regression. Bloom et al. (1998) have postulated that Africa's poor performance can be explained by the inclusion of geographic variables. The negative coefficient on the sub-Saharan Africa dummy is substantially smaller in magnitude than previous studies that have not accounted for the region's physical climate. Indeed, the geographic variables represent one explanation for the insignificant finding on the Africa dummy and the corresponding reduction in the residual.

4.4 HIV/AIDS on Economic Growth

Table 4.2 draws upon the core regression results in order to estimate the impact of the HIV/AIDS epidemic on economic growth within an established growth framework. Columns (1) and (2) replicate the pooled OLS and within-groups estimates derived in Table 4.1 in order to offer a comparison across estimators in relation to the advocated System GMM estimator. In addition to the augmented-Solow regressors, the specifications also includes measures for life expectancy, openness to trade and time dummy variables. It should also be acknowledged that Columns (2) and (3) also control for country-level fixed effects, with Column (3) also offering more robust estimates by addressing the endogeneity of regressors. The reported results for the System GMM estimator are derived from the `xtabond2` package for Stata (Roodman, 2009b). As outlined in Chapter 3, a consistent es-

timate of initial GDP per capita for short dynamic panel data models should fall between the upper and lower bounds of the OLS and within-groups estimates. The coefficient on initial income of -0.147 in Column (3) falls within the desired range of -0.115 for the pooled OLS model and -0.270 for the within-groups specification.

Table 4.2: Core Regression Results across Estimators

	(1) OLS	(2) Within-Groups	(3) SYS-GMM
GDP in base year	-0.115*** (0.03)	-0.270*** (0.07)	-0.147 (0.19)
Average Investment	0.147*** (0.04)	0.196** (0.08)	0.260 (0.28)
Population Growth	-0.053*** (0.01)	-0.084*** (0.02)	-0.208*** (0.07)
Schooling in base year	-0.148*** (0.05)	-0.075 (0.10)	-0.536 (0.55)
Life Expectancy	0.821*** (0.22)	0.742* (0.42)	0.785* (0.43)
HIV Prevalence	0.009 (0.01)	-0.006 (0.01)	0.012 (0.01)
Openness	0.036 (0.03)	-0.015 (0.07)	-0.238 (0.32)
Dummy, 1965-70	0.189** (0.08)	0.074 (0.13)	-0.175 (0.39)
Dummy, 1970-75	0.250*** (0.07)	0.130 (0.11)	-0.111 (0.35)
Dummy, 1975-80	0.104 (0.07)	0.003 (0.10)	-0.190 (0.29)
Dummy, 1980-85	-0.076 (0.09)	-0.145 (0.10)	-0.271** (0.11)
Dummy, 1985-90	-0.020 (0.08)	-0.081 (0.09)	-0.210** (0.10)
Dummy, 1990-95	-0.213*** (0.07)	-0.247*** (0.08)	-0.303*** (0.09)
Dummy, 1995-2000	0.098 (0.07)	0.053 (0.06)	0.022 (0.07)
N	564	564	564

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

A central prediction of the textbook Solow model argues that the coefficients for investment and population growth should be similar in magnitude but opposite in sign. This hypothesis is supported in the favoured model in Column (3) for the System GMM estimator, with both variables illustrating a strong practical significance for economic growth. Although the System GMM approach has been advocated as the preferred estimator on methodological grounds, the results in Column (3) fail to address the concerns over the proxy of human capital. Indeed, the anomaly concerning the marginal effect of education on economic growth across all specifications raises more general concerns regarding the measurement of human capital within growth regressions.

The System GMM has been advocated as the preferred estimator for growth regressions precisely due to its suitability for short dynamic panel data models. Although the strengths of the System GMM for growth regressions have been outlined by Blundell and Bond (1998) and Bond et al. (2001), as well as being successfully adopted by Levine et al. (2000) and Hoeffler (2002), it may not represent a panacea for dynamic panel data models. Instead, Bun and Windmeijer (2010) have recently noted the potential frailty of the System GMM in terms of weak instruments. The manifestation of this conclusion may be observed in the non-significant findings of the key growth determinants, with the exception of population growth, outlined in Column (3) in Table 4.2. By including lagged levels and lagged first differences as instruments, the System GMM estimator aims to ameliorate the weak instrument bias associated with the first-difference GMM estimator. The initial simulation results of Bun and Windmeijer (2010) suggest that the System GMM estimator may suffer from the same weak instrument bias in which it was developed to address. Although the Monte Carlo simulation results of Bun and Windmeijer (2010) represent important developments in the estimation of dynamic panel data models, caution is needed in interpreting the findings until the simulation results have been replicated using directly observable

data.

Life expectancy is included in the regressions in order to capture the productive features of population health on economic growth. The results in Column (3) provide support for the premise of health as a central input into the process of economic growth. An additional two years of life expectancy can be considered to increase the rate of economic growth by over 1.5% over the period. Although improvements in population health may lead to increased growth possibilities, a central research questions relates to the consequences of health shocks on economic growth. The inclusion of a measure of HIV prevalence offers a disease-specific estimate for the consequences of poor population health on national prosperity. The pooled OLS point estimate for HIV prevalence in Column (1) corresponds closely to the estimate reported for the System GMM estimator. Both estimates suggest that the impact of the AIDS epidemic across the full sample of countries has had a marginal and insignificant effect on the rates of national economic growth. The HIV coefficient derived from the within-groups estimator in Column (2) posits a bleaker depiction of the underlying relationship. Although not statistically significant at any conventional level, the economic significance offers a less sanguine outlook. For example, a one standard deviation change in the rate of HIV prevalence corresponds to a reduction in growth by over one percentage point over the period. By failing to account for the endogeneity of health variables and the dynamic nature of growth regressions, it has previously been argued throughout this thesis that the within-groups estimator may suffer from biased estimates. Instead, the System GMM model is advocated in order to address the econometric limitations associated with the pooled OLS, within-groups and first-difference GMM estimators. A fundamental conclusion of this chapter, therefore, implies that the HIV/AIDS epidemic has only had a marginal impact on the rates of economic growth for the full sample of countries from 1960-2004.

4.5 Tests for Conditional Convergence: Catching-up or Falling Behind?

An essential facet of the analysis of economic growth is the concept of convergence. The proliferation of research on this topic has been focused upon testing the theoretical predictions of a catching-up process of real GDP per capita. An empirical consensus has started to emerge regarding the relationship between growth, its determinants and initial income. Absolute β -convergence across a heterogeneous sample of countries has been rejected in favour of conditional β -convergence. Empirical tests for conditional convergence have reported a negative effect of initial income on growth with β commonly estimated to be around 2 per cent per year. This value is very close to the result reported in Table 4.1 for the negative coefficient on initial income. The recent consensus surrounding the estimated value of β is not without its detractors. In particular, Quah (1996) has posited an alternative viewpoint in which the estimates of conditional convergence may simply reflect a statistical artefact. That is, the reported estimates of β may occur independently of the process of convergence. Confirmatory findings of conditional convergence around 2 per cent, therefore, may simply be a manifestation of biased estimates. The inherent model uncertainty in the growth equation has a direct consequence for the interpretation of estimates of conditional convergence. More pertinently, the robustness of the estimated coefficient of initial income is sensitive to the controls implemented to condition on the steady-state. Following Durlauf et al. (2005), the growth regression equation can be stated as:

$$\gamma_i = \beta \log y_{i,0} + \psi X_i + \pi Z_i + \epsilon_i \quad (4.2)$$

Where $\log y_{i,0}$ is initial GDP per capita and X is a vector of growth determinants identified by the augmented-Solow model. X , therefore, contains the variables of population growth, physical and human capital. The additional vector,

Z , is representative of the growth determinants beyond those factors identified by the theoretical model contained in X . The consideration of the growth determinants included in Z is largely an empirical question due to the exhaustive recourse to theory. It is clear from equation 4.1 that the robustness of estimates of β convergence is fully conditional on the control variables included in Z . Bayesian approaches represent a particular method that has been implemented to address such uncertainty. By assigning probabilities to competing models, this approach structures estimates of β that average across each competing model. Doppelhofer, Miller and Sala-i-Martin (2004) adopted this Bayesian Model Averaging approach to assess whether initial income can be considered part of the linear growth model. The reported posterior probability for initial income was 1.00 and the corresponding posterior expected value for β was estimated to be -0.013. The interpretation of the negative coefficient for β provides support for conditional convergence at the rate of 1.3 per cent per year. Indeed, the posterior probability provides strong evidence in favour of conditional β -convergence, albeit with the limitation on the possible determinants included in Z .

An annual rate of convergence of 1.3 per cent suggests the reported estimates of initial income require further evaluation. For example, the reported rate of 2 per cent per annum in Table 4.1 may be related to factors that lead to both inflated and inconsistent estimates of β . The presence of measurement error would directly inflate estimates of β consistent with the hypothesis of conditional convergence. Abramovitz (1986), Romer (1990) and Temple (1998) have all considered this effect as a manifestation of the construction of the growth equation. The measurement error on growth and income operate in opposite directions resulting in a negative correlation between the measured values of the two variables, regardless of the relationship between the true values. In this setting, regression tests of convergence will produce estimates consistent with the hypothesis of β -convergence even in the absence of this behaviour.

Romer (1990) used a standard set of growth determinants to estimate the role of human capital on economic growth. The significant negative coefficient on initial GDP per capita supported the hypothesis of conditional β -convergence. Sceptical of this interpretation, Romer (1990) directly addressed the issue of measurement error in the key variables of initial income and human capital. In addition to the ordinary least squares estimates supporting β -convergence, Romer (1990) estimated a variant of this model using an instrumental variable approach. The number of radios per 1,000 inhabitants and the natural logarithm of per capita newspaper consumption were used as instruments for initial income and the literacy rate used as a proxy for human capital. In contrast to the OLS results, the coefficients on the instrumental variables were insignificant. Romer (1990) concluded that the commonly used OLS estimates of convergence are simply a characteristic of measurement error. Adopting a similar approach to that advocated by Romer (1990), it is possible to test the robustness of the OLS estimates for initial income reported in Table 4.1. Using the number of televisions as an instrument for initial GDP per capita supports the evidence in favour of conditional β -convergence. The level of significance remains at the 5 per cent level for the instrument using the set of explanatory variables reported in Table 4.1. Finally, a test of linearity is implemented by including the square of initial GDP per capita as an additional explanatory variable. In line with the finding of Barro (1991), the quadratic relationship is rejected in favour of a linear approximation due to the weak evidence on the squared term. Barro (1991) interpreted the positive coefficient on the square of initial income as evidence of diminishing returns to the rate of convergence. That is, the rate of convergence is reduced as incomes rise. The rate of convergence was estimated to be positive only for incomes below the value of \$10,800. This figure exceeded all of the 1960 level of incomes for the cross-section of countries used in Barro's (1991) sample. In contrast, a negative coefficient is reported on the square of initial income

for the specification in column 2. The interpretation of the negative coefficient provides evidence of a U-shaped relationship in the rate of convergence. Indeed, the level of income needed to achieve gains from the process of convergence was estimated to be \$588. In this setting, maintaining a minimum standard of living and infrastructure capabilities can be considered prerequisites before a process of catch-up can be realised.

The Solow growth model and its extensions provide an explanation into the differing growth paths experienced across countries. Investments in physical and human capital are considered fundamental determinants of sustained economic growth. In this setting, countries with limited investment in capital stocks, coupled with high fertility rates, experience restricted growth opportunities. Although such variables offer an explanation into the means of prosperity, the neo-classical growth model can also be used to address cross-country growth dynamics. More pertinently, the analysis can be extended beyond simply a measure of wealth to explore the growth path among the development transition. Indeed, a depiction of economic growth is incomplete without consideration of welfare implications across the development spectrum. If economic growth is narrowly defined in terms of the capacity for countries to achieve productivity gains, welfare within this context is best understood in terms of convergence. That is, emphasis is placed upon relative growth through a catching-up process of real GDP per capita. Rather than neglect such welfare implications, this premise is embedded within the Solow models predictions. More explicitly, Solow predicted that poorer countries should achieve faster growth relative to more affluent countries. The models assumption that workers are paid their marginal product is entwined within this concept of catch-up. For example, if workers are paid their marginal product, then returns to investment should be higher for low income countries that have low wages and a high surplus of labour. Therefore, capital should flow from rich to poor countries in order to take advantage of this higher

rate of return on investment.

4.5.1 Absolute β -Convergence in Real GDP per Capita

The Solow model of economic growth explicitly assumes that national growth rates are inversely related to a country's level of GDP per capita. Growth rates for poorer economies, therefore, should exceed those for more affluent countries. This rationale is embedded within the concept of a steady-state. Economies further away from their steady-state are assumed to engage in a process of catch-up through the replication and adoption of technological progress. Convergence, in this setting, is best understood in terms of the capital-labour ratio. Poorer economies are enriched by a wealth of labour but constrained by a shortage of capital. Conversely, richer economies have both a surplus of capital and costly labour force. The theoretical assumption that workers are paid their marginal product invokes predictions of an inflow of capital from rich to poorer economies to address this imbalance (Lucas, 1988, 1990). This representation can be viewed as a direct consequence of greater capital returns for the rich and increased opportunities offered by capital for the poor.

To empirically test the predictions of Solow's model in terms of a convergence of per capita incomes, a simple linear regression model was fitted with initial GDP per capita as the only independent variable on GDP growth. The regression results in Table 4.3 can be used to test the hypothesis of a catching-up process in terms of income as predicted by the Solow model. Barro and Sala-i Martin (1992) term the regression estimates of Table 4.3 as a test for 'Absolute Convergence' or ' β -Divergence'. The positive coefficient on real GDP per capita in the base year results in a rejection of this hypothesis for the full sample of countries but is supported for the homogenous group of countries within the OECD sample. An initial cursory assessment of the positive coefficient for both the full sample of countries and Africa sub-sample in Table 4.3 is difficult to reconcile with the

Solow model predictions. Indeed, the interpretation is one of divergence so that the growth rates of countries further away from their steady-state are not greater than the growth rates of countries considered to be operating at capacity. Table 4.3 also provides evidence of absolute β -convergence for the Latin America sub-sample. It is interesting to note that the results in Table 4.3 also question the common viewpoint of Africa representing a homogenous group of countries. The homogeneity of countries within each sample of Table 4.3 represents a key feature in the interpretation of the steady-state and the absence of absolute β -convergence. Indeed, it is only by acknowledging the heterogeneity within specific sub-samples that the theoretical predictions of the Solow model can be reconciled with the empirical evidence. Figure 4.1 presents a scatter plot of the relationship between initial income and economic growth across two differing samples to highlight this point further. The left panel represents the full country sample illustrating that, rather than convergence, there has been a slight tendency for a process of divergence in income levels over time. That is, across the full sample of countries analysed, the richer nations have achieved faster growth relative to the poorer nations over the past 40 years. The opposite is true, however, when the analysis is restricted to a more homogeneous group of countries. This situation is illustrated in the right hand panel of the scatter plot for the founding OECD member states. The interpretation of the downward sloping regression line for the OECD sample is that countries that had lower levels of real GDP per capita in 1960 achieved faster growth.

The presence of β -divergence within the full sample can be explained through a critique of the capital accumulation equation. Indeed, the evidence supporting the notion of absolute convergence among OECD countries relates to their degree of homogeneity. The founding members of the OECD can be viewed as sharing similar characteristics of the key values of investment, population growth and levels of technology. In contrast, the full sample of countries differ greatly

Table 4.3: Tests for Absolute Convergence across Regions

	(1)	(2)	(3)	(4)
	Full Sample	OECD	Africa	Latin America
Constant	0.21 (0.12)	2.80 (0.23)	0.02 (0.39)	0.76 (0.39)
GDP in base year	0.002 (0.21)	-0.263*** (0.02)	0.013 (0.05)	-0.066 (0.05)
N	942	253	236	231

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

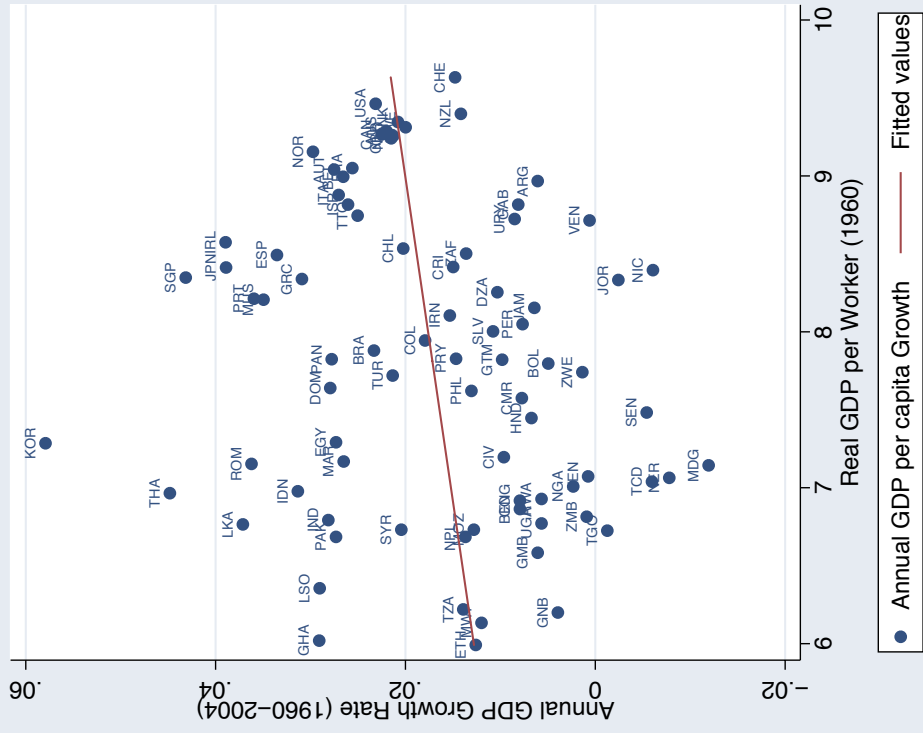
* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

in this regard. The implication from this conclusion is that not all countries share the same steady-state values. Instead, there are multiple steady-states in which each country moves towards its own unique point, resulting in differential growth experiences. The absence of absolute convergence across countries provided the impetus for the development of endogenous growth theory. In contrast, proponents of the Solow model argued that the manifestation of heterogeneous characteristics across countries reinforced the models central predictions. In this setting, they argued that what was needed was a means of conditioning on individual country infrastructure and behaviour. That is, the catching-up process is now one of conditional rather than absolute convergence. Chapter 5 extends upon this premise by adopting a quantile regression approach to assess the heterogeneity in convergence rates across the conditional growth distribution.

