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Threshold Effects of Inequality on the Process of Economic Growth

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Abstract:

This paper explores the relationship between inequality and growth in the context of a unified empirical approach suggested by the theoretical model of Galor and Moav (2004). Based on the model's prediction, we construct a measure of human capital-to-physical capital ratio in order to investigate the threshold effects of inequality on economic growth. Using data of 82 countries for the period 1965–2003, our results are twofold: *first*, there exist significant thresholds of human-to-physical capital ratio below which the effect of inequality on growth is positive, whereas it is negative above it; *second*, human capital drives growth only when the human-to-physical capital ratio is above its threshold level. Our results are generally robust to using different measures of human capital and different data on inequality. These results are consistent with the predictions of Galor and Moav (2004).

Keywords: Inequality; Economic Growth; Human capital accumulation; Capital-skill complementarity; Endogenous Threshold model

JEL Classification: O47, I24, I25

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1. Introduction

The literature on the nature and extent of the relationship between inequality and growth can be divided into three broad categories. *First*, according to classical arguments, income inequality is required to channel resources towards those who already have higher marginal propensity to save and thereby increases aggregate saving, physical capital accumulation and growth[1]. *Second*, initial inequality adversely affects credit market imperfections, political outcomes or technological innovations, and thereby reduces economic growth[2]. *Third*, there is an inverted U-shaped relationship, as proposed by the seminal work of Kuznets (1955) and famously known as Kuznets Hypothesis, whereby causality runs from economic development to inequality, i.e., initially inequality increases and then decreases with economic development. A large body of literature, which is mostly of an empirical nature, provides mixed results on this hypothesis[3].

The theoretical studies of Galor (2000) and Galor and Maov (2004) refocus attention on effects running from income inequality to economic growth and provide a unified analysis at different stages of the development process. In particular, they emphasise the differing roles of physical and human capital accumulation. According to Galor and Maov (2004), the rate of return on physical capital is higher as compared to human capital early in development; since (in a credit-constrained economy) inequality channels resources to owners of capital who have higher marginal propensity to save, it results in increased physical capital accumulation and growth. However, later in development the return on human capital becomes higher relative to physical capital, with equality then reducing the adverse effects of credit constraints on human capital investment and leading to increased economic growth. Thus, a positive relationship between inequality and growth early in development switches to a negative one when development is more advanced, with the switch driven by the relative return on physical versus human capital. The present paper undertakes an empirical investigation of this hypothesis, employing a newly constructed measure of the human capital

[1] Smith (1776); Keynes (1920); Lewis (1954); Kaldor (1955, 1957); Bourguignon, (1981).

[2] Galor and Zeira (1993); Alesina and Rodrik (1994); Persson and Tabellini (1994).

[3] Fields (1988), Ahluwalia (1976); Ram (1988); Anand and Kanbur (1993); Aghion and Bolton (1997); Bandyopadhyay and Basu (2005); Partridge (1997); Li and Zou (1998); Deininger and Squire (1998); Barro (2000); Lopez (2006); Huang (2004); Huang *et al*. (2009); Forbes (2000); Panizza (2002); Chen (2003); Voitchovsky (2005); Lin *et al*. (2009); Chambers and Krause (2010).

to physical capital ratio as the threshold variable in a nonlinear model that captures the effect of inequality on economic growth.

Our study contributes to a growing literature on this topic. Barro (2000) concludes that panel data on a range of countries supports the Kuznets Hypothesis, while Banerjee and Duflo (2003) find evidence against the linearity assumption in a model with inequality explaining growth, but do come to a firm conclusion about the nature of the nonlinearity. Of more direct relevance to our analysis, Lin *et al*. (2009) employ a threshold model with the initial level of economic development (as measured by per capita GDP) as the threshold variable; in contrast to the predictions of Galor and Moav (2004), their results imply that inequality reduces growth in low-income countries and stimulates growth in high income countries. Moreover, the empirical specification used by Lin *et al*. (2009) does not capture fully the Galor and Moav (2004) model in which the relative returns to physical and human capital is the crucial driver of nonlinearity. A similar conclusion is drawn by Chambers and Krause (2010), who examine the inequality-growth relationship across fixed intervals of educational attainment coupled with steady increases in physical capital accumulation using semi-parametric methods. Their findings show that in nations with low levels of education (below median level in education series) the effect of inequality on growth is increasingly negative as physical capital is increased, whereas they observe the opposite behaviour in case of higher education levels (equal to or greater than the median level). Overall, they conclude that the effect of inequality on growth is negative and their findings are partially consistent with Galor and Moav (2004).

Out study also relates to the early literature on inequality and growth in the 1970s and 1980s that followed Kuznets (1955). Due to the shortage of time series data, the literature at that time mostly employed cross-sectional data and results generally conform to the Kuznets Hypothesis, despite some exceptions (see Fields, 1981). For example, Ahluwalia (1976) is a prominent cross-sectional study which exploits data of 20 developed and 40 developing countries. The results, based on pooled data and split data on developing countries, are central to the literature on inequality and development since they confirm the Kuznets Hypothesis and have been used for projections of inequality and poverty by later studies including the World Bank (see Anand and Kanbur, 1993). On the other hand, Ram (1988) uses cross-sectional data on 24 developing and 8 developed countries; his results support the Kuznets Hypothesis if pooled data are used, whereas there is very limited support in the case of developing countries. He concludes that the favourable results in a pooled sample may be due to the structural differences between developed and developing countries or due to the use of dollar income variables that are based on conventional exchange rates.

Anand and Kanbur (1993) test the robustness of Ahluwalia's (1976) results to functional form and data by employing Pesaran's (1974) econometric methodology of comparing non-nested functional forms. Their results reject Ahluwalia's (1976) log-quadratic form in favour of a straight quadratic form, where the latter exhibits a U-shape relation (opposite to Kuznets Hypothesis) between inequality and economic development. They identify the need to derive a functional form based on the theory of the underlying process. Later studies, although based on sophisticated econometric analyses and reliable data on inequality, also exhibit mixed evidence on the Kuznets hypothesis (see Deininger and Square, 1998; Barro, 2000; Savvides and Stengos, 2000; Huang, 2004).

In this context, theoretical models aim to identify channels that may explain the relationship between income inequality and growth, such as credit market imperfections (for example, Galor and Zeira, 1993), majority political rule (Alesina and Rodrik, 1994; Persson and Tabellini, 1994) and technological innovation (Galor and Tsiddon, 1997; Bandyopadhyay and Basu, 2005). Alongside these, recent empirical literature employs reliable data on inequality, mostly as assembled by Deininger and Squire (1996), and modern econometric techniques to draw conclusions regarding the relationship between inequality and economic growth. These studies criticize previous analyses on the basis of data quality, including weak proxies of inequality, and estimation methodology. They stress the need for careful examination of the inequality-growth relationship and the channels through which it is affected. On the one hand, partially consistent with the theoretical predictions, a positive effect of inequality on growth is found (Partridge, 1997; Li and Zou, 1998; Forbes, 2000), while on the other hand a negative effect of inequality on growth is uncovered, mainly driven by low income countries (Panizza, 2002; Huang *et al*., 2009).

Recognizing the potentially nonlinear nature of the relationship between inequality and growth, Banerjee and Duflo (2003) criticize earlier studies, including Forbes (2000) and Li and Zou (1998), for using linear specifications. Banerjee and Duflo (2003) use nonparametric methods and cross-section data, with their results suggesting an 'inverted U-shape' function. Similarly, with cross-country data, Chen (2003) finds an 'inverted U-shape' relationship between initial income distribution and long run economic growth. His results are consistent with the Kuznets Hypothesis, except that long run growth first increases and then decreases with initial inequality, but no support for such a relationship in the short run.

The specification employed in this study addresses the issue of nonlinearity in the inequality-growth relationship implied by the Galor and Moav (2004) model using a new measure of the human capital to physical capital (HK) ratio. By employing this ratio, we are able to represent more precisely than previous empirical studies the role of the relative change in human capital as compared to physical capital in the process of economic development. Further, we study whether the inequality-growth relationship changes across the values of our new measure (the HK ratio) in line with the model of Galor and Moav (2004). Therefore, rather than the implicit approach of Chambers and Krause (2010), who consider the role of physical capital for fixed levels of human capital, we utilise the HK ratio which is specifically constructed for our analysis.