Convergence among Samples

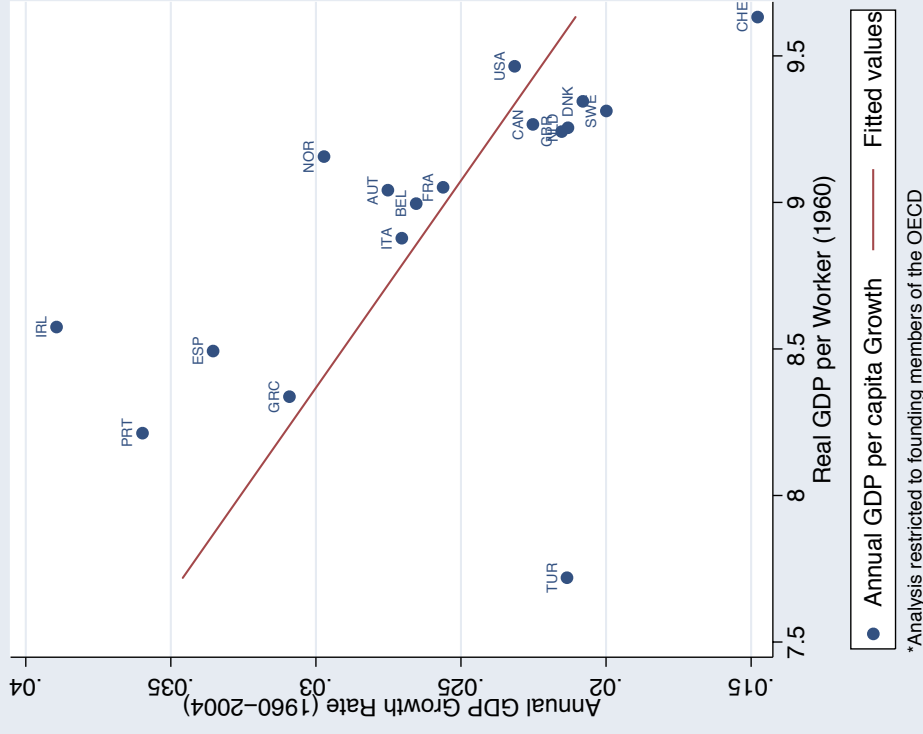
β Convergence across Countries

Growth Rate versus Initial Level of Real GDP



β Convergence across OECD Countries

Growth Rate versus Initial Level of Real GDP



*Analysis restricted to founding members of the OECD

Figure 4.1: Scatterplot of Absolute Convergence for the Full Sample and OECD Member States

4.6 Summary

This chapter has estimated the impact of the AIDS epidemic on economic growth within a dynamic panel data model. Estimates derived from the within-groups estimator highlight the substantial productivity losses associated with the HIV/AIDS epidemic for the full sample of countries. The econometric frailties of this estimator for short dynamic panel data models with endogenous regressors suggests that caution is needed in interpreting the estimated sizeable impact. Instead, the preferred estimation method of system GMM offers confirmatory support for the first-difference GMM results of McDonald and Roberts (2006) for their full sample of countries. An obvious extension of the analysis presented in this chapter may be to replicate the results for specific sub-samples. Indeed, an insight into the estimated impact of the epidemic beyond the world level is a pre-requisite in order to derive robust policy inferences. The methodology adopted in Chapter 5 attempts to reconcile this potential shortcoming by suggesting a sub-sample approach would merely offer average treatment effects across geographic regions. Nonetheless, this thesis offers an alternative approach to sub-sample analysis in which to capture parameter heterogeneity. This potentially more fruitful design will model the relationship between HIV/AIDS and economic growth across the conditional growth distribution. Chapter 5 adopts a quantile regression approach to estimate the impact of the HIV/AIDS epidemic as well as further developing insights into the convergence hypothesis.

Chapter 5

Quantile Regression Estimates of the AIDS Epidemic on Economic Growth

5.1 Introduction

The estimated impact of the HIV/AIDS epidemic on economic growth reported in Chapter 4 emphasised the importance of health when formulating macroeconomic policy decisions. Although improvements in population health may provide an impetus to sustained economic growth, health shocks may pose a more forceful barrier. The policy prescription of 'shock therapy' within the former Soviet Union has been used as a benchmark in which to assess the consequences of macroeconomic policy when failing to account for the role of health. Stuckler et al. (2009) estimated a large short term increase in adult male mortality rates of over 12% within the Soviet Union during the transition from a centrally planned to market economy. The relationship between population health and macroeconomic outcomes is an essential feature of policy agendas within the international aid community. An essential aspect of applied economics research, therefore,

is concerned with robust estimates in which to guide policy positions. In this setting, the need for an appropriate study design is a pre-requisite in which to draw inferences suitable for policy-makers. By drawing upon the methodological stance outlined in Chapter 2, this Chapter complements the existing estimates of the relationship between HIV/AIDS and economic growth through a quantile regression framework.

The existing empirical studies estimating the relationship between economic growth and the HIV/AIDS epidemic have concentrated on the conditional mean of the growth distribution. McDonald and Roberts (2006) highlight the substantial heterogeneity in the marginal effect of the epidemic on economic growth for specific geographic and economic sub-samples. The interpretation of such estimates can be viewed in terms of the impact for the average economy within each sub-sample. That is, the significant negative marginal effect observed for the sub-Saharan African sample illustrates that a 1% increase in HIV prevalence would reduce the growth rate for the average sub-Saharan African economy by 0.55% per annum. A potential shortcoming of such conditional mean estimates relates to the homogeneity of countries within each sub-sample. The economic sub-sample of high income countries used by McDonald and Roberts (2006) can be considered to be reasonably homogeneous in terms of each country's characteristics. In this setting, the conditional mean may provide estimates that closely characterises the behaviour of the average economy for the high income sub-sample. Instead, conditional mean estimates may offer limited information regarding the estimated impact for countries that can be considered sub-sample outliers in which their experiences deviate from the mean. The estimated impact for the sub-Saharan African sample reported by McDonald and Roberts (2006) may not capture the large heterogeneity within the region. Indeed, the growth experiences of Botswana magnify the substantial variation that exists within sub-Saharan Africa. Over the past 40 years, Botswana has achieved growth rates sim-

ilar in magnitude of other high performing economies, such as Singapore, South Korea and Hong Kong. This achievement is all the more remarkable given that the growth has coincided with the country experiencing one of the world's worst HIV/AIDS epidemics. As Heckman et al. (1997) acknowledge, the premise of a "common effect" from conditional mean estimates explicitly assumes a uniform effect for countries sharing similarly observed characteristics.

5.2 Motivation for a Quantile Regression Approach for Growth Regressions

A complementary empirical design to the antecedents developed by Bloom and Mahal (1997) and McDonald and Roberts (2006) have been proposed in the form of median regression techniques. The use of quantile regression methods for growth analyses are still in their infancy relative to conditional mean estimates. In particular, there is a paucity of empirical growth studies estimating quantile regression models for cross-sectional data. It is perhaps not surprising, therefore, that fixed effects quantile regression models are under-utilised given the dominance of cross-sectional methodological designs for growth regressions. The absence of quantile regression routines for panel data in commercial statistical software packages can be considered a primary constraint on the number of empirical papers adopting such techniques. Koenker and Bassett (1978) has remained a prominent advocate of quantile regression methods to address a number of applied economic questions. Indeed, Koenker's research has been an influential force in both theoretical and empirical developments in the field through the promotion of open source software in which to replicate estimation procedures. The analysis presented in this chapter draws heavily upon the `rq.fit.panel` routine developed by Roger Koenker for the R programming language ¹.

¹The `rq.fit.panel` code is currently available on Professor Koenker's research page at the following address: <http://www.econ.uiuc.edu/~roger/research/panel/rq.fit.panel.R>

The quantile regression approach for growth analysis represents a natural extension to the prominent panel data designs denoted in equation 2.6. An essential motivation for the deviation away from conditional mean estimates is the need to assess the relationship between regressors for the entire growth distribution. In order to specify the quantile regression approach, equation 2.6 can be re-written to take the following structural form presented by Koenker and Xiao (2002):

$$Q_{yit}(\tau|x_{it}) = \alpha_i + x_{it}^T\beta(\tau) \quad t = 1, \dots, m_i, \quad i = 1, \dots, n. \quad (5.1)$$

Where y represents the conditional quantile function of economic growth for country i at time t . Parameter heterogeneity is introduced by assuming that the covariates denoted by x_{it} may depend upon the quantile, τ . Panel data estimates of growth regressions explicitly address the issue of unobserved heterogeneity. The quantile regression specification in equation 5.1 purges the fixed effects within the parameter, α . More pertinently, the fixed effects are assumed to be independent of the quantile function represented by τ . Nonetheless, the elimination of the fixed effects is not a prerequisite for panel data quantile regressions. Koenker (2004) has noted the possibility of estimating country-specific distributional shifts captured within $\alpha_i(\tau)$ for a large heterogeneous sample of countries. The practicalities of estimating a τ -dependent country-specific distributional shift are limited within the context of growth analysis. Indeed, the fixed number of countries in the world results in a rather modest m_i despite the advantages of panel data designs.

An intuitive appeal attached to equation 5.1 relates to the ability to vary the parameter τ in order to estimate differing marginal effects across the conditional growth distribution. In essence, the quantile regression approach offers a greater insight into the relationship between the covariates and the dependent variable at differing points on the growth distribution. The median marginal change is, therefore, represented by τ^{50} . In terms of the convergence hypothesis, the coefficient on initial income βy_{it-1}^{75} can be interpreted as estimating the marginal change

in growth for countries in the top 25% of the conditional growth distribution. In contrast, conditional mean estimates implicitly assume a common effect in which the regressors are constrained to have a uniform marginal effect across quantiles of the growth distribution. The ability to capture parameter heterogeneity offers more fruitful policy insights into the growth process by offering estimates on the speed of convergence and policy variables at differing ranges of τ .

The world distribution of income also offers an insight into the motivation of median regression techniques for growth regressions. Figure 5.1 plots the distribution of income across the full sample of countries in 1960, 1980 and 2000.

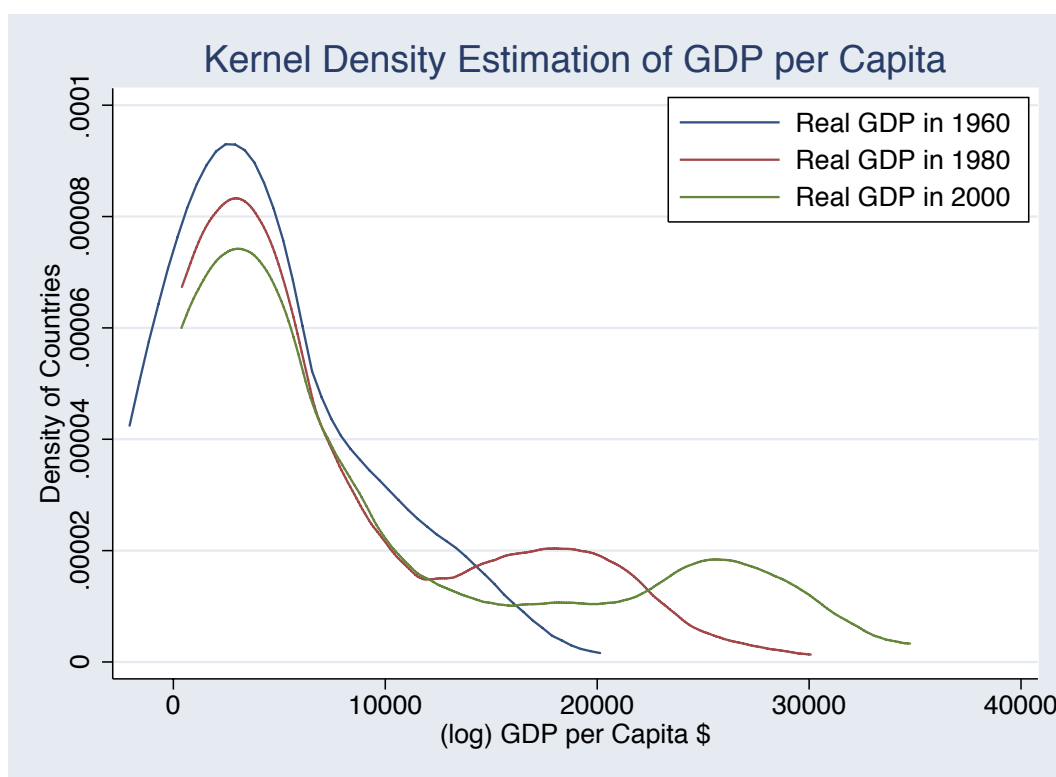


Figure 5.1: Kernel Density Estimates of Real GDP per Capita

At this stage, the observed evolving shape of the world distribution of income over time is not the primary concern but the consequences of this distributional feature will be addressed in Chapter 6. Instead, Figure 5.1 illustrates that the world distribution of income is highly skewed to the right. In this setting, there is evidence of polarisation between the large number of low income countries and a

small group of very rich economies. A consequence of this distributional feature is that the mean of economic growth will be sensitive to the high income outliers, resulting in a mean figure in excess of the median. Estimates based on the mean may, therefore, not fully represent the relationship of economic growth. Estimates based on the conditional median may, therefore, provide a representation more closely aligned to the growth experiences of countries.

5.3 Literature Review on Quantile Panel Data Regressions

The developments by Arellano and Bond (1991) and Blundell and Bond (1998) provided the foundations for the wealth of literature focusing upon dynamic panel data models with fixed effects. More robust estimation procedures have extended upon these foundations by accounting for the bias inherent in the first-differenced GMM estimator for short dynamic panel data models. Although still in its infancy, the area has contributed to the direction of growth analysis through a number of seminal papers. Despite Koenker's diligent endeavours in the development and advocacy of quantile regression methods, there remains a paucity of empirical papers adopting a quantile regression approach for panel data. This case is polarised in the field of growth analysis in which there remains a meagre number of empirical papers estimating quantile regressions for either cross-sectional or panel data designs. To present an application of quantile regression approaches, a review of the literature needs to extend beyond the confines of growth analysis.

Koenker and Hallock (2001) offer an insight into the advantages of quantile regressions through an assessment of conditional mean estimates for infant birth weight and the Engel Curve. Using cross-sectional natality data for a sample of 198,377 babies, Koenker and Hallock (2001) adopted a quantile regression approach to assess the determinants of infant birth weight. More pertinently,

whether a mother's socio-economic characteristics was a determinant for the low birth weight of their child. By considering the effect of the covariates on the conditional distribution of infant birth weight, Koenker and Hallock (2001) highlight the loss of information associated with the conditional mean estimator. That is, the OLS point estimate did not account for the parameter heterogeneity across the conditional distribution of infant birth weight. For example, the quantile regression results estimated that boys were about 45 grams heavier at the 0.05 quantile compared to 130 grams heavier at the 0.95 quantile. Koenker and Hallock (2001) also considered the relationship between food expenditure and household income as depicted by the Engel Curve. In an earlier study, Deaton (1997) estimated the relationship of the Engel Curve using household survey data from Pakistan by adopting a quantile regression approach. Both empirical studies highlight the dispersion around the conditional mean estimate when accounting for the quantile regression lines and note a greater insight into the estimated impact of the covariates.

Gamper-Rabindran et al. (2010) adopted a quantile panel data approach to estimate the impact of piped water provision on the under-1 infant mortality rate (IMR) in Brazil. The estimated results were derived from the quantile regression approach of Chen and Khan (2008) for censored panel data models. Although the estimation procedure is specific for censored data, the design and results offer important policy and econometric insights. By accounting for the heterogeneity inherent in program treatment effects, the reported results offer robust policy inferences for targeting piped water interventions. The estimated impact of the provision of piped water was noted to have a significantly larger reduction in infant mortality at the higher conditional quantiles of the IMR distribution. For a sample of countries with poor development indicators over the period 1980-1991, a one percentage point increase in the number of households receiving piped water resulted in a reduction of 0.86 births per 1,000 live births at the 90th percentile

of the conditional IMR. In contrast, the estimated result at the 10th percentile from a one percentage point increase was reported to lead to a reduction of 0.37 deaths. Gamper-Rabindran et al. (2010) concluded that the estimated marginal effect of 0.68 deaths per 1,000 live births at the conditional mean offered a poor indication of the impact of piped water provision across the IMR distribution.

Lamarche (2008) conducts a fixed effects quantile regression evaluation of the returns to a private school voucher program on educational attainment. The provision of school vouchers are used to enhance the opportunities for students to undertake private schooling and the promotion of school choice. A primary motivation for voucher programs relates to the presupposition of a greater level of productivity and quality of education among private schools relative to the public educational system. By offering tuition support through the school voucher program, governments aim to encourage individuals to take advantage of the increased efficiency associated with private schooling. A central feature of the evaluation was to assess the impact of selection choice into the program on the conditional distribution of educational test scores. That is, the program aimed to estimate the selectivity bias concerning program uptake, as well as an assessment of the differences between educational attainment for public schools and individuals in receipt of vouchers within private schooling. The identification of an appropriate control group in which to evaluate the voucher program represented a fundamental methodological challenge. In order to address the design limitation of standard voucher programs, Lamarche (2008) constructed a sample of individuals who applied to the program between 1990 and 1993 and a control sample of students from the Milwaukee public school system. The treatment group was comprised of African American and Hispanic students who applied to the Milwaukee Parental Choice program. A central motivating factor behind the study design was to gain an insight beyond the average student by accounting for heterogeneous treatment effects. Lamarche (2008) concludes that the distribution

of achievement gains derived from the program were stronger and positive among weaker students relative to the previous high achieving students. In contrast to the conditional mean estimates which considered the program to have no effect on reading, the quantile regression results also denoted a differential effect across the conditional distribution. That is, the weaker students were observed to yield the greatest benefits from the Milwaukee Parental Choice program.

Mello and Perrelli (2003) offer one of the earliest empirical applications of quantile regressions for growth analysis. Although confined to cross-sectional data, the results offer important insights into the growth process by introducing parameter heterogeneity for the key determinants of economic growth. The absence of absolute convergence using OLS for a heterogeneous sample of countries is well established within the growth literature. Mello and Perrelli (2003) question the robustness of this conclusion by estimating the convergence process across the conditional growth distribution. In contrast to the uniform point estimate for the conditional mean, the quantile regression results for absolute convergence illustrate a positive effect in the lower tail and a negative effect in the upper tail of the growth distribution. The heterogeneity in the coefficient estimates across the conditional growth distribution are polarised when considering the effect at the median and 95th quantile. As Mello and Perrelli (2003) conclude, the estimates of absolute convergence at the 50th quantile imply a speed of convergence of almost zero and a half-life of 2,310 years. In contrast, the estimated speed of convergence at the 95th quantile was 0.91% per year, corresponding to a half-life of 76 years. By adopting a Barro-equation approach for growth regressions, Mello and Perrelli (2003) also estimate the impact of the determinants on the conditional growth distribution. The results confirm that conditional mean estimates of growth regressions may not provide adequate information on the estimated impact of regressors across the conditional growth distribution.

More recently, there has been an expansion in the interest of quantile re-

gressions for applied economic research. Dufrenot et al. (2010) and a working paper by Alexander et al. (2009) offer insightful contributions to the application of quantile regressions and the use of modern econometric methods. Nonetheless, the use of quantile regressions are dominated by cross-sectional methodological designs. The limited diffusion of quantile regression approaches in panel data studies is illustrated by the paucity of empirical papers estimating fixed effects quantile regressions. Progression towards the development of quantile regression approaches within a panel data framework offers an important contribution to the expanding field.

5.4 Economic Growth: A Quantile Panel Data Approach

The quantile regression model with fixed effects outlined in equation 5.1 can be considered a general model in which to address the econometric challenges of growth regressions. A central feature of growth analysis concerns the presence of convergence. In this setting, a more fruitful empirical design would account for the dynamic nature between economic growth and initial income. The endogeneity of regressors also limits the application of equation 5.1 within the context of growth analysis. Nonetheless, a central aim of this chapter is to offer an exploratory analysis into quantile regressions with fixed effects for growth research. The current literature addressing the endogeneity of regressors for quantile regressions is almost exclusively confined to cross-sectional study designs. In a series of papers, Chernozhukov and Hansen (2004, 2005, 2006, 2008) present an instrumental variable approach for quantile regressions using cross-sectional data. Given the paucity of applied research utilising quantile regressions with panel data, it is only more recently that the contributions by Victor Chernozhukov and Christian Hansen have been developed for panel data designs. Harding and

Lamarche (2009) and Galvao and Montes-Rojas (2009) offer an initial assessment of the underlying distributional properties of the instrumental variable quantile regression approach based on Monte Carlo simulations. Despite this progression, instrumental variable quantile regression approaches for panel data are very much in their infancy. This case is particularly pertinent when considering the implications for short dynamic panel data models which are characterised by large n , small t as used in growth analysis. The absence of a dominant empirical direction for short dynamic panel data models with endogenous regressors suggests that it is more feasible to offer an exploratory analysis into the growth process. This decision is supported by the paucity of empirical papers highlighting the need to develop the field for panel data quantile regressions before progressing to greater econometric challenges.

5.4.1 Pooled Quantile Regression Estimates

A natural starting point in which to assess the textbook Solow model within a quantile regression framework is to pool the data. The aim of this exploratory analysis is to test whether estimates based on the conditional mean are similar in magnitude to the coefficients for specified quantiles. An essential empirical question relates to the Solow model prediction that poorer economies achieve faster growth rates than richer economies. In this setting, the question relates to whether there is convergence in real GDP per capita over time. To test for this convergence hypothesis, a simple linear regression of GDP growth on initial income can be used to capture the presence of unconditional convergence. The estimates reported in Chapter 4 reject the notion of unconditional convergence for a heterogeneous sample of countries. Instead, a process of 'catch-up' in terms of real GDP per capita was observed only after controlling for country-specific structural characteristics for the full sample of countries.

Table 5.1 reports the unconditional convergence estimates derived from a

quantile regression approach.

Table 5.1: Pooled Quantile Regression Estimates of the Convergence Hypothesis

	(1)	(2)	(3)	(4)	(5)
	QR ₁₀	QR ₂₅	QR ₅₀	QR ₇₅	QR ₉₀
Constant	-1.19 (0.24)	-0.51 (0.10)	0.21 (0.12)	1.11 (0.15)	2.58 (0.27)
GDP in base year	0.117*** (0.03)	0.063*** (0.01)	0.03 (0.01)	-0.080*** (0.02)	-0.223*** (0.03)
N	942	942	942	942	942

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

If the conditional mean provides a suitable representation of the conditional growth distribution then the estimated coefficients on initial income should be uniform. The parameter heterogeneity across quantiles in Table 5.1 raises questions regarding the robustness of conditional mean estimates when testing the convergence hypothesis. A positive coefficient on initial income can be interpreted as providing evidence against unconditional convergence for the full sample of countries. That is, a unit increase in real GDP per capita would be expected to be associated with higher growth rates. The estimates in Table 5.1 generally support the overall finding of absolute β -divergence reported in Chapter 4 for quantiles lower than and including the median. In contrast, absolute β -convergence is observed for quantiles above the median. To polarise the change in the coefficient sign on initial income, Figure 5.1 reproduces the estimates of absolute convergence for all quantiles.

A coefficient on initial income across quantiles that is greater than zero can be used to reject the convergence hypothesis. The conditional mean estimate lies almost equal to the zero-threshold and is represented by the bold dashed line. As an approximate visual reference, therefore, coefficients on initial income which are below or above the OLS estimate provide support for either unconditional β -convergence or divergence. The corresponding OLS confidence interval in Figure

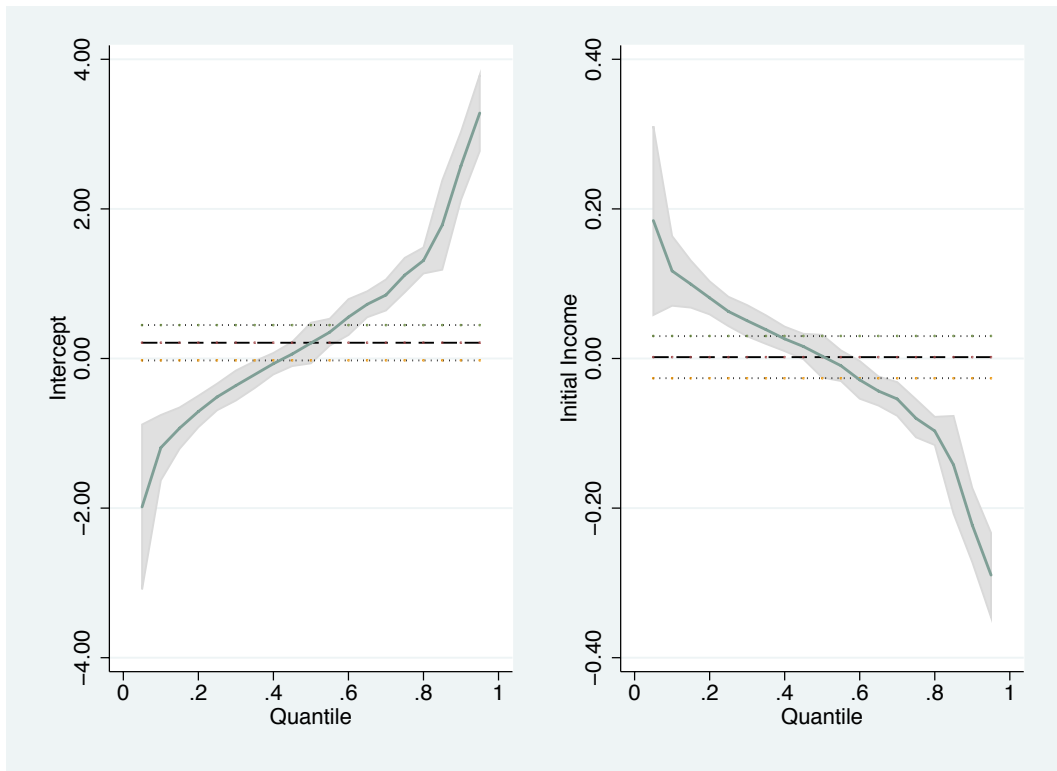


Figure 5.2: Quantile Regression Estimates of the Convergence Hypothesis

5.1 is represented by the two dotted lines. As illustrated in Figure 5.1, the quantile regression estimates display a concave relationship in which there is evidence of a change in the relationship at the median and a strong process of convergence is observed at the 60th quantile. Indeed, the process of convergence increases with the level of τ . That is, the speed of convergence is greater for countries in the upper quantiles of the growth distribution. For example, the coefficient at τ^{90} implies that a one unit increase in initial income leads to reduction in the annual rate of economic growth by almost a quarter. This finding of unconditional convergence for a broad heterogeneous sample of countries is in contrast to the established estimates for the conditional mean. In this setting, a quantile regression approach offers a greater insight into the convergence process.

An intuitive appeal of a quantile regression approach is to assess the degree of parameter heterogeneity for key policy variables. Table 5.2 presents the pooled quantile regression estimates of the textbook Solow model to assess the marginal

effect of the covariates at differing quantiles. Column (1) corresponds to the pooled OLS estimates and Columns (2) to (4) represent estimates at specific quantiles. For example, Column (3) reports the estimated results derived from a median regression specification. The observed differences between the conditional mean estimates in Column (1) and the median estimates in Column (3) highlight the potential benefits of a quantile regression approach for growth research. To further polarise the differences between mean and median estimates, Figure 5.3 plots the coefficients of the quantile regression estimates for each regressor reported in Table 5.2.

Table 5.2: Pooled Quantile Regression Estimates of the Solow Model

	(1)	(2)	(3)	(4)
	OLS	QR ₂₅	QR ₅₀	QR ₇₅
Constant	0.56 (0.15)	-0.02 (0.12)	0.51 (0.08)	1.40 (0.15)
GDP in base year	-0.111*** (0.02)	-0.070*** (0.01)	-0.096*** (0.01)	-0.167*** (-0.02)
Average Investment	0.262*** (0.03)	0.282*** (0.02)	0.222*** (0.02)	0.201*** (0.03)
Population Growth	-0.050*** (0.01)	-0.047*** (0.01)	-0.040*** (0.01)	-0.051*** (0.01)
Dummy, 1965-70	0.132** (0.06)	0.151*** (0.05)	0.119*** (0.03)	0.059 (0.06)
Dummy, 1970-75	0.208*** (0.06)	0.136*** (0.04)	0.152*** (0.03)	0.183*** (0.06)
Dummy, 1975-80	0.099* (0.06)	0.063 (0.04)	0.086*** (0.03)	0.021 (0.05)
Dummy, 1980-85	-0.072 (0.06)	-0.101** (0.04)	-0.092*** (0.03)	-0.103** (0.05)
Dummy, 1985-90	0.012 (0.06)	0.034 (0.04)	0.055* (0.03)	0.005 (0.05)
Dummy, 1990-95	-0.125** (0.06)	-0.078* (0.04)	-0.023 (0.03)	0.022 (0.05)
Dummy, 1995-2000	0.115* (0.06)	0.063 (0.04)	0.040 (0.03)	0.050 (0.05)
N	859	859	859	859

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

The bold dashed line in each panel of Figure 5.3 corresponds to the OLS estimate and the two dotted lines represent the OLS confidence interval. For each of the key drivers of the textbook Solow model, the quantile regression estimates extend beyond the OLS confidence intervals. In this setting, the presence of parameter heterogeneity offers a greater insight into the dynamics of economic growth. This situation is clear from the differing coefficient estimates at specific quantiles. Indeed, a test of the equality of coefficients supports this premise with the coefficient on initial income producing conflicting estimates across quantiles ($p < 0.001$). The convergence hypothesis may therefore be more complex than a location-shift effect. That is, the impact of the regressors may not simply alter the mean of the conditional growth distribution. Instead, the regressors may also change the skewness and kurtosis of the distribution.

The heterogeneity in coefficient estimates for initial income also offers important insights into the convergence process. For countries located in the lowest 25% of the conditional growth distribution, the speed of convergence is estimated to be around 1.5% per annum. This estimate is lower than the commonly reported speed of convergence of 2% observed from cross-sectional growth regressions. More worryingly, however, is the divergence between the lowest and highest 25% of the conditional growth distribution in terms of convergence. For the high growth performing economies, the speed of convergence is estimated to be in excess of 3.5% per annum. The disparity between convergence estimates can be further polarised when considering a half-life calculation. For example, the corresponding half-life estimates are 45 years and 19 years for the lowest and highest countries for the conditional growth distribution.

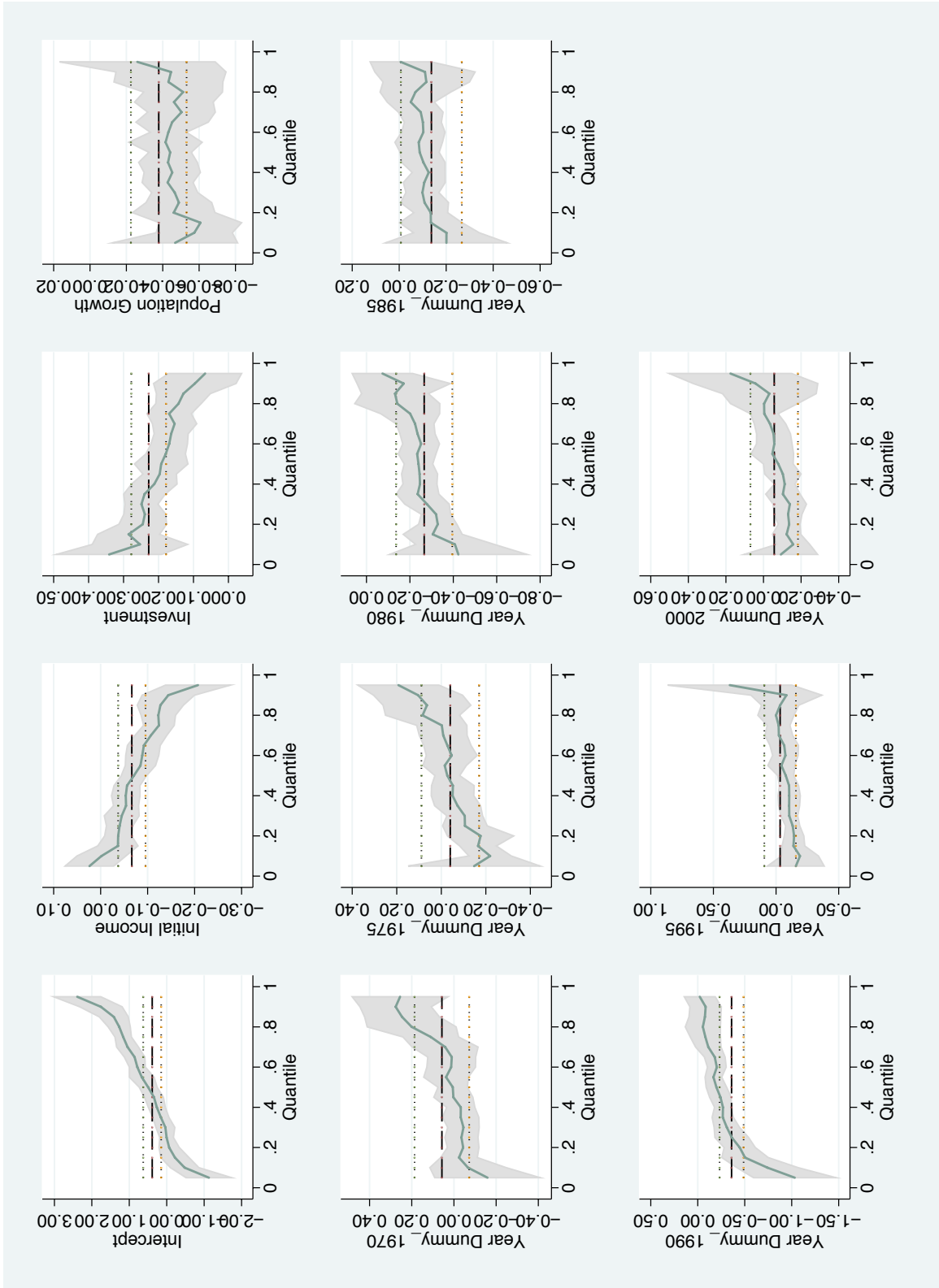


Figure 5.3: Quantile Regression Estimates for the 'Textbook' Solow Model

Koenker and Xiao (2002) extend the work of Khmaladze (1981) by developing a statistical test suitable for quantile regressions. The Khmaladze test is an assessment of the underlying hypothesis that the change in the growth distribution is of the form of a location-shift or location-scale effect. The location-shift hypothesis is based on the assumption that the slope coefficients from the quantile regression estimates are constant and independent of the quantile, τ . A central aim of the Khmaladze test is to assess whether the covariates impact only on the mean of the conditional growth distribution. Failure to reject this hypothesis would provide support for the OLS estimator for growth regressions. This rationale is reflected in the alternative hypothesis which is concerned with whether the covariates affect the mean, skewness and kurtosis of the conditional growth distribution. The location-scale hypothesis can, therefore, be defined as testing whether the covariates alter the shape of the conditional distribution in addition to the scale and location (Koenker and Xiao, 2002). In this setting, the Khmaladze test is concerned with two hypotheses concerning the role of the quantile treatment effect. For a pure location-shift, the impact of the quantile treatment effect would be confined exclusively to a change in the location of the conditional distribution. The location-scale hypothesis can be considered an extension of a pure location-shift by testing whether the quantile treatment effect also impacts on the variance as well as the location of the conditional distribution. In this setting, the location-scale hypothesis is analogous to a linear regression model with heteroskedastic errors (Koenker, 2005).

	Location-shift	Location-scale
GDP in base year	0.878	1.361
Average Investment	1.481	1.883
Population Growth	3.467	2.103
Joint Test Statistic	8.143	4.742
N	859	859

The critical values, as outlined by Koenker and Xiao (2002), are 2.483, 1.986, 1.730, at the 1%, 5% and 10% level for the individual coefficients and 4.893, 4.133 and 3.749 at the 1%, 5%

and 10% level for the joint test statistic.

Table 5.3 reports the results from the Khmaladze test for both the location-scale and location-shift hypotheses for the textbook Solow model. Koenker and Xiao (2002) outline the critical values used for the Khmaladze test for quantile regressions. The joint test statistic for the location-scale hypothesis for the textbook Solow model in Table 5.3 is 4.742. In line with Koenker and Xiao (2002), the critical value at the 5% level of significance is 4.133. As a result, the location-scale null hypothesis can be rejected. The corresponding joint test statistic for the location-shift hypothesis in Table 5.3 is 8.143, with a critical value at the 1% level of significance defined as 4.893. It is clear, therefore, that the location-shift null hypothesis can also be rejected. By rejecting each null hypothesis for the location-shift and location-scale models, the Khmaladze tests support the use of quantile regression methods for growth regressions. Although conditional mean estimates consider the presence of a location-shift for the treatment effect, they ignore a number of important distributional changes. In particular, the rejection of the location-scale null hypothesis supports the premise that key determinants of economic growth not only affect the location but also the dispersion and skewness of the conditional growth distribution. Table 5.3 also reports the test statistics for the individual coefficients of the textbook Solow model for both the location-scale and location-shift hypotheses. The test statistics for the individual coefficients can be considered as identifying the magnitude of each covariate in terms of its contribution to the location-scale and location-shift effects. Table 5.3 illustrates that population growth has the largest contribution for both the location-shift and location-scale hypotheses, with a significant test statistic at the 1% and 5% level, respectively. Investment also has a significant test statistic at the 10% level for the location-scale hypothesis, while real GDP per capita is non-significant for both the location-scale and location-shift hypotheses.