Methodologically, we use the relatively new technique of threshold regression with instruments, developed by Caner and Hansen (2004), which captures any threshold effect endogenously in the inequality-growth relationship without fixing the threshold values. As suggested by the model of Galor and Moav (2004), the HK ratio provides the threshold variable for the effect of inequality on growth. Since the threshold variable needs to be exogenous, the lagged value is used for this purpose. Although Lin *et al.* (2009) also employ this technique, as noted above they do not capture the role of returns on human to physical capital. Following Lin *et al.* (2009), we employ the data on income inequality as assembled by Iradian (2005), based on information from household surveys and consistent units of measurement (as far as possible), across 82 countries for the period 1965-2003 (see the details in Section 3.1).

Our empirical results emphasise the role of the HK ratio in providing evidence of significant nonlinearity in the relationship between economic growth and inequality driven by this variable. In line with the predictions of Galor and Moav (2004), at low levels of the HK ratio the effect of inequality on growth is positive and significant, while it is negative and significant at high HK levels (above the threshold).

The paper is organized as follows. In section 2, we briefly outline the Galor and Maov (2004) model and build the testable hypothesis based on its predictions. Section 3 discusses data and econometric methodology used in our analysis. Section 4 explains empirical findings and Section 5 concludes.

2. Galor and Maov (2004) model: its outline and predictions

In Galor and Moav (2004) model, the output is produced with a neoclassical production technology:

$$Y_t = F(K_t, H_t) \equiv H_t f(k_t) = AH_t k_t^{\alpha}; \quad k_t = \frac{K_t}{H_t}; \quad \alpha \epsilon (0,1) \tag{1}$$

where Y_t, K_t and H_t are the output, physical and human capital accumulation respectively at time 't', and A is the level of technology. Assuming perfectly competitive environment, the rate of return to capital (r_t) and the wage rate per efficiency unit of labour (w_t) are respectively:

$$r_t = f'(k_t) = \alpha A k_t^{\alpha-1} \equiv r(k_t); \tag{2}$$

$$w_t = f(k_t) - f'(k_t).k_t = (1-\alpha)Ak_t^{\alpha} \equiv w(k_t); \tag{3}$$

It is assumed that all the individuals have identical preferences and inherent abilities. However, they may vary in their parental wealth and human capital that may be due to borrowing constraints. Further, in first period the individuals acquire human capital which may increase if their time investment is supplemented with capital investment in education. In second period, they supply their efficiency units of labour and allocate their wage income ($w_{t+1}h_{t+1}^i$) and inheritance (x_{t+1}^i) to consumption (c_{t+1}^i) and transfers to their children (b_{t+1}^i).

Human capital formation or acquired efficiency units of labour takes the following form:

$$h_{t+1}^i = h(e_t^i) \tag{4}$$

where h_{t+1}^i is strictly monotonically increasing and strictly concave function of real expenditures of an individual 'i' on education at time 't', e_t^i.

Given the properties of $f(k_t)$, there exists a unique capital-labour ratio ($\tilde{k}$) below which individuals do not invest in human capital (only basic skills), i.e.,

$$e_t = e(k_{t+1}) \begin{cases} = 0 \; if \; k_{t+1} \le \tilde{k} \\ > 0 \; if \; k_{t+1} > \tilde{k} \end{cases} \tag{5}$$

Here, $e'(k_{t+1}) > 0$ for $k_{t+1} > \tilde{k}$, in case when there are no credit constraints. However, if the credit constraints are binding then the expenditure on education of an individual 'i' at time 't' is limited to his inherited amount (transfers, b_t^i):

$$e_t^i = \min[e(k_{t+1}), b_t^i] \tag{6}$$

Suppose that in period '0' the economy consists of two groups of adult individuals: rich (R) with a fraction λ of all adults in the society who equally own the entire initial physical capital stock and poor (P) with a fraction $(1-\lambda)$ of all adults who have no ownership over the initial stock of physical capital. The optimization of groups P and R of generations '$t-1$' and 't' in period 't' determines the aggregate level of physical capital (K_{t+1}) and human capital (H_{t+1}) in period '$t+1$'. Denoting s_t^R and s_t^P as savings (i.e., whatever is left from inheritance after spending in education, e_t^i) by rich and poor in period 't' respectively (with $K_0 > 0$), and using (4) and (5), the capital-labour ratio (i.e., physical capital to human capital ratio) is:

$$k_{t+1} = \frac{K_{t+1}}{H_{t+1}} = \frac{\lambda(b_t^R - e_t^R) + (1-\lambda)(b_t^P - e_t^P)}{\lambda . h(e_t^R) + (1-\lambda) . h(e_t^P)} = \frac{K(b_t^R, b_t^P, k_{t+1})}{H(b_t^R, b_t^P, k_{t+1})} \quad (7)$$

Here in period zero there is no (non-basic) human capital, i.e. $h_0^i = 1,\ \forall\, i = R, P$ and thus $H_0 = 1$. Also, the initial level of capital-labour ratio is $k_0 \in (0, \tilde{k})$ by assumption.

Hence, the capital-labour ratio in period '$t+1$' is determined by the level of transfers of groups R and P in period 't', i.e.

$$k_{t+1} = \kappa(b_t^R, b_t^P) \quad (8)$$

Further, intergenerational transfers within group 'i' in period $t+1$', b_{t+1}^i are determined by the intergenerational transfers within the group in the preceding period and the rewards to factors of production (capital-labour ratio) in the economy, i.e.

$$b_{t+1}^i \equiv \emptyset(b_t^i, k_{t+1}) \quad (9)$$

Following the model, let $\hat{k}$ be the critical level of the capital-labour ratio below which individuals who do not receive transfers from their parents (i.e. $b_t^i = 0$ and therefore, $h(b_t^i) = 1$) do not transfer income to their offspring, i.e. $w(\hat{k}) = \theta$, where θ is the threshold of wages or incomes. Using (3) and replacing k_t with $\hat{k}$, $\hat{k} = [\frac{\theta}{(1-\alpha).A}]^{\frac{1}{\alpha}} \equiv \hat{k}(\theta)$, which implies that: if $k_{t+1} \leq \hat{k}$ then $w(k_{t+1}) \leq \theta$, whereas if $k_{t+1} > \hat{k}$ then $w(k_{t+1}) > \theta$. Hence, b_{t+1}^i are positive if and only if $k_{t+1} > \hat{k}$, i.e.

$$b_{t+1}^i = \emptyset(0, k_{t+1}) \begin{cases} = 0 \ if\ k_{t+1} \leq \hat{k} \\ > 0 \ if\ k_{t+1} > \hat{k} \end{cases} \quad (10)$$

In order to reduce the number of feasible scenarios, the model assumes that once wages increase sufficiently such that members of group P transfer resources to their offspring, i.e., $k_{t+1} > \hat{k}$, investment in human capital becomes profitable, i.e., $k_{t+1} > \tilde{k}$. This implies that $\tilde{k} \leq \hat{k}$.

The evolution of transfers within each group, as follows from (9) and (10), is now fully determined by the evolution of transfers within both types of dynasties,

$$b_{t+1}^i = \emptyset\big(b_t^i, k_{t+1}\big) = \emptyset\big(b_t^i, \kappa(b_t^R, b_t^P)\big) \equiv \psi^i(b_t^R, b_t^P); \quad i = R, P \quad (11)$$

Following the outcomes in period zero as discussed above, the intergenerational transfers of Rich are higher than that of members of group P (the poor) in every time period, i.e.,

$$b_t^R \geq b_t^P \qquad \forall\, t \tag{12}$$

Following (11) and (12), the dynamical system is uniquely determined by the joint evolution of the intergenerational transfers of Rich and Poor groups, where the economy endogenously evolves through two fundamental regimes.

Regime I: No human capital accumulation

In this early stage of development the rate of return to human capital is lower than the rate of return to physical capital and the process of development is fuelled by capital accumulation only by rich group, representing inequality.

Following (5), the level of real expenditure on education in Regime I is zero and the members of both groups acquire only basic skills, i.e., $h\big(\mathrm{e}\ (k_{t+1})\big) = 1$. Furthermore, as the income of members of the poor group is lower than the required threshold, there are no intergenerational transfers among their dynasties. Therefore, for the time interval $0 \leq t \leq \hat{t}$, the capital-labour ratio is determined by the intergenerational transfers and hence capital accumulation by the rich group only;

$$k_{t+1} = \kappa(b_t^R, 0) = \lambda b_t^R \qquad \text{for } b_t^R \in \big[0, \tilde{b}\big] \tag{13}$$

Moreover, if still the economy goes for human capital accumulation, then some resources would be wasted without any productivity that could be used for physical capital accumulation to drive growth. This implies that in this regime, human capital would have no (even negative) effect on growth.

Regime II: human capital accumulation taking place

In this regime, the rate of return to human capital increases sufficiently so as to induce human capital accumulation, and the process of development is fuelled by human capital as well as physical capital accumulation.

Physical capital accumulation of rich group gradually raises the wage rate and the return to human capital which in turn induces the human capital accumulation and the economy enters into Regime II, where the process of development is fuelled by human capital accumulation as well as physical capital accumulation in three sub-stages.

Stage-I: Investment in human capital is selective and it is feasible only for the Rich. The capital-labour ratio is higher than Regime-I which generates high rate of return on human capital (wages) that may justify investment in human capital but it is still below the critical level at which intergenerational transfer of resources by the Poor takes place (i.e., $e_t^P = b_t^P = 0$), representing inequality (i.e., both physical and human capital accumulation by the rich) again alongside economic growth:

$$k_{t+1} = \frac{\lambda\left(b_t^R - e(k_{t+1})\right)}{(1-\lambda) + \lambda h\left(e(k_{t+1})\right)} \tag{14}$$

Stage-II: Investment in human capital is universal but is still sub-optimal due to binding credit constraints. The capital-labour ratio in the economy generates wage rate that permits some investment by all members of the society. Poor's investment in human capital remains suboptimal as compared to Rich because of their parental wealth constraint. Consequently, their marginal rate of return on investment in human capital is higher than the Rich. As human capital is inherently embodied in humans, its accumulation is larger if it is shared by a larger segment of society, thus equality in the presence of credit constraints, stimulates investment in human capital and promotes economic growth. As income further increases, credit constraints gradually diminish, differences in saving rates decline, and the effect of inequality on economic growth ultimately becomes insignificant.

$$k_{t+1} = \frac{\lambda\left(b_t^R - e(k_{t+1})\right)}{(1-\lambda) h\left(b_t^P\right) + \lambda h\left(e(k_{t+1})\right)} \qquad \text{where } e_t^P = b_t^P < e_t \text{ and } e_t^R = e_t \tag{15}$$

Stage-III: the investment in human capital is optimal since credit constraints are no longer binding and the rate of return to human capital is equalized across all the groups which cause inequality to have no effect on economic growth.

$$k_{t+1} = \frac{\beta(Y_t - \theta) - e(k_{t+1})}{h\left(e(k_{t+1})\right)} \qquad \text{where } b_t^R \geq b_t^P \geq e_t \text{ and } e_t^R = e_t^P = e_t \tag{16}$$

Equations (13) – (16) summarize the predicted result of the model. For example, in the early stage of development (Regime-I) inequality between Poor and Rich is mainly due to the difference in their ownership of physical capital. As physical capital is relatively scarce in this regime, the rate of return on physical capital is higher than the human capital. Consequently, inequality favours the owners of capital (Rich) with higher marginal propensity to save (MPS) which results in increased physical capital accumulation and growth, thus economy enters in the later stage of development (Regime-II).

However, in later stage of development as the wage rate of Poor gradually increases they have incentive to invest in human capital because of relatively higher rate of return on it. Thus, increased investment in human capital by the Poor induces further human capital accumulation which gradually equalizes the rate of return on human capital across all members of society in the presence of diminishing credit constraints. Hence, equality leads to higher level of human capital formation and growth, physical capital being replaced by human capital as major force behind economic growth. Therefore, in later stage inequality is harmful for growth as far as credit constraints are binding otherwise it has no effect on growth.

Following the above line of argument, we construct a new measure of human capital to physical capital ratio (HK ratio) which is low in early stage of development (Regime-I) where physical capital is the main reason of economic growth and the effect of inequality on growth is positive. However, in the later stage of development (Regime-II) human capital accumulation gradually replaces physical capital accumulation and becomes the engine of growth. Consequently, HK ratio is relatively higher in this stage and the effect of inequality on growth is negative or insignificant. Hence, our new measure of HK ratio has the ability to capture more clearly the message of Galor and Moav (2004) regarding the replacement of physical capital by human capital as the economy evolves through two fundamental regimes or stages of development.

In order to empirically examine the model of Galor and Moav (2004) for the relationship between inequality and growth, we believe that a measure needs to be constructed to capture the relative change in human capital as compared to physical capital. Hence, in this paper we construct the HK ratio, which rises with an increase in human capital as compared to physical capital and falls for relatively lower levels of human capital as compared to physical capital. This measure is used to estimate the threshold of the HK ratio below and above which inequality-growth relationship changes, as predicted by Galor and Moav (2004).

Thus, based on Galor and Moav (2004) and using the HK ratio, we can examine the following hypotheses:

H1: *There exists a threshold level of the HK ratio that changes the relationship between inequality and economic growth.*

H2: *The effect of inequality on economic growth is positive at values of the HK ratio below the threshold and negative above it.*

As appropriate to these hypotheses, we employ threshold regression as developed by Caner and Hansen (2004), which endogenously captures the threshold effects in the regressions with instruments.

3. Data and Methodology

This section considers our data and methodology. Subsection 3.1 discusses the data on growth and inequality, while subsection 3.2 considers the HK ratio we construct as the threshold variable for our nonlinear analysis. The econometric methodology employed is outlined in subsection 3.3, with the nature of the robustness analyses in subsection 3.4. Variables and sources are given in Appendix Table A1, while Appendix Table A2 provides summary statistics.

We use pooled data for 82 countries for the period 1965–2003. Data on real per capita GDP growth, initial real per capita GDP, inequality, secondary school enrolment, government expenditures to GDP ratio, population growth, and inflation are taken from Iradian (2005), which we extend by including capital stock per worker, average years of schooling, trade openness and two measures of the human capital to physical capital ratio.

3.1. Data: Growth and Inequality

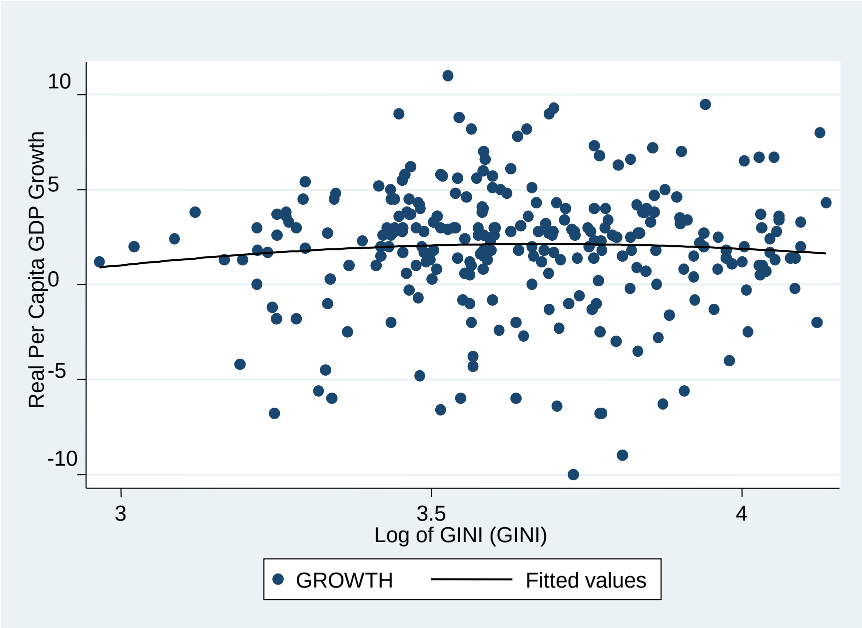
When assembling his data, Iradian (2005) expanded the existing World Bank data by including comparable data on inequality from household surveys included in IMF Staff Reports and Poverty Reduction Strategy Papers. The time periods employed by Iradian (2005) are dictated by the availability of household expenditure or income survey data. Since the time span between surveys ranges from three to fourteen years, the data are irregularly spaced over time. He handles issues of data quality and measurement error by ensuring that the statistics are comparable across countries and over time using (as far as possible) similar definitions of variables for each country and year.