5.4.2 Quantile Regression Estimates with Fixed Effects

The estimates reported in Table 5.2 and further illustrated in Figure 5.3 suffer from the same limitations as the OLS estimates derived in Chapter 4. Instead, a more fruitful quantile regression estimator would control for the time invariant factors inherent in panel data growth regressions. The specification derived by Koenker and Xiao (2002) in equation 5.1 suitably addresses the unobserved heterogeneity through the parameter α . In order to derive quantile regression estimates that control for the country-specific fixed effects, equation 5.1 can be estimated within a two stage process. By performing a mean deviation transformation on the panel data, the fixed effects can be considered to be purged within this initial stage. If the fixed effects are controlled within the initial stage, a pooled quantile regression estimator can then be used to derive coefficients that are identical to a quantile regression approach with fixed effects. That is, the two stage process can be characterised as:

$$\Delta y_{it} = \alpha \Delta y_{i,t-1} + \Delta x'_{it} \beta + \Delta v_{it}$$

$$Q_{yi}(\tau|x_i) = \alpha_i + x_i \beta(\tau) \quad i = 1, \dots, n. \quad (5.2)$$

Although the coefficients for the second stage of equation 5.2 (pooled quantile) will be identical to a quantile regression model with fixed effects, the corresponding standard errors will be biased. The rationale for the bias is due to a failure to account for the loss of degrees of freedom following the mean deviation transformation within the second stage analysis. To partly address this limitation, Table 5.4 replicates the pooled quantile regression estimates using an estimator to address the country-specific fixed effects and reports bootstrapped standard errors. Column (1) corresponds to the within-groups estimates of the textbook Solow

model reported in Chapter 3. In line with the results of the previous Chapter, the coefficient on initial real GDP per capita is higher in magnitude than the pooled estimates. The remaining columns in Table 5.4 provide the estimates across differing values of τ .

Table 5.4: Fixed Effects Quantile Regression Estimates of the Solow Model

	(1) Within-Groups	(2) QR ₂₅	(3) QR ₅₀	(4) QR ₇₅
Constant	2.52 (0.48)	1.92 (0.48)	1.91 (0.25)	2.38 (0.68)
GDP in base year	-0.339 (0.54)	-0.298*** (0.06)	-0.277*** (0.06)	-0.307*** (0.09)
Average Investment	0.270 (0.48)	0.315*** (0.06)	0.283*** (0.06)	0.267*** (0.07)
Population Growth	-0.060*** (0.01)	-0.034 (0.03)	-0.037* (0.02)	-0.059** (0.03)
Dummy, 1965-70	0.001 (0.07)	-0.041 (0.06)	0.038 (0.03)	0.049 (0.09)
Dummy, 1970-75	0.100* (0.06)	-0.016 (0.06)	0.059** (0.03)	0.180** (0.08)
Dummy, 1975-80	0.019 (0.06)	-0.050 (0.06)	0.002 (0.02)	0.002 (0.07)
Dummy, 1980-85	-0.124** (0.05)	-0.224*** (0.05)	-0.123*** (0.03)	-0.118* (0.07)
Dummy, 1985-90	-0.031 (0.05)	-0.069 (0.05)	0.022 (0.03)	-0.000 (0.06)
Dummy, 1990-95	-0.155*** (0.05)	-0.148*** (0.05)	-0.067** (0.03)	-0.011 (0.06)
Dummy, 1995-00	0.089* (0.05)	0.001 (0.05)	0.037 (0.03)	0.051 (0.06)
N	859	859	859	859

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

To see the homogeneity of estimates more clearly, Figure 5.4 reproduces the estimates obtained in Table 5.4. In contrast to the pooled quantile regression plot, the bold dashed line in Figure 5.4 corresponds to the within-groups estimator. In addition, the two dashed lines represent the confidence interval for the within-groups estimator. The coefficients for initial income are reasonably

uniform across levels of τ with the exception of the top 25% of the conditional growth distribution. Indeed, the speed of convergence is reported to be greater for the high growth performing countries, albeit not as high as the level reported for the within-groups estimator. For both investment and population growth, the within-groups estimator appears to offer a reasonable fit of the data. This is illustrated with the coefficients across all quantiles remaining between the confidence interval of the within-groups estimator.

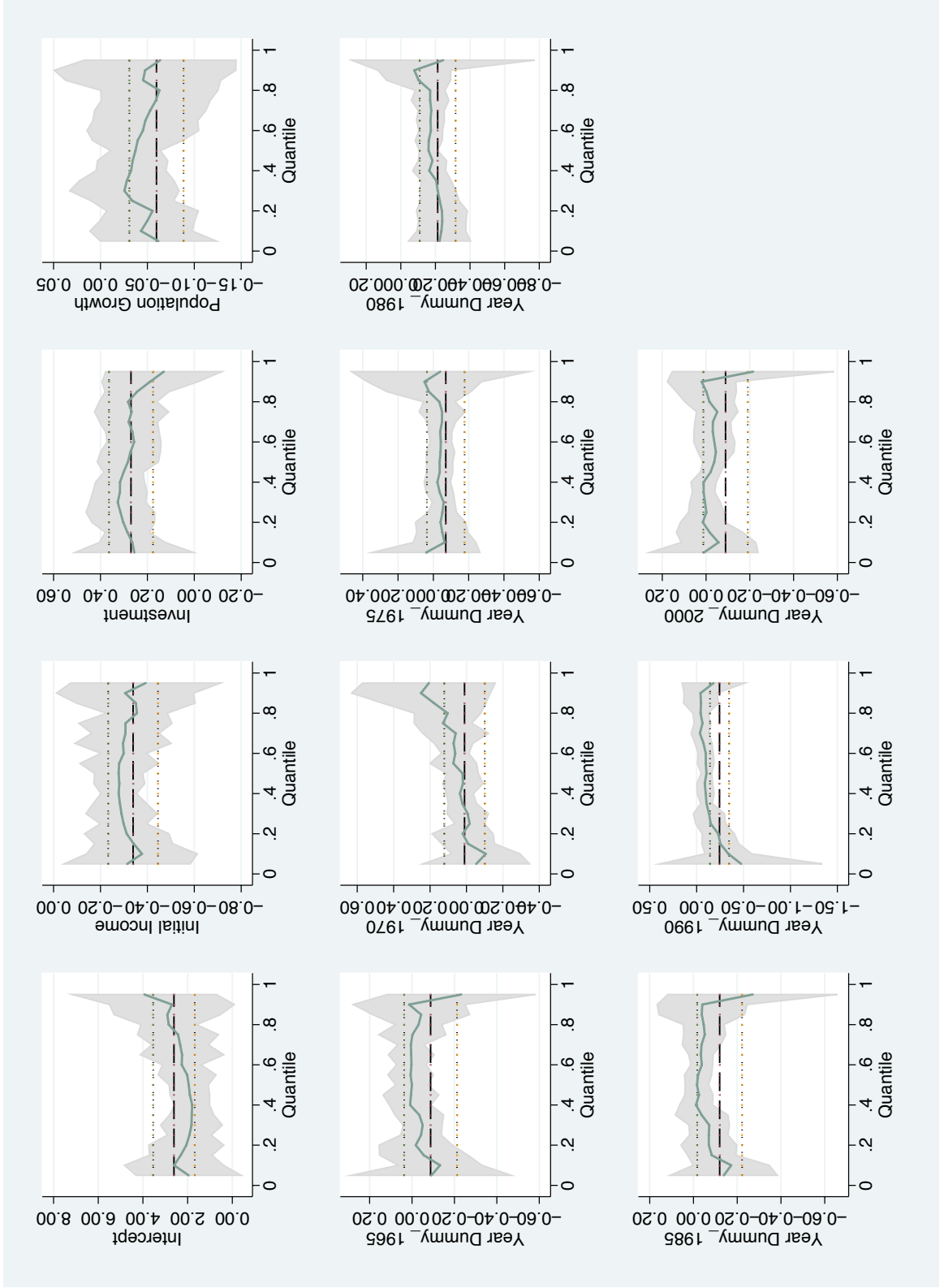


Figure 5.4: Quantile Regression Estimates with Fixed Effects for the 'Textbook' Solow Model

The previous estimates presented in this chapter aimed to offer an insight into the quantile regression process. The attention now focuses upon building on the core regression model outlined in Chapter 4 in order to estimate the impact of the HIV/AIDS epidemic across the conditional growth distribution within an established empirical model. Figure 5.3 illustrated that the OLS point estimate offered a limited insight into the estimated relationship of the key determinants of economic growth across the conditional growth distribution. In contrast, the within-groups estimator within Figure 5.4 provides a reasonable description of the estimated effects for the textbook Solow model. By adopting a Barro-style growth regression model as outlined in Chapter 4, Table 5.5 directly estimates the impact of the HIV/AIDS epidemic within a quantile regression framework. The results aim to supplement the estimated impact of the epidemic on economic growth reported in Chapter 4. By introducing parameter heterogeneity into the estimated relationship, the estimates reported in Table 5.5 aim to offer more robust estimates for the impact of the HIV/AIDS epidemic on national productivity. The variables included correspond to the core regression model of Chapter 4, including the augmented-Solow model variables, life expectancy, HIV prevalence, openness to trade as well as time dummy variables.

In order to offer a comparison across quantile estimates, Figure 5.5 replicates the results for Table 5.5 and includes the within-groups estimator and corresponding confidence interval. The estimates for the augmented Solow model variables are closely approximated by the within-groups estimator. This is evident from the estimated impact across levels of τ remaining within the confidence interval of the within-groups estimator. In contrast, the two measures of health exhibit a greater degree of heterogeneity across the conditional growth distribution. This situation is polarised with the HIV prevalence coefficient at the top 5% (-0.0364) of the conditional distribution being almost 45 times larger in magnitude than the estimated coefficient for the bottom 5% (-0.0008). For life expectancy, the

Table 5.5: Fixed Effects Quantile Regression Estimates for the AIDS Epidemic

	(1) QR ₁₀	(2) QR ₂₅	(3) QR ₅₀	(4) QR ₇₅	(5) QR ₉₀
Constant	-0.57 (2.09)	2.11 (1.58)	2.27 (0.97)	2.94 (1.33)	4.34 (5.67)
GDP in base year	-0.384*** (0.06)	-0.287*** (0.06)	-0.209*** (0.04)	-0.228*** (0.06)	-0.182 (0.23)
Average Investment	0.113 (0.08)	0.333*** (0.08)	0.304*** (0.05)	0.243*** (0.06)	0.104 (0.19)
Population Growth	-0.086*** (0.02)	-0.055*** (0.02)	-0.072*** (0.01)	-0.085*** (0.02)	-0.068 (0.10)
Education	0.109 (0.08)	-0.036 (0.08)	-0.027 (0.06)	0.020 (0.07)	-0.044 (0.20)
Life Expectancy	0.765 (0.52)	-0.024 (0.39)	-0.176 (0.23)	-0.224 (0.30)	-0.592*** (0.19)
HIV Prevalence	-0.015 (0.01)	-0.013 (0.01)	-0.009 (0.01)	-0.011 (0.01)	-0.026 (0.02)
Openness	0.088 (0.06)	-0.017 (0.07)	-0.028 (0.04)	-0.045 (0.05)	0.056 (0.20)
Dummy, 1965-70	0.213*** (0.10)	-0.072 (0.11)	0.049 (0.07)	0.018 (0.10)	-0.041 (0.38)
Dummy, 1970-75	0.133 (0.09)	-0.044 (0.09)	0.090 (0.06)	0.069 (0.08)	0.160 (0.32)
Dummy, 1975-80	0.124 (0.09)	-0.077 (0.08)	-0.021 (0.06)	-0.039 (0.07)	-0.126 (0.28)
Dummy, 1980-85	-0.088 (0.07)	-0.225*** (0.07)	-0.145** (0.06)	-0.207*** (0.07)	-0.120 (0.26)
Dummy, 1985-90	-0.136* (0.07)	-0.099 (0.07)	0.016 (0.05)	-0.017 (0.06)	-0.129 (0.22)
Dummy, 1990-95	-0.200*** (0.06)	-0.155*** (0.06)	-0.065 (0.04)	-0.060 (0.06)	-0.089 (0.20)
Dummy, 1995-00	-0.033 (0.05)	-0.027 (0.06)	0.066* (0.04)	0.024 (0.04)	0.031 (0.13)
N	564	564	564	564	564

Dependent variable: $\Delta \ln y_{i,t}$ across all specifications.

Standard errors are in parentheses.

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

estimated heterogeneity across the two levels of τ are even more dramatic given the change in coefficient sign between the highest and lowest conditional quantiles. An interesting observation between both measures of population health is that they exhibit a similar distributional shape across the conditional growth distribution. For example, there is a strong downward trend at the upper tail of the conditional distribution. In terms of HIV prevalence, the interpretation of the changing distributional feature implies that the AIDS epidemic has a stronger, negative effect for high growth performing economies. Across all quantiles, the impact of the epidemic was estimated to be non-significant and the economic significance for the high growth performing economies was also observed to be marginal.

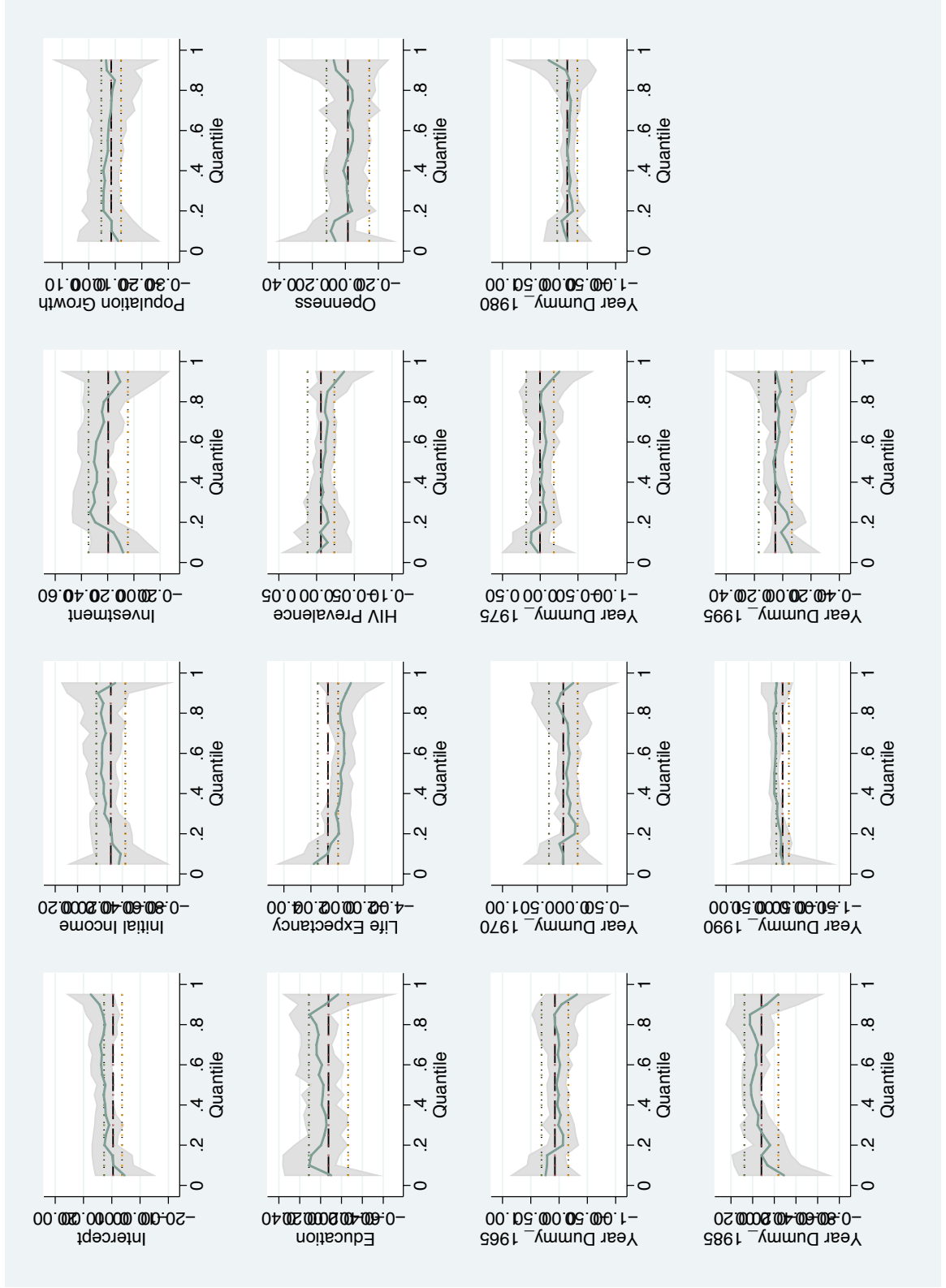


Figure 5.5: Quantile Regression Estimates with Fixed Effects for AIDS Epidemic

5.5 Summary

The quantile regression results presented in this chapter illustrate that estimates based on the conditional mean fail to capture the parameter heterogeneity for the determinants of economic growth. In contrast, the within-groups estimator was observed to provide a reasonable fit for the augmented-Solow model across the conditional growth distribution. The OLS and System GMM point estimate results in Chapter 4 provided support for the premise that the HIV/AIDS epidemic has had a trivial impact on the rate of growth for the full sample of countries. By estimating the impact of the epidemic across the entire growth distribution, the quantile regression results depicted in Figure 5.5 raise questions regarding the robustness of average treatment effects for growth regressions. In particular, the HIV/AIDS epidemic is estimated to have a more damaging effect for countries experiencing higher levels of economic growth. The increased trade activity associated with growth improvements may offer one rationale for the observed effect. Oster (2007) has estimated the greater incidence of HIV following an increase in exports. Indeed, a doubling of exports were estimated to lead to an increase in new HIV infection between 10% and 70% within Sub-Saharan Africa. This result is particularly pertinent if economic growth is associated with improvements in a country's infrastructure through the investment in roads and other transportation methods which may provide a prosperous environment for increased infections. In this setting, the greater mobility of both goods and individuals may represent a positive impact for economic growth, whilst simultaneously representing a public health concern. The pursuit of economic growth may, therefore, yield negative externalities on population health if the underlying growth process fails to account for the role of health in macroeconomic policy decisions.