This dataset includes 16 countries from Latin America, 12 from sub-Saharan Africa, 12 from South and East Asia, 11 from the former Soviet Union, 6 from Central and Eastern Europe, 8 from the Middle East and North Africa, and 17 OECD countries. Consistent with Iradian's (2005) approach, the additional variables we construct are formed as averages over the time span between the two survey years. The sample from Iradian (2005) includes 380 observations, but this is reduced to 216 in our analysis due to data availability for the additional variables and the creation of lags.

As usual in such analyses, economic growth (GROWTH) is measured by real per capita GDP growth. Inequality is represented by the log of the GINI coefficient (GINI), which is calculated from the Lorenz Curve and higher values represent greater inequality. Since inequality is endogenous in a growth regression, we later instrument this by its lagged value

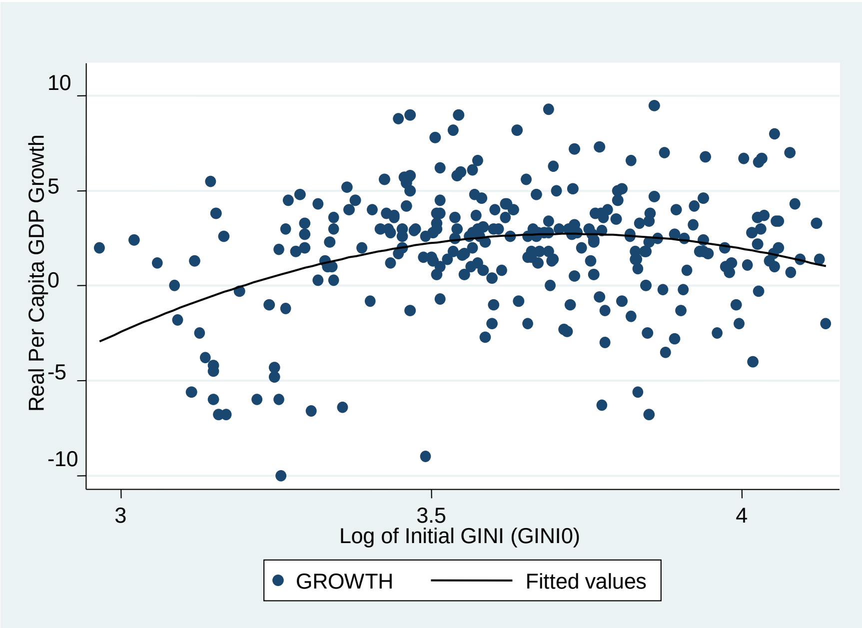
(GINI0). The scatter plots of income inequality and growth suggest a nonlinear relationship, which appears more marked when initial inequality (GINI0) is plotted against economic growth; see Figures 1 and 2. In particular, Figure 2 indicates that growth increases with initial inequality up to some value of the latter, after which it declines as initial inequality increases.

Figure 1 Income Inequality (GINI) and GROWTH



Note: GROWTH is real per capita GDP growth, GINI is Inequality as measured by the GINI coefficient. The variables are used in log form. In this plot, the fitting line is based on the calculation of prediction for GROWTH from a linear regression of GROWTH on GINI and its square values.

Figure 2 Initial Income Inequality (GINI0) and GROWTH



Note: As for Figure 1. GINI0 is initial value of GINI coefficient.

Based on the model of Galor and Moav (2004) summarized in Section 2, our empirical analysis employs the HK ratio as the threshold variable which drives the nonlinearity observed in Figures 1 and 2; the construction of this variable is discussed in the next subsection. All regression models include log of initial value of real per capita income (LY0) to control for convergence, while population growth (POP) incorporates demographic effects.

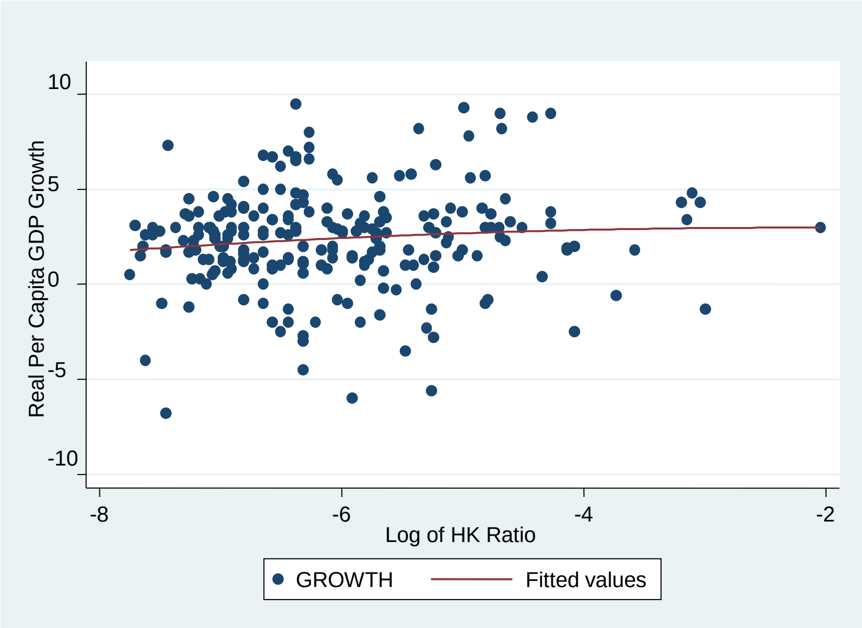
3.2 Human Capital to Physical Capital Ratio

Consistent with Galor and Moav (2004), we construct a new measure of the human capital to physical capital ratio (HK ratio) in order to capture the effect of an increase in human capital relative to physical capital accumulation on the relationship between inequality and growth. Therefore, rather than viewing the coefficient of inequality as a function of human capital and physical capital measures, as in the semi-parametric analysis of Chambers and Krause (2010), we employ the HK ratio which is more directly related to the arguments of Galor and Moav (2004).

The HK ratio is anticipated to be relatively low for developing countries, which have generally low levels of education compared to industrialized or developed countries (see Son, 2010). According to Galor and Moav (2004), physical capital accumulation is the main engine of economic growth at low levels of the HK ratio and in this stage the effect of inequality on growth is anticipated to be positive. After a certain threshold level of the HK ratio, when human capital replaces physical capital accumulation to become the engine of economic growth, as in industrialized countries, the effect of inequality is anticipated to be negative for growth.

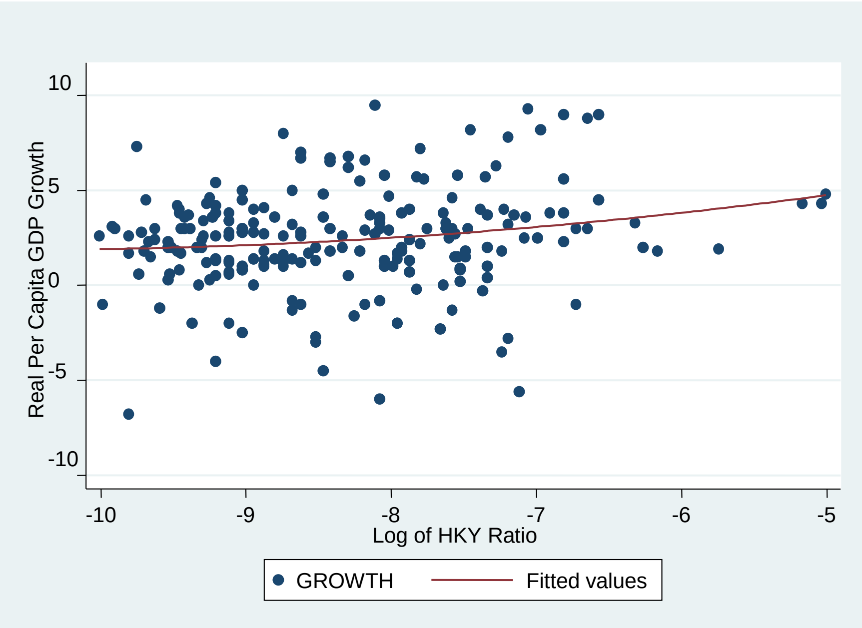
In view of the available proxies for human capital, we construct two HK ratios, namely based on secondary school enrolment (%) and average years of schooling. Each of these human capital measures is divided by the capital stock per worker to form the corresponding ratio. The principal measure we use is based on secondary school enrolment and is simply denoted as *HK*, while the corresponding measure computed using average years of schooling is denoted as *HKY*. The scatter plots of *HK* and *HKY* with growth in Figures 3 and 4 reveal a weak positive relationship between these measures and economic growth. However, the inverted U-shape nonlinear relationship between the HK ratios and inequality (*GINI*) appears clear in the scatter plots of Figures 5 and 6. This implies there may be threshold effects in the relationship between inequality and the HK ratio, which could lead to a threshold effects of the HK ratio on the inequality-growth relationship as hypothesized at the end of Section 2.