Chapter 6

Convergence and Polarisation in the Health and Wealth of Nations

6.1 Introduction

Economic growth is often advocated as a means of escaping poverty. This policy proposal, however, should not be viewed as a panacea for poverty reduction in isolation. The pursuit of economic growth may be associated with a number of features that are detrimental to national welfare. By its very nature, economic growth can be considered as adopting a *laissez-faire* approach to inequality. This premise reflects the viewpoint that changes in economic growth will inevitably lead to an increase at a differential rate across the income distribution. For example, economic growth can be considered to have a neutral effect on inequality if the change in income is proportional to the mean. That is, economic growth increases the income levels of all citizens by the same magnitude. It is clear that this theoretical realisation is often violated in practice. Instead, there are inevitable winners and losers within the growth process. In this setting, the pursuit of economic growth may lead to a cyclical process of increases in inequality and poverty. Chapter 5 introduced a distributional approach to estimate the

HIV/AIDS epidemic. This chapter extends on this methodological design by adopting a distributional approach to the other facets of the growth process, represented by poverty and inequality. The results presented in this chapter are derived from two complementary software packages - the DASP package for Stata (Abdelkrim and Duclos, 2007) and the ineq package (Zeileis, 2007) developed for the R programming language (R Development Core Team, 2008). A central feature of the neoclassical growth paradigm relates to the convergence hypothesis. By drawing upon the distributional changes in national income over time for a broad cross-section of countries, this chapter will assess the potential barriers that violate the theoretical predictions of the convergence hypothesis. An empirical assessment of the role of convergence clubs, mortality and poverty traps will be presented through an analysis of the changes in health and income inequality over time. The distributional shifts that have occurred over the previous 40 year period will be discussed in relation to the changing level of welfare across countries.

This chapter aims to address three research questions, focusing on the interdependent relationship between growth, poverty and inequality. An initial research question concerns the role of economic growth in terms of poverty reduction. By estimating the sensitivity of poverty reduction from economic growth, this initial research objective aims to address whether there is evidence of pro-poor growth across countries from 1960-2000. A complementary research question concerns the evolving world distribution of income. The persistence of income levels and polarisation of economic positions will be analysed to address the presence of σ -convergence and formation of convergence clubs in both income and health. In this setting, this chapter aims to address whether there is evidence of both poverty and mortality traps across a broad cross-section of countries from 1960-2000. The final research question of this chapter captures the unifying theme of the thesis through an assessment of the diverging global inequalities in income and health over time. In particular, the thesis aims to analyse the distributional

shifts associated with improvements and divergences in both national income and life expectancy in order to estimate the location of distributional dynamics. Inequality measures which are sensitive to differing locations of the distribution will be used to address this final research question.

6.2 Economic Growth, Inequality and Poverty Reduction

A central theme throughout the previous chapters of this thesis concerned the appraisal of the growth process by acknowledging the differential growth experiences across countries as well as the possible determinants of economic growth. This section offers an assessment of the underlying mechanisms behind the growth process by introducing the concepts of poverty and inequality. Economic growth can be considered a benchmark in which to evaluate the macroeconomic performance of an economy. The pursuit of economic prosperity, however, may bring increased societal benefits beyond simply a measure of national output. In terms of policy initiatives, economic growth has maintained a pivotal role in the development process. The World Bank's advocacy of growth as a means of escaping poverty is embedded within the concept and process of enhancing human capabilities. That is, the inputs to sustained growth reinforce and complement the process of economic development. There is, however, an ambiguity regarding the relationship between economic growth, inequality and poverty reduction from the existing empirical literature. Focusing solely on the relationship between growth and inequality in a cross-country context, Perotti (1996) noted the presence of inequality to be detrimental to economic growth. In contrast, Li (1998) and supported by Forbes (2000) estimate inequality to be an impetus, rather than a barrier, to increased growth activity. Barro (2000) observed inequality to be a barrier for poor economies but act as a growth stimulus among richer

economies. The conflicting empirical results can be viewed as a manifestation of the lack of a dominant theoretical paradigm in which to address the growth triad (Bourguignon, 2004). This section will elucidate the relationship between growth, inequality and poverty in isolation in order to construct fruitful insights into the interdependent relationship. Before considering this relationship in detail, it is important to consider the measures of inequality outlined within this chapter.

6.2.1 Measuring Inequality

This section does not aim to offer an exhaustive account of the measures of inequality. Instead, focus is confined to measures commonly used to estimate inequalities in both income and health. By outlining the key inequality measures, this section aims to highlight the differing scale of each measure as well as their sensitivity to changes in the distribution.

Gini Coefficient

The Gini coefficient can be considered the most widely used measure of inequality for both income and health. By ranking the cumulative percentage of the population from poor to rich and the cumulative percentage of income, it is clear that the Gini coefficient is derived from the Lorenz curve. The Gini coefficient is bounded by zero to one, with increasing values signifying greater inequality and the coefficient is sensitive to changes in the middle of the distribution. A Gini coefficient of zero can be considered to represent a hypothetical scenario in which there is a perfectly egalitarian state signifying an absence of inequality. That is, a situation in which there is perfect equality. Conversely, a Gini coefficient of one supports the premise that a single individual would control all the population's resources. In this setting, there is complete inequality in the population. The derivation of the Gini coefficient can be defined as:

$$Gini = \frac{1}{2m} \frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^n |y_i - y_j| \quad (6.1)$$

Where the mean income level of country i is denoted by y_i and country j denoted by y_j . The Gini coefficient can, therefore, be considered as measuring the absolute difference in income between all pairs of income levels. In this setting, the Gini coefficient can be considered equivalent to half the relative mean difference (Sen, 1997).

Theil Index

The dominance of the Gini coefficient as a standard measure of inequality in applied research is precisely due to its ease in interpretation. As a result, the Theil index is less frequently used by both analysts and policymakers relative to the Gini coefficient. Theil (1967) drew upon entropy within information theory in order to derive the inequality measure. The Theil index, therefore, falls within the generalised entropy measures of inequality and can be decomposed into two separate measures of inequality. Throughout the thesis, the Theil index is used to refer to Theil's T measure of inequality. The corresponding inequality measure of Theil's L is referred to as the mean logarithmic deviation as outlined below. Theil's T measure of inequality can be defined as:

$$E(1) = \frac{1}{n} \sum_{i=1}^n \frac{y_i}{\mu} \ln \left(\frac{y_i}{\mu} \right) \quad (6.2)$$

Where the income level of individual countries, n , is denoted by y_i and the mean equivalence level of income is given by u . For both the Theil index and the mean logarithmic deviation, perfect equality is denoted by zero. The key differences between the two Theil (1967) measures arise in their upper bounds of measuring inequality as well as the sensitivity to distributional changes. For example, Theil's T measure of inequality attaches greater weight to changes at

the upper end of the distribution. The upper bound of Theil's T is constrained by $n \ln(n)$, with higher values signifying a greater measure of inequality and the upper bound determined by the population size. By measuring the distance from perfect equality, the Theil index can be considered to measure the disorder in the distribution (Theil, 1967). A primary motivation for the use of the Theil index within applied research relates to the ease of measuring inequality within sub-populations by decomposing inequality within and between specific sub-populations. This demarcation of within and between inequality represents a fruitful feature of the Theil index due to the means of identifying the underlying mechanisms of inequality.

Mean Log Deviation

The mean log deviation is an analogous measure of inequality derived from the Theil index and is also known as Theil's L. In contrast to the standard Theil index, the mean log deviation is more sensitive to changes at the lower end of the distribution. The mean log deviation is constrained by an upper bound of one in which to measure complete inequality and can be defined as:

$$E(0) = \frac{1}{n} \sum_{i=1}^n \ln \left(\frac{\mu}{y_i} \right) = \ln \left(\frac{1}{n} \sum_{i=1}^n y_i \right) - \frac{1}{n} \sum_{i=1}^n \ln (y_i) \quad (6.3)$$

Where the income level of individual countries, n , is denoted by y_i and the mean equivalence level of income is given by u . To highlight the two opposing measures of inequality outlined by Theil (1967), the general framework for measuring inequality can be denoted as:

$$E(\alpha) = \frac{1}{\alpha(\alpha - 1)} \left[\frac{1}{n} \sum_{i=1}^n \left(\frac{y_i}{\bar{y}} \right)^\alpha - 1 \right] \quad (6.4)$$

Within this specification, α corresponds to an inequality aversion parameter. Higher values of α are associated with a more sanguine tolerance of inequality

within society. It is clear, therefore, that the mean log deviation is more sensitive to changes at the lower end of the distribution whilst the Theil index has a greater sensitivity at the opposing tail.

Relative Mean Deviation

The range can be defined as polarising the extremes of a distribution. An analogous measure of statistical dispersion suitable for inequality analysis is the relative mean deviation. In contrast to the range, the relative mean deviation accounts for the entire distribution and can be formally defined as:

$$RMD = \frac{1}{n\mu} \sum_{i=1}^n |y_i - \mu| \quad (6.5)$$

The measure is derived by comparing the full set of data points with the sample mean. By calculating the sum of the absolute differences between the income levels and the sample mean level of income divided by the total income level, the relative mean deviation offers an intuitive measure of inequality. Indeed, the relative mean deviation can be defined as representing the percentage of total income that should be redistributed so that all incomes are equalised. The relative mean deviation is bounded by 0 and 1, with higher values associated with increased inequality.

Standard Deviation of Logarithms

Empirical analyses of inequality are explicitly interested in the extremes of the distribution. By attaching greater weight to lower income levels, the standard deviation of logarithms represents a useful measure of inequality in which to evaluate redistributive policies. The weighting mechanism associated with the standard deviation of logarithms ensures that the inequality measure is more sensitive to changes at the lower end of the distribution. As Sen (1997) notes, the main appeal of the standard deviation of logarithms is through the greater

insight into lower quantiles of the distribution. Like the Theil index, the standard deviation of logarithms also falls within the generalised entropy class of inequality measures and can be defined as:

$$SDL = \sqrt{\frac{1}{n} \sum_{i=1}^n (\ln \bar{y} - \ln y_i)^2} \quad (6.6)$$

where the natural logarithm of the sample mean income is denoted by \bar{y} and the natural logarithm of the mean income level of country, i , is given by y_i . In this setting, an initial step in deriving the standard deviation of logarithms corresponds to the difference between the natural logarithm of mean income and the mean of each national income. The standard deviation of logarithms corresponds to the squared difference in log income over the population size, n .

Coefficient of Variation

The coefficient of variation measures inequality in the world distribution of income through an assessment of the distributions standard deviation divided by the mean level of income. More formally, the coefficient of variation can be defined as:

$$CV = \frac{\sqrt{V}}{\bar{y}} \quad (6.7)$$

whereby the denominator denotes the average income level and the numerator represents the standard deviation of the sample distribution. Increases in the magnitude of the coefficient of variation corresponds to greater dispersion of income levels. For example, two countries with the same mean level of income will have the same coefficient of variation providing the dispersion of income is identical in each country. If one country has a greater standard deviation in terms of their income distribution despite the same average income level, it is clear that they will also have a higher degree of inequality as represented by the

coefficient of variation. Like the Gini coefficient, a situation of perfect equality is observed when the coefficient of variation is equal to zero. An intuitive appeal of the coefficient of variation is that it represents a unitless measure of inequality. In this setting, it is possible to compare coefficients of variation across competing data sources.

6.2.2 Pro-poor Growth and the Growth Elasticity of Poverty

The unprecedented growth rates observed for the post-war period in some high performing economies have resulted in substantial improvements in national standards of living. Most notably, the successes of the Southeast Asian Tiger economies have signified the potential benefits available from the growth process. Such success stories have been realised in times in which other economies have been stagnant or declined. This polarisation of social and economic positions has generated questions regarding equitable arrangements within the world distribution of income and the returns to growth. More pertinently, policy concerns have focused upon whether growth is a sustainable tool for poverty reduction. In this setting, the policy viewpoint is concerned with the extent to which growth is 'pro-poor'. Previous insights into the relationship between growth and poverty were based on the form of a "trickle down" effect. Kakwani and Pernia (2000) recall the rationale of the 1950s and '60s as one in which the benefits of growth are hierarchically structured within society. The returns to growth, therefore, will initially accrue to the rich before any lagged benefits to the poor will be realised. That is, the trickle down hypothesis assumes that improvements in the national average income level will also lead to income increases for the poor. The key interpretation of this taxonomy concerning a lagged diffusion of growth is that the process ensures that the proportional benefits will always be greater for the rich rather than the poor. More recently, attention has shifted from average income levels to whether the incomes of the poor grow faster than the mean as

well as the analysis of national poverty levels.

Ravallion (2004) summarises two disparate definitions of 'pro-poor growth' commonly advocated and applied in empirical analysis. The difference in competing interpretations is more than simply a case of semantics but also reflects the normative question of poverty measurement. For McCulloch and Baulch (1999), growth can be considered 'pro-poor' if the distributional change in income leads to a reduction in poverty. The key assumption underlying this interpretation is that the growth in income levels of the poorest poor should be higher than for the rich, or even moderately poor. As Ravallion (2004) noted, any contractions, or indeed expansions, in national output could be considered pro-poor if the poor lose proportionately less than the rich despite the net effect leaving the poor worse off in absolute terms. This is a clear limitation of the definition advocated by McCulloch and Baulch (1999) as it does not adequately capture the interdependent relationship between growth, inequality and poverty. Instead, a more persuasive interpretation of 'pro-poor growth' is one in which the process leads to a reduction in poverty (Ravallion and Chen, 2003). The interpretation of 'pro-poor growth' in terms of a distributional shift represents only one part of the story of poverty. By focusing solely on a change in poverty, the approach of Ravallion and Chen (2003) captures the distributional information as well as the change in national living standards. Kakwani (1993) argues that it is these two factors together that account for the degree of poverty.

The absence of a robust association between growth and inequality from cross-country analyses has not transcended to other spheres of the growth process. There is little ambiguity regarding the relationship between economic growth and poverty reduction from the existing empirical literature. The overwhelming evidence supports the viewpoint of a positive association between economic growth and poverty reduction. To support this general hypothesis, Table 6.1 presents estimates of the growth elasticity of poverty for both the full sample of countries

and an Africa sub-sample. By specifying the degree of inequality aversion, α , and poverty threshold across samples, Table 6.1 captures the sensitivity of poverty to changes in economic growth. The growth elasticity of poverty can be defined as:

$$\varepsilon = \begin{cases} -\frac{zf(k,z)}{f(z)} & \text{if } \alpha = 0 \\ \alpha \frac{\bar{P}(k,z;\alpha) - \bar{P}(k,z;\alpha-1)}{\bar{P}(z,\alpha)} & \text{if } \alpha \geq 1 \end{cases}$$

Where the poverty line is represented by, z , and population groups denoted by k , then $f(k,z)$ corresponds to the population below the poverty threshold (Abdelkrim and Duclos, 2007). The parameter α represents a measure of inequality aversion. An increase in α , therefore, attaches greater weight to the poorest poor. A weighting in favour of the world's poorest is also feature of a lower poverty threshold, reflecting a greater sensitivity to the ultra-poor (Kakwani, 1993). Across all specifications in Table 6.1, the estimated elasticity is greater in magnitude when α is larger in value and a lower poverty line is implemented. The implication of this premise is that the benefits of growth are proportionately higher for the poorest poor than the moderately poor.

Table 6.1: Growth Elasticity of Poverty

	$\alpha=0$			$\alpha=1$		
	Poverty Line	Elasticity	S.D.	Poverty Line	Elasticity	S.D.
Full Sample	Absolute	-1.67	0.23	Absolute	-2.92	0.33
Full Sample	Relative	-0.58	0.03	Relative	-0.69	0.03
Africa	Absolute	-6.69	0.89	Absolute	-6.73	1.02
Africa	Relative	-0.77	0.11	Relative	-3.00	0.18

The relative poverty thresholds used are based on a constant proportion of the sample mean of real GDP per capita for each sample. For example, the poverty threshold for the Africa sample is set to three-quarters of the sub-sample mean resulting in a poverty line of \$1731. Using the same criteria, the poverty threshold for the full sample of countries yields a poverty line equal to \$4745. A fundamental shortcoming associated with implementing a relative poverty line reflects their sensitivity to the sample under analysis. A more fruitful approach

is to specify a fixed poverty threshold based on the minimum welfare level needed in which to satisfy basic needs. The absolute poverty line adopted was based on the World Bank's poverty threshold of two-dollars-a-day in 2000 prices¹, equating to a real GDP per capita value of \$680 per annum.

The growth elasticity of poverty for the full sample of countries using a relative poverty line was estimated to be -0.54. In this setting, a one-percent increase in growth would lead to a reduction in poverty of just over half a percent per annum. This figure increased to -0.69 when the inequality aversion parameter was altered from 0 to 1. Using the more robust specification of an absolute poverty line, the reduction in poverty is estimated to be nearly 3% from a one-percent increase in growth for the higher inequality aversion parameter. It is not surprising to observe higher absolute elasticities for the Africa sub-sample. The magnitude of the elasticities across both α and poverty threshold measures are difficult to ignore. This situation is exemplified using a higher inequality aversion parameter and an absolute poverty line of 2-dollars-a-day. As reported in Table 6.1, a one-percent increase in growth is associated with a 6.7 percent reduction in poverty. Although large in magnitude, the practical significance of this elasticity is marginal considering the growth performance over the last 40 years within sub-Saharan Africa.

Figure 6.1 captures the heterogeneity in terms of growth performance within Africa over the last two decades. The salient feature of the growth incidence curve depicted in Figure 6.1 is reflected in the differing growth performances for the top and bottom quartiles. Africa's relatively rich can be considered to be benefiting most from the growth process. The paradox, therefore, is that the countries that would benefit most are currently constrained by opportunities and structural capabilities. In terms of policy, the question centres around the means

¹Sala-i-Martin (2006) notes the nontrivial loss in precision derived from altering baseline year estimates, with the poverty threshold increasing by \$155 when changing from 2000 to 1985 prices. The baseline year of 2000 is used throughout the thesis and specified by PWT 6.2.

of promoting growth among Africa's bottom quartile and the potential benefits that would be rewarded.