Figure 3 HK Ratio and GROWTH



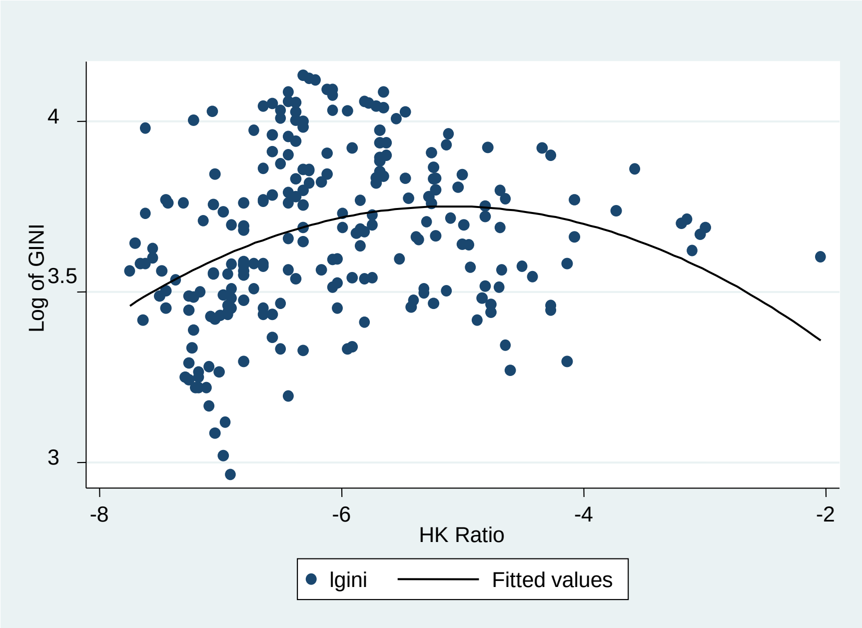
Note: As for Figure 1. HK Ratio is human capital to physical capital ratio, where human capital is secondary school enrolment.

Figure 4 HKY Ratio and GROWTH



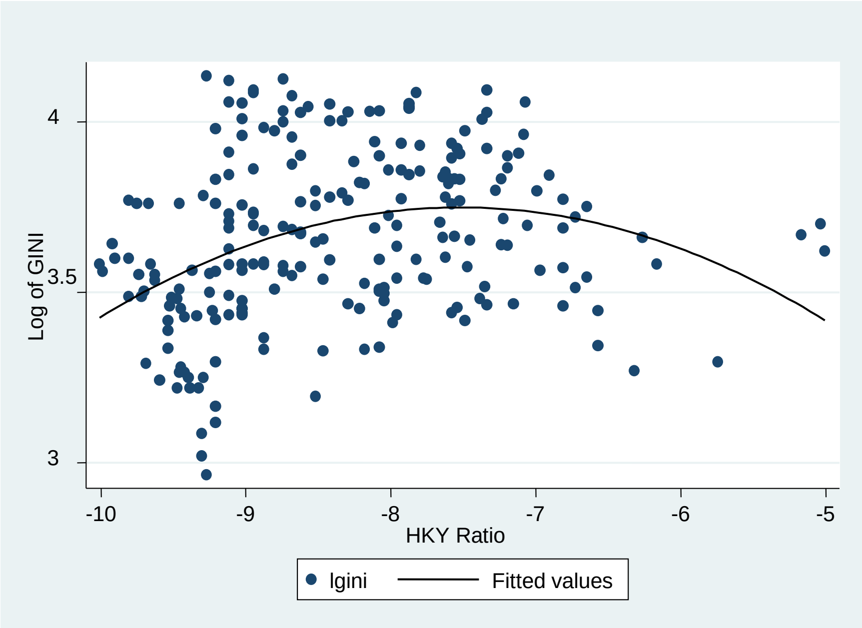
Note: As for Figure 1. HKY Ratio is human capital to physical capital ratio, where human capital is average years of schooling.

Figure 5 HK Ratio and Income Inequality (GINI)



Note: As for Figures 1 and 3.

Figure 6 HKY Ratio and Income Inequality (GINI)



Note: As for Figures 1 and 4.

3.3. Methodology: Threshold Regression Analysis

A linear form of the pooled regression model on which our analysis is based is given by

$$GROWTH_{i,t} = \beta_1 + \beta_2 GINI_{i,t} + \beta_3 HK_{i,t-1} + \beta_4 LY0_{i,t-1} + \beta_5 POP_{i,t-1} + u_{i,t} \quad (1)$$

where i refers to country and t is a time index; the variables are defined in Section 3 and Appendix Table A1. Our focus is on the relationship between growth and inequality, for which $GINI_{i,t}$ is endogenous, and hence this variable is instrumented by its lagged value. To avoid further endogeneity issues[4], lagged values are employed for other variables in (1), including the additional variables added in the robustness analysis.

To allow for the nonlinearity implied by the analysis of Galor and Moav (2004) for the effect of inequality on growth, (1) is extended to the nonlinear two-regime threshold model

$$\begin{aligned} GROWTH_{i,t} = {} & [\, \beta_{11} + \beta_{21} GINI_{i,t} + \beta_{31} HK_{i,t-1} + \beta_{41} LY0_{i,t-1} + \beta_{51} POP_{i,t-1} \,]\, \mathrm{I}(HK_{i,t-1} \leq \gamma) \\ & + [\, \beta_{12} + \beta_{22} GINI_{i,t} + \beta_{32} HK_{i,t-1} + \beta_{42} LY0_{i,t-1} + \beta_{52} POP_{i,t-1}]\, \mathrm{I}(HK_{i,t-1} > \gamma) + u_{i,t} \end{aligned} \quad (2)$$

where I(.) is the indicator function which takes the value unity when the expression in parentheses is satisfied, $HK_{i,t-1}$ is the threshold variable and γ is the threshold parameter that determines the switch between the two regimes. The disturbance $u_{i,t}$ is assumed to follow a martingale difference sequence. This model permits all regression parameters ($\beta_{i1}, \beta_{i2}; \forall\, i = 1,2, \ldots ,5$) to switch between regimes depending on whether $HK_{i,t-1}$ is smaller or larger than the (unknown) threshold value γ.

If all regressors are exogenous, (2) can be estimated based on ordinary least squares (OLS) method, as suggested by Hansen (2000). The threshold value γ is estimated by minimizing the residual sum of squared for (2) over a grid of possible values for γ, with other parameters then obtained given the estimate $\hat{\gamma}$. Since γ is not identified under a null hypothesis of no threshold effect, there is a 'nuisance' parameter problem that implies conventional asymptotic tests have nonstandard asymptotic distributions. Hansen (1996) avoids this problem through a heteroscedasticity consistent Lagrange multiplier (LM) test for the presence of a threshold and proposes a bootstrap procedure to obtain asymptotically correct *p*-values for the test.

In our case, $GINI_{i,t}$ is endogenous[5] in (2) and is instrumented by its lagged value through the nonlinear reduced form relationship

[4] With more than one right-hand side endogenous variables in (2), the method of Caner and Hansen (2004) that we employ requires any regime-dependent behaviour in these variables to have a common threshold.

[5] We also estimate our threshold regressions using the OLS method with lagged values $GINI_{i,t-1}$ instead of current values with instruments. This specification leads to minor improvements in the significance of the

$$GINI_{i,t} = [\,\alpha_{11} + \alpha_{21}GINI_{i,t-1} + \alpha_{31}HK_{i,t-1} + \alpha_{41}LY0_{i,t-1} + \alpha_{51}POP_{i,t-1}\,]\;\mathrm{I}(HK_{i,t-1} \leq \rho)$$
$$+ [\,\alpha_{12} + \alpha_{22}GINI_{i,t-1} + \alpha_{32}HK_{i,t-1} + \alpha_{42}LY0_{i,t-1} + \alpha_{52}POP_{i,t-1}]\;\mathrm{I}(HK_{i,t-1} > \rho) + v_{i,t} \qquad (3)$$

where, using the methodology of Caner and Hansen (2004), the threshold ρ in (3) is not required to be the same as that in (2). This involves first estimating (3) using the OLS method just outlined, and obtaining the fitted values $\widehat{GINI}_{i,t}$. These fitted values are substituted into (2) to estimate γ, again using the OLS method. Based on threshold estimate ($\hat{\gamma}$), the whole sample is split into the two indicated subsamples, with the generalized method of moments (GMM) method applied to each subsample to obtain the estimates of (2). In the light of the nonlinearity indicated between the HK ratio and *GINI* in Figures 5 and 6, the use of a regime-dependent reduced form specification as in (3) is important.

Caner and Hansen (2004) discuss the asymptotic distributions for test statistics of interest applied to (2). In particular, they show that the LM test of Hansen (1996) extends to this case, allowing inference to be conducted on the presence of a threshold effect. Our estimation and inference results employ the GAUSS codes provided by Caner and Hansen (2004) and Lin *et al*. (2009).

3.4. Robustness Analyses

A robustness check for our results on the effect of inequality on growth is undertaken by including further control variables in (2) and (3). These additional variables are the log of trade openness (*OPEN*), inflation (*INF*) which is included to capture the effects of macroeconomic instability, and the log of government expenditures as a percentage of GDP (*GOV*) which is included to allow for the effects of fiscal policy.

As an additional robustness check, our threshold regression model is estimated using data of Chambers and Krause (2010), who use a semi-parametric approach to study the predictions of the Galor and Moav (2004) model. Their data consist of an unbalanced panel of 294 observations for 54 countries, which spans eight five-year intervals ranging from 1960-65 to 1995-2000. We extend this data by adding variables on human capital to physical capital ratio (*HKY*), together with the control variables *POP*, *OPEN*, *INF*, and *GOV* [6]. Due to missing observations on *INF* and *GOV*, we use 230 pooled observations in this robustness analysis. Further due to the limited availability of secondary school enrolment data for the

overall threshold effect, with some change in the magnitudes of the coefficients. However, the signs remain unchanged.

[6] The definitions of these variables and data sources are given in Appendix Table A1.

period, we construct only one measure of the HK ratio in this case, which is *HKY*, computed as the average years of schooling (15 years or above) divided by capital stock per worker.

4. Results

In this section we discuss our threshold regression results using both measures of the HK ratio, together with a robustness analysis.

4.1 Baseline Estimates

Table 1 presents the estimates of threshold level and regression coefficients where human capital is measured by secondary school enrolment (%) in constructing our threshold variable, the HK ratio[7]. Model 1 of Table 1 uses the full data set to estimate (2). The results (specifically the highly significant LM statistic) provide clear support for our hypothesis **H1** developed at the end of Section 2, namely that a threshold value of *HK* exists at which the effect of inequality on growth alters. The threshold value -5.682, which is above both the mean and median values of this variable (see Table A2) and hence the majority of observations fall in the lower regime. Further, the coefficients of inequality (*GINI*) also support our hypothesis **H2**, since this variable is estimated to have a positive effect on economic growth in the lower regime, when *HK* is at or below the threshold, and a negative effect in the upper regime. Although both coefficients are significantly different from zero at the 10% level, the upper regime is more highly significant (*p*-value of 0.8%). These findings, therefore, are in line with the predictions of Galor and Moav (2004), namely that when returns to human capital are relatively high in comparison to returns to physical capital (which generally applies in more developed economies), inequality is harmful for growth. However, the conclusion that inequality is beneficial for growth when *HK* is relatively low is less clear-cut, in that the statistical significance of the coefficient on *GINI* is less compelling in the lower regime.

[Insert Table 1 here]

The results of our baseline Model 1 contrast with those of Lin *et al*. (2009), who estimate a similar model, also using pooled data from Iradian (2005) and Caner and Hansen (2004) instrumental variables threshold estimation, but who find the coefficients on inequality to have signs opposite to those predicted by Galor and Moav (2004). Our specification, however, differs from theirs in the key respect that we use a measure of human to physical

[7] We take the natural log of our measure of the human capital to physical capital ratio (*HK*) to avoid large coefficients on this variable. However, use of the ratio without logarithms does not substantively change the results.

capital as the threshold variable, whereas Lin *et al*. (2009) use initial per capita income (in 1965) for this purpose; as argued in the Introduction, we believe that our measure captures more adequately the mechanism of the Galor and Moav (2004) theory.

In terms of other coefficients of (2) estimated using the full data set, it is notable that population growth has a negative and significant effect on growth in both regimes. As anticipated, convergence (measured by the coefficient of *LY0*) is negative and significant in the lower regime. It is interesting, however, that this variable apparently plays no role in the upper *HK* regime. On the other hand, the *HK* ratio itself has a positive and significant (at close to 1%) effect on growth in the upper regime, supporting the Galor and Moav (2004) claim that human capital provides the engine of growth in such cases. In contrast, *HK* is not significant in the lower regime, so there is less evidence that physical capital is the key driver of growth when this ratio is low.

As noted in Section 3, the Iradian (2005) data is unequally spaced in time because it is based on the availability of household survey data. For example, therefore, the dependent growth variable is computed over periods ranging from three to fourteen years. In order to check the robustness of our results to this temporal issue, we estimate our baseline model using data calculated over less than five year intervals and five year intervals, resulting in Models 2 and 3 respectively of Table 1[8]. Of course, fewer observations are available for estimation in these cases than for Model 1, and different types of countries may undertake household surveys at different frequencies. Nevertheless, the broad pattern of the key results carries over to these additional estimations of Table 1. In particular, the LM test finds threshold nonlinearity to be significant at the 10% level, with inequality having a positive effect on growth in the lower HK regime and a negative effect in the upper regime. The general implications of other coefficients (although not necessarily their statistical significance) also largely carry over from Model 1 to Models 2 and 3.

Hence, we observe that our main findings of Model 1 in support of hypotheses **H1** and **H2** remain intact when different data averaging spans are examined, in the sense that the nature of the relationship between inequality and growth is nonlinear and of an inverted U-shape, in line with the theoretical outcomes of Galor and Moav (2004).

[Insert Table 2 here]

[8] The number of observations using survey data at intervals of more than five years are too few to enable reliable estimates to be obtained for the threshold model.

4.2. Robustness Analysis

As discussed in subsection 3.4, the robustness of our baseline results[9] (Model 1 of Table 1) are checked by including additional control variables, both one by one and as a group, with results shown as Models 4 to 7 in Table 2. These also support a nonlinear relationship between inequality and growth consistent with Galor and Moav's (2004) theoretical predictions. Although the null hypothesis of linearity is less strongly rejected in Model 7 than in other cases, this model is more highly parameterized, making nonlinearity more difficult to detect. Nevertheless, the estimated threshold value is virtually unchanged across all the models estimated with the full data set in Tables 1 and 2, with inequality having a negative and significant effect on growth in the upper *HK* regime, but a positive (albeit not always statistically significant) one in the lower regime. We also note that inflation and government expeenditure to GDP (*INF* and *GOV* respectively) are estimated to have negative impacts on economic growth, in line with other empirical literature on inflation, fiscal policy, and growth (see Fisher, 1993; Easterly and Rebelo, 1993).

[Insert Table 3 here]

Table 3 provides a further robustness analysis of our baseline results by using the alternate measure of our threshold variable, namely *HKY*, calculated using average years of schooling as the proxy for human capital. Although this form of the threshold variable provides less strong evidence than the baseline case, nevertheless the LM statistic for Model 8 rejects linearity at the 5% level, with the majority of observations again in the lower HK regime. We note that *HKY* itself has a positive but insignificant effect on growth below the estimated threshold of -7.884, whereas it is positive and significant (close to the 1% level) in the upper regime. Further, the effect of population growth is again negative and significant in both the regimes of Model 8. Table A3 in the Appendix reports the results of including *OPEN*, *INF* and *GOV* in this specification. The broad results are in agreement with these findings, although the significance of threshold nonlinearity and individual estimated coefficients varies across the regressions.