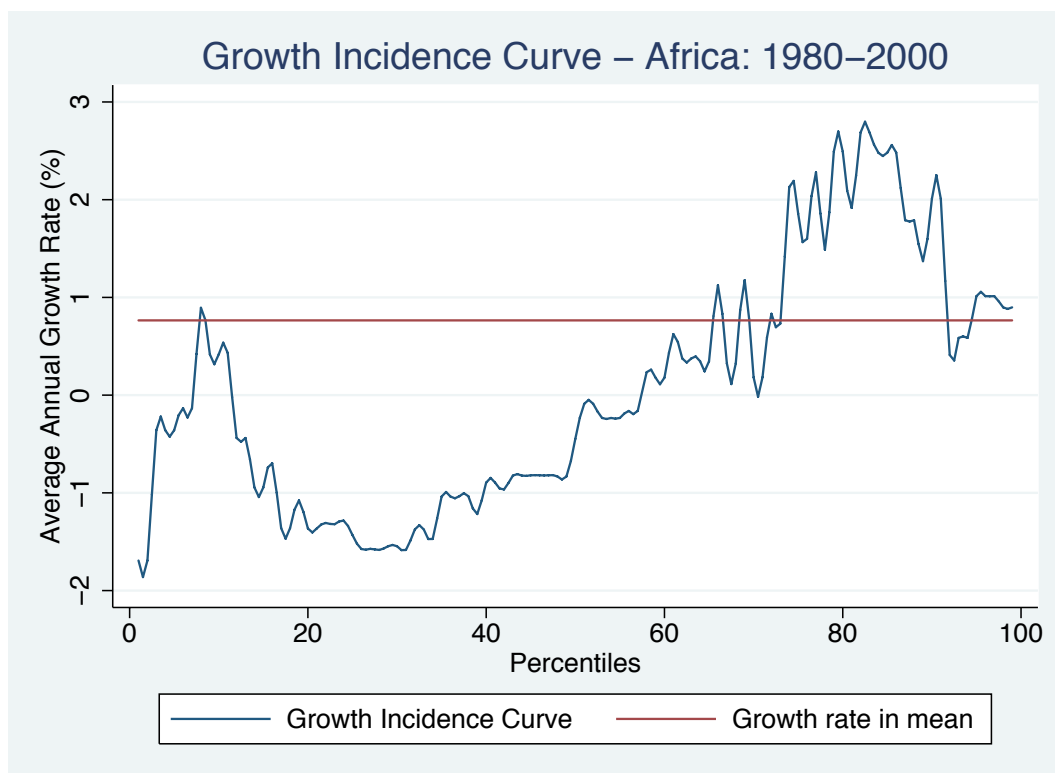


Figure 6.1: Growth Incidence Curve for the Africa sub-Sample, 1980-2000

6.3 Distribution Dynamics: σ -Convergence

The regression estimates of convergence presented in the previous chapters support the notion of Conditional β -convergence across the full sample of countries. This regression based approach to the analysis of convergence can be interpreted in terms of whether a single economy moves towards its own steady-state. Indeed, the results generally support the predictions of the Solow model. By narrowly focusing upon single economies, however, such results fail to capture a number of important distributional dynamics. More recently, theoretical and empirical advancements have been proposed in the form of club convergence. To fully elucidate the concept of club convergence, consider the distribution of income previously presented in Figure 5.1. As outlined previously in Chapter 5, Figure

5.1 plots the distribution of income across the full sample of countries in 1960, 1980 and 2000. A bivariate replication of Figure 5.1 is also depicted later within this chapter. Two salient characteristics are worth noting from the estimated distributions of the kernel density plot. In particular, there has been a widening of the world distribution of income over the past 40 years. More pertinently, the income distribution in 1960 can be considered unimodal. By 1980, this distributional property had disappeared resulting in a bimodal income distribution, with this representation remaining in 2000.

The changing distributional structure from unimodal to bimodal raises important empirical questions regarding the analysis of convergence. To simply show that poorer countries are engaging in a process of catch-up in terms GDP per capita may misrepresent the true picture of the world distribution of income. This caricature of a bimodal world distribution of income forms the basis of the club convergence hypothesis. Quah (1996), a strong proponent of this hypothesis, terms this phenomenon one of 'twin-peaked' dynamics. This definition astutely captures the characteristics underpinning the transformation of the world distribution of income. By attempting to explain the formation of the clustering of countries around diverging income levels, the interest of club convergence is one of polarisation. In this setting, the absence of a large number of middle income countries under the bimodal distribution has led to a concentration of countries at the extremes of the income spectrum. That is, the two clubs of countries can be considered to be polarised. In Figure 5.1, the two convergence clubs can be classified as poor and rich based upon their formation around the corresponding income levels. It is clear that this demarcation of convergence clubs is mutually exclusive and fully exhaustive.

Polarisation embodies a country's desire to avoid the former convergence club in order to achieve improvements in national standards of living. The aim of this approach to convergence analysis, therefore, is concerned with explaining the

degree of persistence among the two clubs. More pertinently, whether countries remain in the same convergence club over time or whether there is some degree of intra-distributional mobility. It is clear that a list of the poorest countries in 1960 would contain some of the same names for a list constructed in 2000. This viewpoint can be encapsulated by considering whether a countries position in a league table of real GDP per capita in 1960 would provide a good indicator of their position in 2000. A spearman rank correlation of 0.89 provides compelling evidence in support of this viewpoint. The high degree of association postulates little mobility across the full cross-section of countries. But to what extent does this level of persistence remain? A hypothetical, undesirable, scenario of total persistence would rule out any mobility across income groups. Such a scenario may provide support for the premise of a poverty trap in which poor convergence club countries cannot escape through conventional measures.

In order to test for the mobility across convergence clubs, preliminary analysis is needed to fully explore the distributional properties underpinning Figure 5.1. It was noted previously that the world distribution of income has widened over the past 40 years. An inspection of the inter-quartile range (IQR) and standard deviation of real GDP per capita over time provides a partial explanation into this increased inequality. Across the full sample of countries, the standard deviation and IQR were \$5571 and \$2746 in 1970 respectively. By 2000, the IQR had increased by 69% to \$4634 as well as the standard deviation increasing by a quarter to \$9525. The value derived from such approximate calculations is reflected in the substantial variation in percentage increases between the IQR and standard deviation. The implication of the two-fold increase in the IQR compared to the standard deviation provides evidence for the notion of upward mobility. Indeed, the sizeable percentage differences represent a more sanguine outlook than that postulated in the scenario of total persistence. To fully validate the approximate calculations, however, a more formal empirical design is needed. The use of tran-

sition probabilities captures the degree of persistence and mobility of real GDP per capita over time. By specifying the intra-distributional dynamics of income in this form, income transitions form the basis in which to estimate the evolving distributional structure from 1960 to 2000.

Table 6.2: Transition Probability Matrix

Development State	Low Income	Middle Income	High Income
Low Income	89.32%	10.68%	0.00%
Middle Income	13.21%	77.36%	9.43%
High Income	0.00%	4.84%	95.16%

Overall the transition probabilities in Table 6.2 highlight the high degree of persistence within the three income groups. This situation is polarised at the extremes of the income classifications. Within the high income group in 1960, 95 per cent of countries remained in the same income classification. Similarly, nearly 90 per cent of the countries of the low income group in 1960 reinforced their position within the lowest income club in 2000. Table 6.2 further illustrates the absence of upward or downward mobility between the high income and poor income groups. Instead, group mobility is confined to the countries of the middle income club. That is, the group of middle income countries act as a supplier for future membership of both low and high income clubs. The consequences for the middle income club can be illustrated from the bimodal distribution of Figure 6.2 after the initial period. To reinforce the notion of a decreasing concentration of middle income countries, a bivariate replication of Figure 5.1 is presented for the gaussian kernel estimates of real GDP per capita and is depicted in Figure 6.2.

Corresponding to Figure 5.1, the bivariate replication in Figure 6.2 plots the distribution of income in 1960, 1980 and 2000. Membership of the middle income club diminishes as performance is rewarded or punished through mobility to other groups. The persistence among the low and high income groups reinforces the concept of polarisation.² Indeed, the transition probabilities highlight presence

²The appendices include an alternative depiction of the polarisation by presenting a contour plot of the distribution of income over time across the full sample of countries

Bivariate Kernel Density Estimates

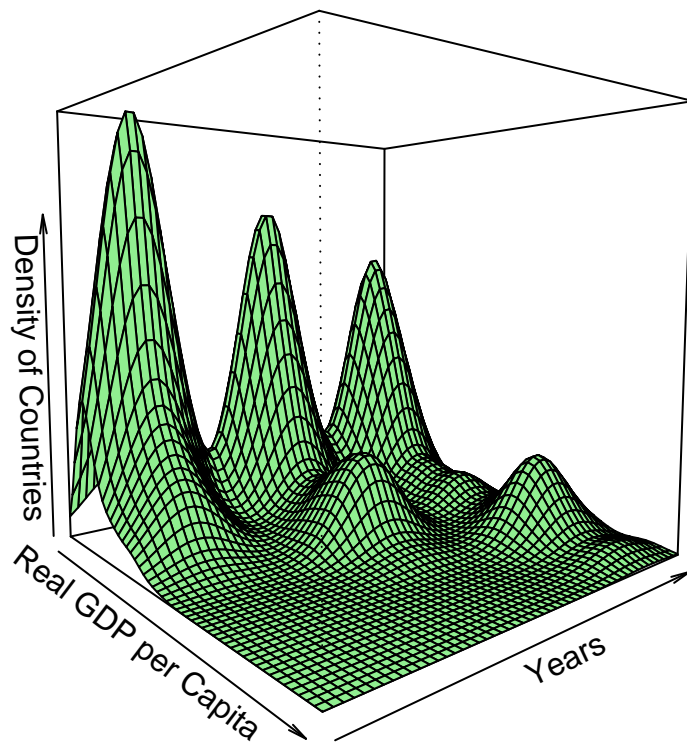


Figure 6.2: Bivariate Kernel Density Estimates of Real GDP per Capita, 1960-2000

of both winners and losers within the development process.

6.4 Inequalities in Health and Income

β and σ convergence highlight the substantial cross-country disparities in economic prosperity. This approach to the analysis of inequality explicitly assumes welfare is to be measured by real GDP per capita. Countries with higher incomes are considered to be more closely aligned to the concept of utility maximisation, due to the greater opportunities created by increased wealth. The accumulation of wealth, therefore, is not seen solely in terms of prosperity but encompasses aspects of wellbeing and happiness. Ray (1998) considers income to possess all the necessary characteristics for a suitable proxy for welfare precisely due to its role in creating opportunities. More recently, Becker et al. (2005) have proposed a more fruitful measure of welfare that captures both the quality and quantity of life. If income is a measure of quality, then life expectancy can be used to measure the number of years available to enjoy the greater utility offered by income. The empirical interest in this composite index reflects the diverging patterns between income and health inequality over time. The existing empirical literature on the analysis of σ convergence has reported, almost exclusively, the finding of a widening of the income distribution over the last 40 years. Using income as a measure of welfare, therefore, illustrates an increase in cross-country inequality for the post-war period. A more sanguine outlook is depicted if life expectancy is used as a measure of welfare.

Table 6.3: Cross-country Inequality in Health and Income

	Income per capita			Life Expectancy		
	1960	1990	2000	1960	1990	2000
Relative mean dev.	0.3745	0.4229	0.4368	0.1027	0.0738	0.0862
Coeff. of variation	0.9351	1.0272	1.0581	0.2330	0.1764	0.2012
Std. Dev. of logs	0.9872	1.1659	1.2274	0.2370	0.1947	0.2236
Gini coeff.	0.4785	0.5328	0.5449	0.1327	0.0979	0.1099

Table 6.3 constructs estimates for a selection of standard measures of inequality for both income and health over time across the full sample of countries. A higher value is associated with increased inequality for all of the inequality indicators presented in Table 6.3. There has been no evidence of a reversal of the trend of increased income inequality across all time periods. The Gini coefficient, commonly used to measure income inequality, increased by 12 percentage points from 1960 reaching a value of 54 per cent in 2000. Bourguignon and Morrisson (2002) have noted that Gini coefficients greater than 60 per cent are uncommon even in the most in-egalitarian countries of the world. The world level will reach this value by 2040 if the rate of inequality continues at the level observed from the previous decade of 1990-2000. This level of inequality will be achieved even sooner if the rate of acceleration remains as that experienced from 1960-2000. Income inequality has increased across all of the indicators used in Table 6.3. It should be noted, however, that the estimates are not constructed on the basis of any empirical weights. Population-weighted estimates of Table 6.3 support the conclusion of Sala-i Martin (2006) in that there has been a narrowing of the world distribution of income over the past 40 years. Deaton (2006) has noted the need for caution in the use of population weights within the context of cross-country inequality analyses due to the unfeasibility of disaggregation and the strong growth performances of both India and China. A fundamental reason for using population weights is to gain a greater insight into welfare by moving away from countries to individuals as the unit of observation. With the population of China almost twice the size of the level reported for sub-Saharan Africa as a whole, the use of population weights may dilute the inferences for sub-Saharan Africa and other small economies of primary interest.

Life expectancy is used as a measure of health within Table 6.3. The persistence of health inequalities diminished up to 1990, rising again after this period across all four indicators. The reversal of the downward trend post-1990 has

been largely attributed to the HIV/AIDS epidemic within sub-Saharan Africa (UNAIDS, 1998, 2002; Goesling and Firebaugh, 2004; Deaton, 2006). The collapse of the Soviet Union has also been considered to be an important factor in reduced health status during this period. The removal of post-Soviet countries at the stage of the study design, however, limits this explanation within this context. The coefficient of variation is a unitless measure which makes it possible to directly compare the diverging distributions of income and health. In contrast to income, there has been a narrowing of the world distribution of life expectancy from 1960 to 2000. More recently, the presence of health shocks such as the HIV/AIDS epidemic post-1990 have diluted such health improvements. Nonetheless, the trend remains of health improvements and income divergences. In terms of inequality, the empirical question emerges as to which of the diverging measures of welfare dominates.

Table 6.4 presents the trends in life expectancy in order to polarise the regional differentials that exist in terms of average health status. The final columns in Table 6.4 calculate the percentage changes in life expectancy across time periods. A central feature of the percentage estimates records the greatest percentage returns for regions below the world average of life expectancy. In this setting, there is evidence of regional convergence in life expectancy, which continues up until 1990. The evidence of post-1990 divergence in health status can be viewed as a direct consequence of the current situation in sub-Saharan Africa. Indeed, life expectancy in the region for the year 2000 was lower than that recorded in 1980 due to the decline in average health status over the previous decade. The reversal of the trend of reduced health inequalities post-1990 can be considered to alter the distribution of life expectancy over time. For example, the range in regional life expectancy increased from 25 years in 1960 to 28 years in 2000. By utilising measures of inequality that are sensitive to distributional structures, it is possible to identify the true impact of the distributional changes. That is, whether recent

health divergences are a consequence of the experiences in sub-Saharan Africa or the steady improvements in longevity in the opposing distributional tail.

Table 6.4: Regional Trends in Life Expectancy

Region	Life Expectancy					Percentage Change		
	1960	1970	1980	1990	2000	1960-1980	1980-1990	1990-2000
World	53.3	57.3	61.2	64.0	65.1	14.8	4.6	1.7
South Asia	42.6	47.3	52.3	57.3	61.6	22.8	9.6	7.5
Europe & Central Asia	64.5	67.4	68.3	69.6	70.4	5.9	1.9	1.1
Middle East & North Africa	46.8	52.4	58.9	64.6	67.8	25.9	9.7	5.0
Sub-Saharan Africa	41.3	45.4	49.2	51.1	49.0	19.1	3.9	-4.1
Latin America & Caribbean	56.6	61.1	65.1	68.4	70.7	15.0	5.1	3.4
East Asia & Pacific	46.9	53.0	57.8	62.0	64.3	23.2	7.3	3.7
High Income	66.5	69.2	72.3	74.9	77.3	8.7	3.6	3.2

Table 6.5 includes measures of health inequality over time in order to identify the direction of the distributional changes of life expectancy. Each measure included in Table 6.5 is sensitive to changes within the distributional structure. For example, the Gini coefficient is sensitive to changes towards the middle of the distribution. In contrast, the Theil Index and squared coefficient of variation are both sensitive to changes towards the right of the distribution. Finally, the mean logarithmic deviation is sensitive to changes towards the left of the distribution. Across the full time period of 1960-2000, the largest percentage change is reported for both the Theil Index and squared coefficient of variation measures. In this setting, improvements in longevity towards the right-hand end of the distributional tail have led to reduced health inequalities across regions over the last 40 years. More pertinently, the increased inequality that has emerged post-1990 can be attributed to the negative health experiences in sub-Saharan Africa. The largest percentage change reported for the years 1990-2000 is for the mean logarithmic deviation which is sensitive to lower ends of the distributional structure. Adverse health shocks in sub-Saharan Africa can be directly attributable to the recent divergence in life expectancy across regions.

Table 6.5: Trends in Health Inequality Measures

Year	Gini Coefficient	Theil Index	MLD	CV²
1960	0.13119	0.02628	0.02699	0.02599
1980	0.09813	0.01561	0.0164	0.01501
1990	0.09254	0.01484	0.01594	0.01401
2000	0.10253	0.01847	0.01992	0.01737
% Change, 1960-1980	-25.2	-40.6	-39.2	-42.2
% Change, 1980-1990	-5.7	-4.9	-2.8	-6.7
% Change, 1990-2000	10.8	24.5	25.0	24.0
% Change, 1960-2000	-21.8	-29.7	-26.2	-33.2

The catch-up in terms of life expectancy up to 1990 in Table 6.5 implies a process of convergence. That is, countries with poor health outcomes achieved greater gains in longevity than healthier economies. A simple linear regression of

the change in life expectancy from 1960-2004 on the initial level of life expectancy provides support for this hypothesis. However, the linear approximation is rejected in favour of the quadratic model. Bloom and Canning (2007) also observe the same relationship when estimating the convergence in the world distribution of life expectancy. The improved fit from the quadratic approximation implies an inverted U shaped relationship. That is, a threshold level of health needs to be achieved before convergence occurs. To illustrate the progress and convergence in health, Figure 6.2 presents the kernel density estimates for life expectancy from 1960-2000. In contrast to the distribution of income in 1960, life expectancy in the initial period exhibits a bimodal distribution. The initial period of 1960 can be characterised as representing a world in which there is an equal number of countries with very high and very poor population health. By 2000, there is a noticeable improvement in the world distribution of life expectancy with a greater concentration of countries with high levels of population health. Nonetheless, the observed convergence in life expectancy in Figure 6.2 does not imply that the polarisation in population health outcomes is in any way diminished. This is clearly evident from the small peak in 2000 which represents the clustering of countries with poor health outcomes.