Models 9 and 10 of Table 3 utilize the data for different time intervals (namely less than five years and five years), based on the frequency of household survey data used by Iradian (2005) and corresponding to Models 2 and 3 (respectively) of Table 1. These results generally support the baseline results of Table 1. Although the coefficient on inequality is

[9] This analysis was also conducted using the sub-samples of data less than 5 years and 5 year averages. The results are broadly the same, with some differences in significance. These results are not reported both to conserve space and because the smaller numbers of observations for these cases imply that the results from more highly parameterized models may be less reliable.

positive in Model 10, it is not significant and the estimates in this upper regime are obtained from a relatively small number of observations.

Finally, Model 11 of Table 3 provide results analogous to those of Model 8, but are based on the data used by Chambers and Krause (2010), which they obtain from the Penn World Tables. As discussed above, these authors also examine the empirical implications of the Galor and Moav (2004) model, but employ semi-parametric techniques and separate variables to represent human and physical capital. Although their findings largely support the Galor and Moav (2004) predictions, their use of separate variables does not capture fully the theoretical analysis which is based on a relative measure. Once again, this data provides evidence in favour of a threshold level of human capital to physical capital ratio (*HKY*) at which the coefficients of the growth-inequality model of equation (2) change. In this case, the effect of inequality on economic growth is estimated to be negative below the threshold value; although contrary to the theoretical predictions and not in line with all other results across Tables 1 to 3, this coefficient is not statistically significant at any conventional level of significance. On the other hand, inequality has a negative and highly significant impact on growth above the threshold, in line with our baseline result of Model 1 of Table 1. Using this data, all variables have insignificant coefficients in the lower *HKY* regime, while the coefficient of initial per capita GDP (*LY0*) is positive and significant (at 1%) in the upper regime, which does not support convergence. Also, unlike Model 8 using our preferred data, the coefficient of *HKY* itself is insignificant across both regimes. Overall, these results partially support our hypotheses, in terms of the presence of nonlinearity and the effect of inequality on growth being negative and significant above the threshold of the HK ratio[10]. However, the differences with the baseline results in Table 1 and also Model 8 of Table 3 may be due to the quality of the data on inequality and the composition of countries in data sets.

Overall, our threshold regression results from Tables 1 and 2 show that the relationship between inequality (as measured by log of GINI index) and economic growth is nonlinear, where inequality has positive and significant effect on growth in earlier stage of economic development when the HK ratio is below the estimated threshold level, whereas it has negative and significant impact on growth in the latter stage when the HK ratio is high and lies above the estimated threshold. Therefore, our threshold regression results verify the

[10] Similar findings overall are obtained when the additional control variables openness (*OPEN*), inflation (*INF*) and government size (*GOV*) are included in Model 11; these results are available on request.

existence of nonlinear relationship between inequality and economic growth along the human capital to physical capital ratio (HK) as suggested by the theoretical findings of Galor and Moav (2004).

5. Conclusion

Although huge volume of theoretical and empirical research has been devoted to understanding the complex relationship between inequality and economic growth since the seminal work of Kuznets (1955), empirical studies have been unable to establish a clear cut view on this relationship. The reason may be the lack of a theoretical base, data quality, econometric methodology, or use of an inappropriate specification.

However, Galor and Moav (2004) did a remarkable task by combining two previous strands of literature, resulting in their prediction of an inverted U-shaped relationship running from inequality to economic growth. They argue that in the early stage of economic development, the classical approach is dominant where inequality channels resources towards the owners of capital with higher marginal propensity to save, thus enhancing physical capital accumulation and growth. Moreover, human capital is less important in this stage because the marginal rate of return on physical capital is relatively higher. However, in the latter stage human capital replaces physical capital and becomes a primary engine of growth because of relatively higher returns on it. Further, the wages of the poor increase and equality alleviates the adverse effect of credit constraints on investment in human capital in the latter stage.

Following Galor and Moav (2004) and using our new measure of the human capital to physical capital ratio (HK ratio), we establish two testable hypotheses: *First*, there exists a threshold of HK ratio in the relationship between inequality and growth. *Second*, the effect of inequality on economic growth is positive before a threshold value of the HK ratio and negative above it. We test our hypotheses using the relatively new technique of threshold regression with instruments, developed by Caner and Hansen (2004). Our baseline results show that there exists a significant threshold level of the HK ratio below which the effect of inequality on growth is positive, whereas it is negative above it, thus validating our maintained hypotheses.

For robustness, we include additional control variables, namely trade openness, inflation and the government expenditure to GDP ratio. These confirm the baseline findings, although statistical significance varies across the robustness regressions. The threshold regression model is also estimated by extending the data employed in the related study by Chambers and Krause (2010). Results from this data also favour the existence of significant nonlinearity of the threshold form related to the value of the human capital to physical capital ratio. However, these results are only in partial agreement with our baseline results, possibly due to the different inequality data employed (Iradian, 2005).

Our results shed light on the complex relationship between inequality and economic growth, but also emphasize the crucial role of human to physical capital ratio. Below the threshold level, we find HK ratio to have insignificant effect on growth, while it generates significant positive effect above the threshold. This suggests that the governments may pursue the policy of encouraging physical capital accumulation to generate economic growth at the initial stage of development as human capital accumulation may not be effective at this stage. However, according to our findings this emphasis on physical capital would inevitably lead to income inequality. So the policy makers and analysts should not be alarmed to see this happening as long as they want to keep their focus on generating economic growth. This gives us the next level of understanding that the governments or policy makers need to keep a close eye on when the emphasis should start changing from physical capital to human capital. Because if the economy cannot identify the need for switching this emphasis at the right time, they might eventually end up with not only high income inequality but also lower economic growth along with it.

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Table 1: Baseline Threshold Model Estimates

	Model 1 Full data set		**Model 2** Less than five-year averages		**Model 3** Five-year averages	
Threshold estimates						
$\hat{\gamma}$	-5.682		-5.954		-5.887	
LM Statistic	49.326		30.816		38.548	
p-value	0.000		0.050		0.073	
Coefficient estimates						
	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$
GINI	2.253*	-5.526***	7.541**	-13.215**	2.542**	-1.405
	(0.071)	(0.008)	(0.015)	(0.023)	(0.038)	(0.567)
Constant	1.706	31.672***	-20.165	45.738***	-8.254	28.380***
	(0.818)	(0.000)	(0.189)	(0.001)	(0.448)	(0.004)
HK	-0.120	1.080**	-2.023	2.462***	-0.376	0.124
	(0.858)	(0.013)	(0.1940)	(0.000)	(0.737)	(0.689)
LY0	-0.862**	0.561	-1.853*	2.866**	-0.097	-1.557***
	(0.020)	(0.270)	(0.084)	(0.015)	(0.820)	(0.003)
POP	-0.809**	-3.229***	-2.540**	-1.515	-0.030	-3.344***
	(0.026)	(0.000)	(0.048)	(0.347)	(0.943)	(0.000)
Observations	147	69	32	38	72	19

Notes: Values in parentheses are asymptotic heteroscedasticity-consistent *p*-values. ***, **, and * indicate significant at 1%, 5%, and 10% respectively. The model estimated is given by (2), with dependent variable is real per capita GDP growth and threshold variable the log of human capital to physical capital ratio (HK), measured as secondary school enrolment (%) with physical capital measured as capital stock per worker. *GINI* is endogenous variable and instrumented by its lagged value through (3); all other explanatory variables are lagged. The table uses three pooled data sets, consisting of all cases (216), data intervals of less than five years (70) and five years (91).

Table 2: Robustness of Baseline Threshold Model Estimates - Full Data Set with Control Variables

	Model 4		Model 5		Model 6		Model 7	
<u>Threshold estimates</u>								
$\hat{\gamma}$	-5.682		-5.682		-5.682		-5.666	
LM Statistic	51.102		52.202		38.284		43.114	
p-value	0.003		0.009		0.006		0.075	
<u>Coefficient estimates</u>								
	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$	$HK \leq \hat{\gamma}$	$HK > \hat{\gamma}$
GINI	2.525* (0.072)	-5.290** (0.011)	2.308* (0.055)	-4.816** (0.030)	0.629 (0.698)	-4.629** (0.018)	0.592 (0.703)	-3.889* (0.077)
Constant	-1.346 (0.881)	31.064*** (0.000)	6.188 (0.309)	30.128*** (0.000)	11.214 (0.246)	35.088*** (0.000)	16.195* (0.066)	36.196*** (0.000)
HK	-0.211 (0.750)	1.073** (0.013)	0.046 (0.941)	0.979** (0.018)	-0.412 (0.573)	1.033** (0.017)	-0.225 (0.736)	0.918** (0.031)
LY0	-0.850** (0.023)	0.595 (0.248)	-1.192*** (0.001)	0.377 (0.471)	-0.813** (0.017)	0.302 (0.563)	-1.095*** (0.001)	-0.153 (0.799)
POP	-0.829** (0.024)	-3.211*** (0.000)	-0.858** (0.015)	-3.220*** (0.000)	-0.864** (0.019)	-3.262*** (0.000)	-0.913** (0.013)	-3.305*** (0.000)
OPEN	0.353 (0.431)	-0.160 (0.704)					0.025 (0.955)	0.274 (0.631)
INF			-0.043*** (0.000)	-0.019 (0.214)			-0.043*** (0.001)	-0.020 (0.176)
GOV					-1.714 (0.109)	-1.714 (0.129)	-1.870* (0.063)	-2.324 (0.109)
Observations	147	69	147	69	147	69	148	68

Notes: As for Table 1, except that all observations are used to estimate the models of this table.

Table 3: Baseline Threshold Model Estimates Using Alternate HK Ratio Measure

	Model 8 Full data set		**Model 9** Less than five year averages		**Model 10** Five year averages		**Model 11** Chambers-Krause data	
Threshold estimates								
$\hat{\gamma}$	-7.884		-7.967		-8.069		-8.515	
LM Statistic	30.229		32.738		37.530		36.186	
p-value	0.040		0.035		0.089		0.050	
Coefficient estimates								
	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$
GINI	2.467**	-3.427*	7.813***	-11.315**	2.461**	0.666	-0.560	-6.174***
	(0.039)	(0.073)	(0.010)	(0.038)	(0.038)	(0.816)	(0.461)	(0.000)
Constant	-0.078	30.546***	-15.476	48.785***	-6.739	26.975**	6.468	20.612***
	(0.992)	(0.000)	(0.342)	(0.000)	(0.618)	(0.014)	(0.313)	(0.000)
HKY	0.063	1.184**	-1.213	2.084***	-0.100	1.245	0.257	0.952
	(0.915)	(0.011)	(0.346)	(0.000)	(0.920)	(0.354)	(0.693)	(0.1225)
LY0	-0.596**	0.138	-2.154	2.085**	-0.048	-1.218	0.009	1.533***
	(0.038)	(0.771)	(0.109)	(0.045)	(0.901)	(0.214)	(0.986)	(0.001)
POP	-0.832**	-3.307***	-2.644**	-2.174	-0.052	-3.507***	-0.227	-0.011
	(0.015)	(0.000)	(0.026)	(0.141)	(0.900)	(0.005)	(0.410)	(0.944)
Observations	142	67	30	37	71	19	156	104

Notes: As for Table 1, except that the threshold variable is the log of human capital to physical capital ratio (*HKY*), which is the number of years of secondary education with physical capital measured as capital stock per worker. Models 8 to 10 otherwise use the same data as Table 1, while Model 11 is based on the data employed by Chambers and Krause (2010); see text for details.

Appendix

Table A1: Definitions and Sources of Variables used in the Analysis

Variable	Abbreviation	Definition	Source
Real per capita GDP growth	*GROWTH*	Annual average between two survey years	Iradian (2005)
Initial real per capita GDP	*LY0*	Log of GNP per capita at PPP (US$)	Iradian (2005)
Human capital: school enrolment	*HC*	Secondary school enrolment (% of age group) at the beginning of the period.	Iradian (2005)
Human capital: years of schooling	*HCY*	Average years of schooling for the total population aged 15 and over	Barro and Lee (2010)
Per capita physical stock	*K*	Ratio of the total stock of physical capital to labour force.	Authors' construction from Penn World Tables 6.2 (PWT 6.2)
Human capital to physical capital ratio: school enrolment	*HK*	Log of *HC* to *K* ratio	Authors' construction using data from Iradian (2005) and PWT 6.2
Human capital to physical capital ratio: years of schooling	*HKY*	Log of *HCY* to *K* ratio	Author's construction using data from Barro and Lee (2010) and PWT 6.2
Inequality	*GINI*	Inequality as measured by the Gini coefficient	Iradian (2005)
Initial Inequality	*GINI0*	Initial value of *GINI*	Iradian (2005)
Population growth rate	*POP*	Population growth rate	Iradian (2005)
Openness	*OPEN*	Log of exports plus imports as percentage of GDP	PWT 6.2
Inflation	*INF*	Annual average CPI inflation rate between two survey years	Iradian (2005)
Government Size	*GOV*	Government expenditure as share of GDP, averages between two survey years	Iradian (2005)

In our threshold analysis “less than five years averages” and “five years averages” means the cases for which the data is averaged over a time span of less than five and five years respectively. Our full sample includes all of the cases for which data is available. The data are available upon request.

Table A2: Summary Statistics

	GROWTH	*GINI*	*LGINI0*	*LY0*	*HK*	*HKY*	*POP*	*OPEN*	**INF**	**GOV**
Mean	2.354	3.654	3.648	8.186	-6.039	-8.366	1.563	3.903	14.735	3.282
Median	2.600	3.658	3.661	8.320	-6.301	-8.503	1.600	3.938	9.000	3.256
Std. Deviation	2.672	0.232	0.243	1.040	1.070	0.990	0.991	0.549	18.795	0.412
Minimum	-6.750	2.965	2.965	5.561	-7.752	-10.000	-0.500	2.220	-1.000	2.477
Maximum	9.500	4.094	4.079	10.062	-2.064	-5.009	4.200	5.321	150.000	4.168
Correlations										
GROWTH	1.000									
GINI	-0.022	1.000								
GINI0	-0.047	0.920	1.000							
LY0	-0.141	-0.232	-0.202	1.000						
HK	0.116	0.194	0.133	-0.826	1.000					
HKY	0.139	0.251	0.192	-0.755	0.890	1.000				
POP	-0.118	0.532	0.513	-0.661	0.604	0.589	1.000			
OPEN	-0.103	0.035	0.051	0.205	-0.197	-0.043	-0.041	1.000		
INF	-0.257	0.209	0.169	-0.154	0.061	0.088	0.126	-0.134	1.000	
GOV	-0.206	-0.540	-0.512	0.622	-0.631	-0.662	-0.641	0.262	-0.118	1.000

Note: See Table A1 for definitions of all variables.

Table A3: Threshold Model Estimates using Alternate HK Ratio Measure with Additional Control Variables

	Model 12		Model 13		Model 14		Model 15	
Threshold estimates								
$\hat{\gamma}$	-7.881		-7.884		-7.466		-7.583	
LM Statistic	34.029		33.433		27.924		30.432	
p-value	0.040		0.064		0.091		0.411	
Coefficient estimates								
	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$	$HKY \leq \hat{\gamma}$	$HKY > \hat{\gamma}$
GINI	2.593**	-3.303*	2.833**	-2.753	0.900	1.393	1.292	-5.171
	(0.039)	(0.089)	(0.017)	(0.161)	(0.478)	(0.476)	(0.339)	(0.194)
Constant	-2.046	30.028***	2.785	29.277***	8.930	40.404***	10.405	55.209***
	(0.801)	(0.000)	(0.670)	(0.000)	(0.175)	(0.000)	(0.132)	(0.001)
HKY	-0.055	1.191**	0.107	1.177***	-0.173	1.761***	-0.281	1.715***
	(0.923)	(0.011)	(0.846)	(0.009)	(0.756)	(0.002)	(0.603)	(0.000)
LY0	-0.683**	0.163	-0.948***	0.001	-0.614**	-0.892	-0.918***	-0.949
	(0.022)	(0.729)	(0.001)	(0.999)	(0.015)	(0.218)	(0.001)	(0.121)
POP	-0.854**	-3.331***	-0.919***	-3.245***	-0.954***	-4.084***	-1.078***	-3.621***
	(0.014)	(0.000)	(0.005)	(0.000)	(0.006)	(0.000)	(0.002)	(0.000)
OPEN	0.321	-0.001					0.241	2.013
	(0.416)	(0.998)					(0.516)	(0.128)
INF			-0.041***	-0.031*			-0.040***	-0.025
			(0.001)	(0.083)			(0.002)	(0.120)
GOV					-1.481	-5.068***	-1.882*	-4.590**
					(0.136)	(0.001)	(0.065)	(0.030)
Observations	143	66	142	67	169	40	160	49

Notes: As for Table 2, except that the threshold variable is *HKY*.