The absence of convergence for countries lagging behind in terms of life expectancy in Figure 6.2 can be considered to be determined by a number of multifaceted social, political and economic factors. It may be that such countries have not yet achieved the requisite threshold level of health in order to enjoy improved health transitions as part of the convergence process. The kernel density estimates presented in Figures 6.2 and 6.3, and reinforced by the transition probabilities in Table 6.2, illustrate the persistence of poverty. A fundamental feature of this analysis relates to the inheritability of poverty (Bliss, 2007). The theoretical predictions of convergence in income levels across countries can be questioned in light of the observed divergence over the past 40 years. Indeed, a list of the poorest

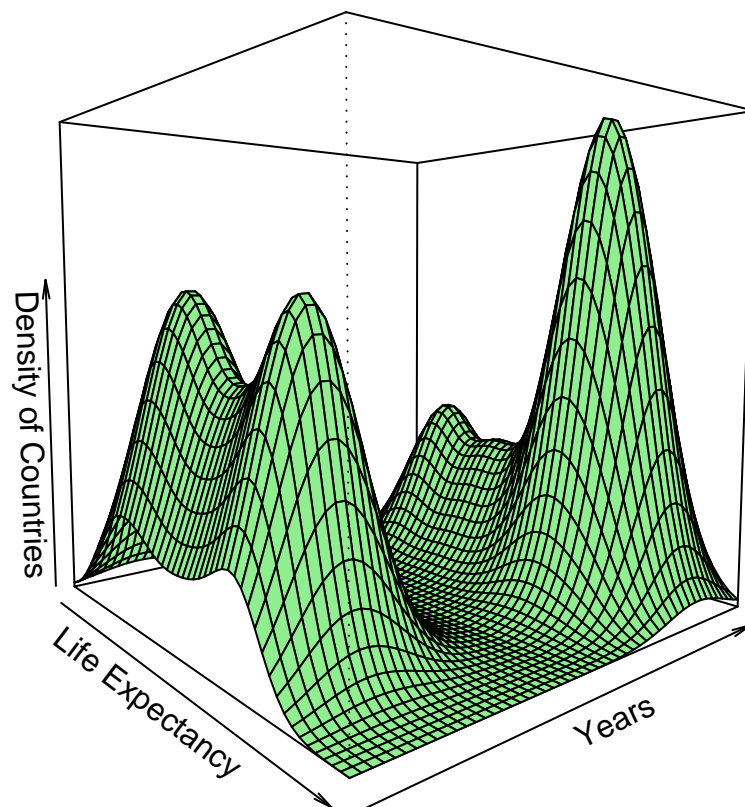


Figure 6.3: Bivariate Kernel Density Estimates of Life Expectancy, 1960-2004

countries in 1960 would closely correspond to the world's poorest nations in 2000, with some countries experiencing further poverty. If countries remain stagnant or fall further behind in terms of income growth then the question arises as to whether there are barriers on a country's ability to achieve economic prosperity. It could be the case that the growth trajectories of poorer economies are temporarily constrained by some exogenous factor resulting in poorer nations taking longer to experience the development transition. In this setting, the persistence of poverty may simply represent a manifestation of the underlying growth process in which the poor simply take longer to experience long-run economic growth. Some of the world's most vulnerable economies may also be constrained by factors that contribute to the limited growth and increased inequality and poverty. These factors can be defined as creating poverty and mortality traps in which countries cannot escape through conventional measures.

Conflict and civil war, corruption, poor governance, credit market imperfections and the absence of an established legal framework can all be considered factors that severely constrain a country's growth possibilities. The cyclical process of poor health and educational outcomes may also add to the persistence of poverty. All factors can be defined as contributing to the poverty and mortality traps experienced by the world's poorest economies. It is clear that the list of possible constraints can be mitigated by the policies and actions of governments. Nonetheless, other factors fall beyond the control of governmental policies and even national boundaries. This case is exemplified through the negative effects of a neighbouring country experiencing a period of civil unrest. Poverty and mortality traps offer one explanation for the polarisation in both income and health across the world.

This chapter has considered the positive effects of economic growth in relation to poverty reduction. The potential barriers of poverty and mortality traps have ensured that the world's poorest economies have not yet experienced the

reduction in poverty derived from the growth process. In contrast to income, there has been a process of convergence in life expectancy over the past 40 year period. Nonetheless, large inequalities remain regarding the health and wealth of nations. To supplement this conclusion of widespread income inequalities, it is important to consider the concentration of world income. That is, the extent to which countries differ in their share of the world's wealth across the distributional spectrum. The Lorenz Curve captures this distributional information by illustrating the proportion of income that accrues to differing percentiles of the sample population. Figure 6.4 presents the Lorenz Curve for the full sample of countries and reinforces the notion of an established level of inequality within the world distribution of income.

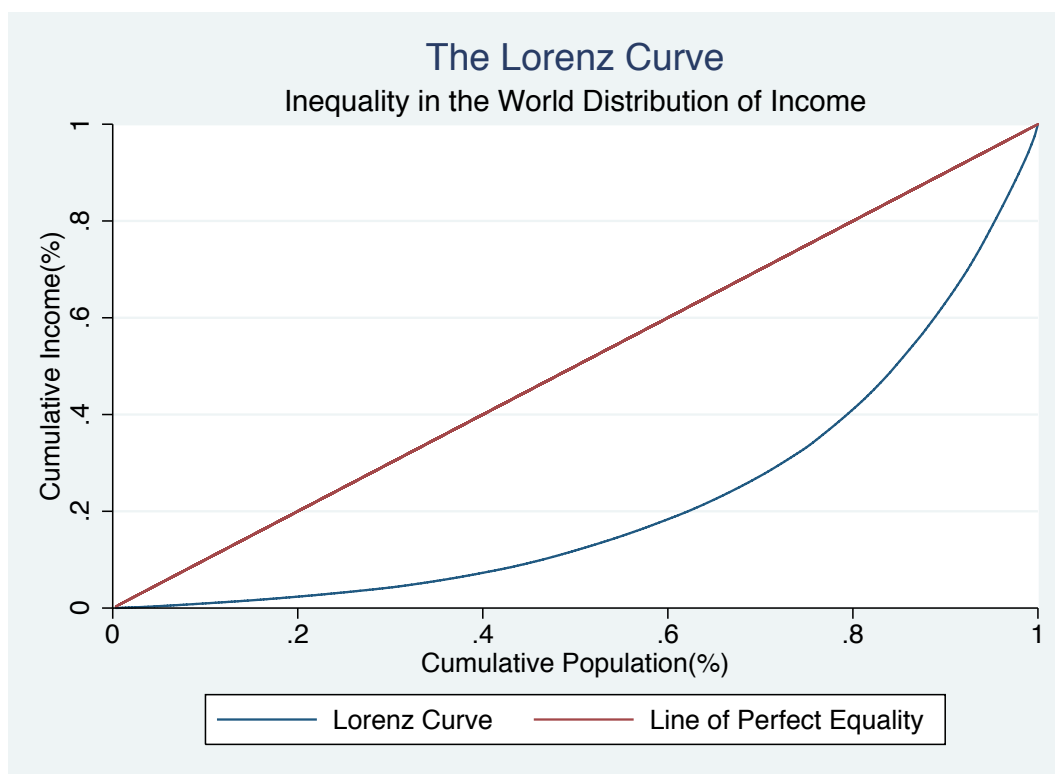


Figure 6.4: Lorenz Curve, 1960-2004

The diagonal 45 degree line, termed the Line of Equality, represents the hypothetical scenario of an even distribution of income. In this setting, the Line of Equality ensures that any percentile of the population would have an equivalent

value share of income. Forty per cent of the population, therefore, would have exactly 40% of the world's wealth. The fact that the Lorenz Curve is markedly lower than the Line of Equality confirms the presence of large income inequalities across countries. Indeed, the areas below both the Line of Equality and the Lorenz Curve are used in the derivation of the Gini coefficient. The poorest 20 percent of the population corresponds to the estimated one billion individuals living on less than 1 dollar per day, as well as a number of additional poor African and Latin American nations. It is, perhaps, not surprising that despite representing one-sixth of the population, the cumulative income share of this bottom two deciles is a meagre 3 per cent. More ominously is the income share pertaining to the 80th percentile. The polarised positions are exemplified by the richest 20 per cent of the population enjoying over 60 per cent of the world's income.

6.5 Summary

The aims of this chapter were to address three research questions in order to gain a greater insight into the relationship between growth, poverty and inequality. Using either an absolute or relative poverty line, the growth elasticity of poverty overwhelming highlighted the positive role of economic growth in terms of poverty reduction. Although positive benefits were estimated for economic growth in terms of poverty reduction, a less sanguine outlook was observed for inequality. An analysis of the world distribution of income highlighted both the persistence of income and formation of convergence clubs from 1960-2000. The polarisation of income levels was also observed for global health, with an equal number of countries clustering around high and low levels of life expectancy in 2000. Although inequalities in health have reduced over the past 40 year period, there has been a slight increase in health inequalities post-1990. In contrast, the persistence of income positions across countries has led to a manifestation of diverging global income levels.

Chapter 7

Conclusion

A unifying theme throughout the thesis has been the interdependent relationship between economic growth, poverty and inequality across nations. The determinants of economic growth have been considered at both a theoretical and empirical level in order to highlight the importance of health on the accumulation of national income. Although life expectancy and reduced infant mortality represent measures of health improvements, the thesis has also considered the consequences of poor population health in restricting economic prosperity. The inclusion of disease-specific measures of population health within growth regressions represents a fruitful development for estimating the potentially damaging effect of health limitations on national productivity. Indeed, the thesis draws upon these foundations in order to estimate whether the HIV/AIDS epidemic impedes economic growth for a broad cross-section of countries as well as across the conditional growth distribution.

The use of time-series data from 1960-2004 has offered a unique insight into the HIV/AIDS epidemic from its infancy through to a major public health concern. A fundamental conclusion outlined in Chapter 4 is that the HIV/AIDS epidemic has only had a marginal, non-significant, impact on the rates of economic growth for the full sample of countries from 1960-2004. It is interesting to note that the impact was sizeable for the Within-Groups estimator, with a standard de-

viation increase in the average rate of HIV prevalence across the world leading to a 1% reduction in economic growth over the period. Nonetheless, the thesis has highlighted the limitations associated with the Within-Groups estimator and outlined the potential strengths associated with the System GMM estimator for short dynamic panel data models in Chapter 3. By failing to account for the endogeneity of health variables and the dynamic nature of growth regressions, it has previously been argued throughout the thesis that the Within-Groups estimator may suffer from biased estimates. Instead, the results from the preferred System GMM estimator in Chapter 4 report not only a trivial impact of the epidemic but also a sign on the HIV coefficient that is qualitatively at odds with the results of the Within-Groups specifications. The results from Chapter 4 support the premise that the HIV/AIDS epidemic has not restricted the growth possibilities of countries for the full sample of countries from 1960-2004.

The results outlined in Chapter 4 are confined to the full sample of countries. In this setting, it does not rule out the possibility that the HIV/AIDS epidemic may impede the economic growth rates for a sub-group of the sample population. For example, McDonald and Roberts (2006) observe that although there is no impact of the HIV/AIDS epidemic for the full sample of countries, they also estimate a sizeable impact for an African sub-sample. Although geographic and economic sub-samples represent one means of sub-group analysis, the thesis has also highlighted the heterogeneity within sub-groups that raises questions regarding the robustness of average treatment effects for policy prescriptions. Chapter 5 posits an alternative viewpoint by estimating the impact of the HIV/AIDS epidemic across the conditional growth distribution. The research question, therefore, aimed to estimate whether there was a differential impact of the HIV/AIDS epidemic for high and low growth performing economies. Quantile regression methods that account for the panel data design offer an insight into the parameter heterogeneity associated with the HIV/AIDS epidemic. The results in

Chapter 5 highlighted the differential impact of the HIV/AIDS epidemic across the conditional growth distribution, with high growth performing economies observed to be worst affected by the epidemic. Across all quantiles, the impact of the epidemic was estimated to be non-significant and the economic significance for the high growth performing economies was also observed to be marginal. Nonetheless, the results also demonstrated the robustness of the Within-Groups model in estimating the quantile treatment effects. The quantile regression estimates with fixed effects outlined in Chapter 5 can be considered exploratory analyses that introduce parameter heterogeneity into growth regressions. As will be discussed later in this chapter, more fruitful quantile regression approaches will need to be developed that account for the endogeneity of regressors. The use of quantile regressions also offered important insights into the convergence hypothesis. Chapter 5 reported that absolute convergence increased with the level of τ , with a strong process of convergence observed at the 60th quantile.

Chapter 6 aimed to estimate the role of economic growth in terms of poverty reduction. Using either an absolute or relative poverty line, the growth elasticity of poverty overwhelming highlighted the positive role of economic growth in terms of poverty reduction. For example, the growth elasticity of poverty for the full sample of countries using a relative poverty line was estimated to be -0.54. In this setting, a 1% increase in growth was estimated to lead to a reduction in poverty of just over half a percent per annum. By exploiting the time-series dimension of the dataset, Chapter 6 also analysed the evolving world distribution of income and health. Although economic growth was estimated to have a positive impact on poverty reduction, a less sanguine outlook was observed for inequality. An analysis of the world distribution of income highlighted both the persistence of income and formation of convergence clubs from 1960-2000. The polarisation of income levels was also observed for global health, with an equal number of countries clustering around high and low levels of life expectancy in

2000. Although inequalities in health have reduced over the past 40 year period, there has been a slight increase in health inequalities post-1990. In contrast, the persistence of income positions across countries has led to a manifestation of diverging global income levels. The polarisation of economic positions presented in Chapter 6 posits a bleak outlook through the formation of convergence clubs as well as poverty and mortality traps.

The research throughout the thesis has highlighted that the process of economic growth cannot be viewed in isolation as a purely economic subject matter. Instead, changes in national income are dependent upon the social, economic and political environment of an economy. Without the essential infrastructural arrangements in which to cultivate growth, any policy prescriptions to remedy failing economies will be largely redundant in the long-run. Government investment in health and human capabilities are essential components to promote and maintain economic growth. An assessment of the spatial distribution of health outcomes, previously outlined in the thesis, also illustrates evidence of cross-sectional dependence within sub-Saharan Africa. For many of the world's poorest economies, the absence of a stable government, protection of property rights through a well defined legal framework and the promotion of civil liberties severely constrain a country's ability to escape poverty. This viewpoint supports the notion that although the determinants of income are multi-faceted, so too are the potential consequences of the accumulation of wealth. The potential consequences can be defined as the triadic relationship between growth, poverty and inequality. Notwithstanding causal relationships, each dimension of the relationship can be considered to be intrinsically dependent. A central premise, however, is that the relationship is largely country-specific. The success of a policy proposal promoting growth in one country may have a detrimental effect in another. Growth, poverty and inequality may all contribute to the changing distributional shape of national income. The synthesis of all three dimensions

forms the collective theme of this thesis.

The acknowledgement of the importance of country-specific factors within the growth process directly motivated the methodological design of the thesis. Panel data estimates of growth regressions may offer more informative results if the growth process is dependent upon individual country experiences. Econometric analysis of growth regressions has been largely confined to cross-sectional study designs. By exploiting the variation within countries, the panel data methodology adopted within the thesis explicitly accounts for the country-specific effects of the growth process. In contrast to cross-sectional studies, panel data approaches are able to relax the assumption regarding homogenous levels of initial efficiency across countries. A number of country-specific infrastructural factors can be defined as fixed effect characteristics. For example, a country's physical characteristics will contribute to their economic performance but are also stable over time. The ability to control for such time-invariant factors within panel data designs allows for improved parameter estimates by accounting for the omitted variable bias inherent in cross-sectional growth regressions. Despite the dominance of the cross-sectional growth paradigm, a central aim of the thesis was to contribute to the development of panel data designs of growth regressions. This thesis has contributed to the emerging literature adopting panel data designs of growth regressions using a large sample of countries. The use of modern econometric methods suitable for short dynamic panel data models in the form of the System GMM estimator represents a fruitful development in this field.

The advantages associated with a panel data methodology have also polarised the estimates for growth analyses based on cross-sectional designs. This case is particularly evident for the convergence hypothesis in which parameter estimates on initial income differ greatly between the competing designs. The commonly reported estimate of a 2% speed of convergence from cross-sectional studies has been questioned as a statistical artefact and further considered analogous to a

universal constant in physics (Quah, 1993). Panel data estimates have generated renewed interest in the convergence hypothesis precisely due to the heterogeneity of parameter estimates of the speed of convergence. Although noting a higher speed of convergence than the uniform 2% observed from cross-sectional data, panel data studies have not reached a consensus regarding the speed of convergence. The thesis has outlined the sensitivity of parameter estimates in relation to model specifications for panel data estimates of the convergence hypothesis. For example, the speed of convergence was reported to be significantly higher adopting the within-groups estimator as opposed to OLS estimates. The short dynamic panel data design of growth regressions was also identified as a cause for the variation in convergence estimates for panel data studies in applied growth research. By adopting a quantile regression approach, the thesis also contributes to the convergence hypothesis literature by offering a reassessment of the current orthodoxy regarding absolute β -convergence for a broad sample of countries.

The existing literature on the convergence hypothesis has rejected the presence of absolute β -convergence for a broad heterogeneous sample of countries. Instead, it has been argued that absolute convergence is only observed for a homogenous sample of countries that share similar infrastructural characteristics. The large sample of countries, covering over 90% of the world's population, outlined within the thesis supports the existing literature. Absolute convergence for the full sample of countries is rejected in favour of conditional convergence. The plethora of applied research testing the predictions of the convergence hypotheses are well established within the empirical growth literature. It is, perhaps, not surprising therefore that the results for the thesis endorse the overall findings of the existing literature on the convergence hypothesis. Nonetheless, the results rejecting the presence of absolute convergence are confined to conditional mean estimates. The thesis addresses this limitation through a quantile regression approach in order to test the predictions of the convergence hypothesis across the conditional growth

distribution. An intuitive appeal of this approach relates to the movement away from an average point estimate of the speed of convergence based on conditional mean models. By accounting for the parameter heterogeneity for the coefficient on initial income, the quantile regression approach identified the variation in convergence across quantiles of the growth distribution.

Quantile regression approaches to growth analysis offer estimates based on the conditional growth distribution. The analysis of σ -convergence complements this distributional approach through an assessment of the world distribution of income over time. In contrast to the regression based approach of β -convergence analysis, σ -convergence offers an assessment of the evolving distributional structure of income for the full sample of countries. The results for σ -convergence outlined in Chapter 6 capture a number of important distributional dynamics which are missed by regression based approaches confined to β -convergence analysis. In particular, the widening of the world distribution of income over the past 40 years has resulted in a changing distributional shape from unimodal to bimodal. The formation of convergence clubs and polarisation between rich and poor economies represents a major challenge for future economic prosperity. Although economic growth was estimated to be pro-poor, the consequences of inequality in the world distribution of income and health may curtail the benefits of the future growth.

A central aim of this thesis was to elucidate the importance of health as a determinant of economic growth. More pertinently, the research has modelled the consequences of adverse health shocks to national welfare by focusing on the relationship between the HIV/AIDS epidemic and aggregate productivity. In a series of publications, Sen (1999, 2002) has argued for health to be considered a basic human right. There has been a greater acknowledgement of the role of health in the pursuit of economic growth at a theoretical, empirical and policy perspective. Health's contribution to the prosperity of an economy extends beyond increasing human capabilities and functional capacity. Although a healthy population can

be considered to represent a more productive labour force, the consequences of poor population health may create additional barriers. The health of the world's poorest economies are constrained by conflict, civil war and epidemics. A potential manifestation of such factors relates to the diverging levels of both income and health across the world distribution of health and wealth. A central contribution of the thesis concerns the estimation of a disease-specific factor of poor population health on economic growth. The results estimating the impact of the HIV/AIDS epidemic for the full sample of countries aims to reconcile the diverging positions within the existing empirical literature. This contribution is further developed by estimating the impact of the HIV/AIDS epidemic on the conditional growth distribution. Indeed, the use of quantile regressions that account for the panel data design of the thesis represents a significant development for introducing parameter heterogeneity into growth regressions as well as extending the analysis on the HIV/AIDS epidemic on economic growth.

7.1 Potential Limitations and Future Directions of the Thesis

A common limitation associated with cross-country data relates to the quality of estimates among developing countries. This case is polarised for national accounts data in which many of the poorest economies lack the infrastructural capabilities to routinely record such information. There is an inevitable concern regarding a sample selection bias if data for LDCs is disregarded due to limited data points or quality issues. To alleviate such concerns it is imperative to mitigate data quality issues through attempts at retaining a large heterogeneous sample of countries. Depending on the research question, it may be justifiable to replace missing values with the corresponding responses of neighbouring economies. In the context of economic growth, Sala-i-Martin (2006) adopted such an approach by noting the

shared social, economic and political structures between neighbouring countries. For example, levels of income, education and life expectancy will be relatively homogenous across neighbouring economies within the poorest regions of the world. It was possible to gain a balance between data quality and breadth of sample within the thesis. Indeed, the full sample of 112 countries represents a relatively large sample for growth analysis. Due to the explicit research question on the AIDS epidemic, it was imperative to retain a large sample of countries that were fully representative of the world's economies, particularly focusing on countries with lower levels of income and high HIV prevalence rates. A Bayesian Melding approach was used in order to construct national estimates of HIV prevalence in light of the limited time-series data and concerns over the previously over-inflated estimates within some countries. Despite the initial reservations regarding data quality and availability, this approach greatly improved the number of data points available in which to estimate the impact of the HIV/AIDS epidemic on economic growth.

In light of the limitations associated with aggregate data, it was important to adopt a cautious approach when defining the research questions in order to ensure they were feasible given the nature of the data. In particular, the research aims of the thesis attempted to complement the data rather than expose its weaknesses. This presented a number of challenges regarding the analysis of poverty and inequality outlined in Chapter 6. The Social Epidemiology literature has offered a number of insights into the absolute and relative income hypotheses using similar aggregate data sources. This approach, however, was considered to be asking too much of the data. This conclusion is supported by Gravelle et al. (2002) who acknowledge that the underlying research question is inherently microeconomic in nature. Chapter 6 aimed to reconcile the unifying theme of the thesis of growth, poverty and inequality, by adopting a distributional approach. A primary motivation for this approach related to the emphasis on countries as

the unit of observation in which to explore global dynamics. It is anticipated that future research will explore the possibility of using microeconomic datasets in which to complement the existing estimates of health, income, poverty and inequality outlined within the thesis.

The alternative methodological designs of growth regressions provide diverging empirical results. Cross-sectional growth regressions are based on averages over the entire period under consideration. Panel data designs preserve the variation within countries by collapsing the dynamics down over a much shorter period, commonly based on five year averages. The advantage of a panel data methodology is that the growth process is inherently dynamic. Investments in physical capital, education and health all require increases in expenditure with the expectation of future benefits. The ability to model this process through lagged variables within panel data designs provides a greater insight into the realisation of investment decisions. This thesis has previously echoed the caution needed when interpreting regression coefficients for investment variables. For example, a negative coefficient on education does not necessarily support the premise that investment in human capital leads to a reduction in national income. Instead, there may be a delayed effect between investment and benefits so that an assumption of an immediate return on the investment may be unrealistic. A potential limitation of the thesis relates to the inclusion of lagged policy variables within the adopted short dynamic panel data design. Indeed, the damaging loss of observations resulting from the inclusion of lagged policy variables, such as HIV prevalence and education, represents a significant constraint.

The System GMM was advocated as the preferred estimator for the growth regressions precisely due to its suitability for short dynamic panel data models. Although the strengths of the System GMM for growth regressions have been outlined by Bond et al. (2001), and successfully adopted by Levine et al. (2000) and Hoeffler (2002), it may not represent a panacea for dynamic panel data mod-

els. This conclusion follows the recent analysis by Bun and Windmeijer (2010). By including lagged levels and lagged first differences as instruments, the System GMM estimator aims to ameliorate the weak instrument bias associated with the first-difference GMM estimator. The initial simulation results of Bun and Windmeijer (2010) suggest that the System GMM estimator may suffer from the same weak instrument bias in which it was developed to address. Although the Monte Carlo simulation results represent important developments in the estimation of dynamic panel data models, caution is needed in interpreting the findings until the simulation results have been replicated using directly observable data.

The quantile regression estimates for growth regressions presented in Chapter 5 offer a contribution to both growth analysis and the application of panel data quantile regressions. A natural extension of this contribution relates to the development and adoption of instrumental variable quantile regressions for panel data designs. Although still in its infancy, seminal contributions to the literature have started to emerge within the field (Harding and Lamarche, 2009). The future econometric developments in the use of instrumental variable quantile regressions for short dynamic panel data models, represents a logical progression in which to analyse the health and wealth of nations.

Appendix A

Full Sample of Countries and Description of Variables

An * indicates membership of the OECD and is therefore included in the OECD sample. ** is used to denote the founding member countries of the OECD following the analysis of absolute convergence.

Algeria, Angola, Argentina, Australia*, Austria**, Bangladesh, Belarus, Belgium**, Benin, Bolivia, Botswana, Brazil, Cambodia, Cameroon, Canada**, Central African Republic, Chad, Chile, Colombia, Dem. Rep. Congo, Rep. Congo, Costa Rica, Cote d'Ivoire, Cuba, Denmark**, Dominican Republic, Arab Rep. Egypt, El Salvador, Eritrea, Ethiopia, France**, Gabon, The Gambia, Germany**, Ghana, Greece**, Guatemala, Guinea-Bissau, Haiti, Honduras, India, Indonesia, Iran, Iraq, Ireland**, Israel, Italy**, Jamaica, Japan*, Jordan, Dem. Rep. Kenya, Rep. Korea*, Kuwait, Lao PDR, Lebanon, Lesotho, Liberia, Libya, FYR Macedonia, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mauritius, Mexico*, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands**, New Zealand*, Nicaragua, Niger, Nigeria, Norway**, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland*, Portugal**, Romania, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, Somalia, South Africa, Spain**, Sri Lanka, Sudan, Swaziland, Sweden**, Switzerland**, Syrian Arab Republic, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey**, Uganda, United Arab Emirates, United Kingdom**, United States**, Uruguay,

RB Venezuela, Vietnam, Rep. Yemen, Zambia, Zimbabwe.

Table A.1: Description of Variables

Variable	Description	Data Source
Growth	Logarithmic difference in Real GDP per capita over 5 year period (%)	PWT 6.2
Initial Income	log Real GDP per capita in the base year	PWT 6.2
Investment	Average Investment share of GDP over 5 year period (%)	PWT 6.2
Population Growth	Average Rate of Population Growth over 5 year period (%)	WDI (2006)
Education	log Average Schooling Years in the total population (15+)	Barro-Lee (2000)
Life Expectancy	log Life Expectancy at birth in the base year	WDI (2006)
HIV Prevalence	log HIV Prevalence in the base year base year	UNAIDS/WDI (2006)
Openness	log Sum of Trade as a share of GDP (%)	WDI (2006)
Sub-Saharan Africa	1= if country is in Sub-Saharan Africa, 0= otherwise	Derived variable
Southeast Asia	1= if country is in Southeast Asia, 0= otherwise	Derived variable
Tropics	1= if country is located in the tropics, 0= otherwise	Derived variable
Landlocked	1= if country is landlocked, 0= otherwise	Derived variable
Year 1965-1970	1= if Year is 1965, 0= otherwise	Derived variable
Year 1970-1975	1= if Year is 1970, 0= otherwise	Derived variable
Year 1975-1980	1= if Year is 1975, 0= otherwise	Derived variable
Year 1980-1985	1= if Year is 1980, 0= otherwise	Derived variable
Year 1985-1990	1= if Year is 1985, 0= otherwise	Derived variable
Year 1990-1995	1= if Year is 1990, 0= otherwise	Derived variable
Year 1995-2000	1= if Year is 1995, 0=otherwise	Derived variable

Table A.2: Descriptive Statistics for the Full Sample across Waves

		1970	1975	1980	1985	1990	1995	2000
Economic Growth	Average	0.40	0.30	0.10	0.16	0.02	0.28	0.14
	Std. Dev.	0.42	0.39	0.39	0.39	0.74	0.48	0.40
ln GDP in base year	Average	8.15	8.28	8.40	8.44	8.50	8.53	8.64
	Std. Dev.	1.01	1.01	1.02	1.02	1.07	1.15	1.17
Average Investment	Average	2.59	2.65	2.59	2.47	2.48	2.52	2.49
	Std. Dev.	0.72	0.60	0.58	0.59	0.61	0.66	0.62
Population Growth	Average	2.63	2.56	2.55	2.41	2.30	2.06	2.06
	Std. Dev.	1.45	1.34	1.66	1.66	1.58	1.80	1.68
Life Expectancy	Average	58.51	60.37	62.78	64.39	65.23	65.79	66.31
	Std. Dev.	10.94	10.75	10.25	10.05	11.04	11.69	12.65
HIV Prevalence	Average	0.00	0.00	0.05	0.18	1.61	2.01	2.24
	Std. Dev.	0.00	0.00	0.07	0.32	3.42	4.68	5.11

To complement Table 3.4, Table A.2 presents descriptive statistics for the full sample of countries for each wave of the panel data study. The fluctuation in the rate of economic growth across waves is polarised by the lower average rate of global economic growth during the 1980s and early 1990s. In contrast, the average rate of investment for the full sample of countries has maintained a persistent share of GDP of around 2.5% across waves. Table A.2 also highlights the gradual decline in population growth, as well as the linear increase in life expectancy across each 5 year period. It is interesting to observe the increase in the average HIV prevalence rate and standard deviation from the initial origin of 1970, through the epidemics infancy as well as its role as a major public health concern post-1990.

Appendix B

Bayesian Melding for Estimating HIV Prevalence Rates

Figure A.1 presents an example of the Bayesian melding approach to assess the uncertainty in HIV prevalence estimates for Botswana. The y-axis denotes HIV prevalence whilst the corresponding x-axis plots the relevant year. A sample from the posterior distribution of the prevalence curve is depicted by the grey curves. Furthermore, the red curve shows the posterior mode, whilst the dashed blue lines illustrates the 95 % confidence interval.

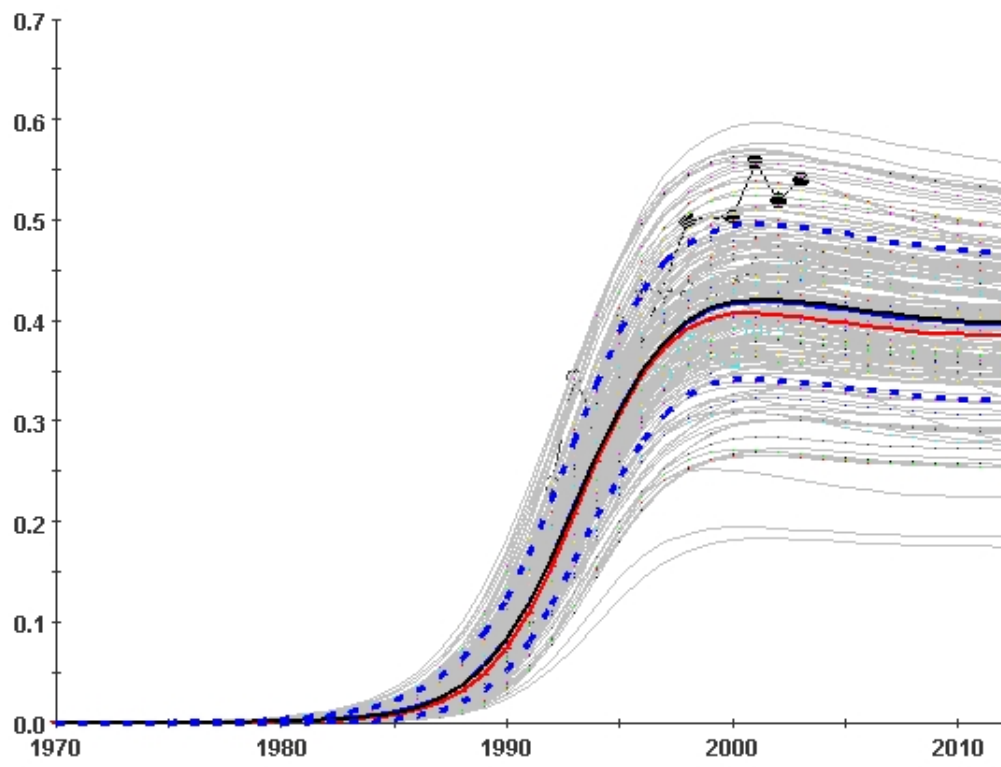


Figure B.1: Bayesian Melding Curves for Botswana HIV Prevalence

Appendix C

Robust Determinants

Robust Determinants Identified by Sala-i-Martin (1997)

Core variables included in all regressions

Log (GDP per capita, 1960) -

Rate of primary school enrollment, 1960 +

Life expectancy, 1960 +

Ranking of variables passing Sala-i-Martin's criteria

Equipment investment +

Number of years open economy +

Fraction confucian +

Rule of law +

Fraction muslim +

Political rights +

Latin American dummy -

Sub-Saharan Africa dummy -

Civil liberties +

Revolutions and coups -

Fraction of GDP in mining +

Std. Dev of black market premium -

Fraction of GDP in Primary Exports in 1970 -

Degree of capitalism +

War dummy -

Non-equipment investment +

Absolute latitude +

Exchange rate distortions -

Fraction protestant -

Fraction buddhist +

Fraction catholic -

Appendix D

Quantile Regressions

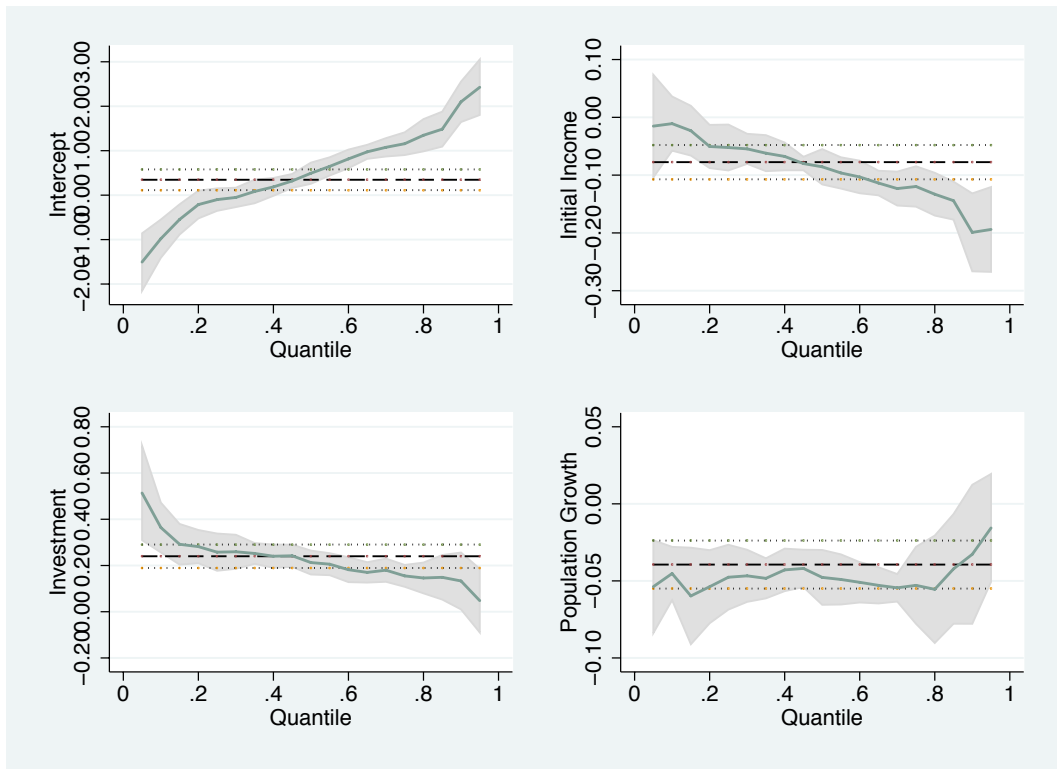


Figure D.1: Quantile Regression Estimates for the 'Textbook' Solow Model

Appendix E

World Distribution of Income

Contour Plot of the Distribution of Income

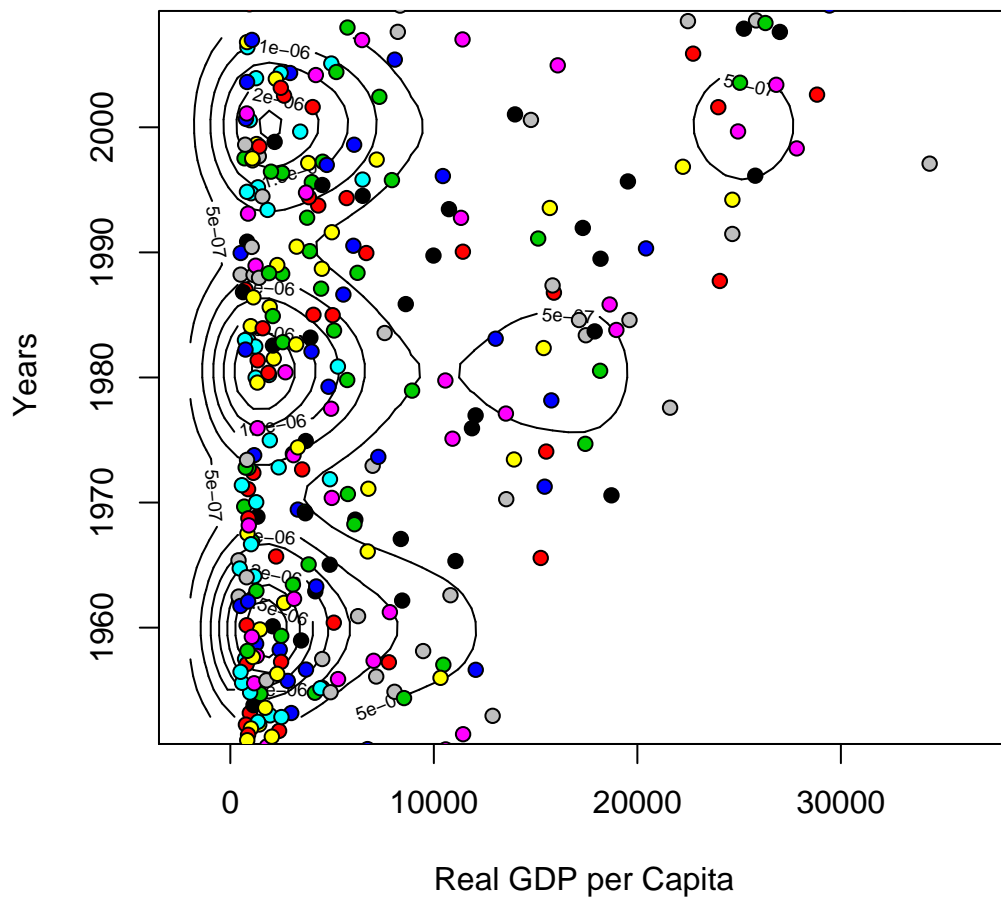


Figure E.1: Contour Plot

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