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INEQUALITY AND GROWTH: NON-MONOTONIC EFFECTS VIA EDUCATION AND FERTILITY

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Inequality and growth: Non-monotonic effects via education and fertility

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Abstract

This paper examines the effect of inequality upon economic growth. Much of the existing empirical literature has found a negative effect of inequality upon long run growth. In contrast, our theoretical model, in which heterogeneous individuals jointly determine the levels of investment in human capital and fertility, predicts that the effect of inequality upon growth is non-monotonic: inequality impedes growth in low fertility economies, but fosters growth in high fertility economies. We provide empirical support for this prediction by estimating a system of equations to which growth, investment in human capital, and fertility are endogenous.

JEL Classification: D31, J13, O15, O41
Keywords: Growth, Inequality, Human Capital, Fertility

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1 Introduction

A number of empirical studies have found an economically and statistically significant negative relationship between inequality and long run growth.[1] The idea that low income inequality and high long run growth are consistent objectives appears to have become a common agreement. In this paper, we cast doubt upon this statement, arguing that the effect of inequality upon growth may be non-monotonic in the long run.

There is a large literature regarding why inequality might impede growth.[2] A branch of the literature regards an endogenously determined redistibutive policy as a catalyst.[3] It asserts that, in more unequal economies, greater distortion due to higher redistributive tax, which is determined endogenously by vote, is likely to impede more investment. Another branch of the literature argues that more inequality will lead to more sociopolitical instability, which in turn will discourage investment.[4]

Our paper relates to a third branch of the literature, which focuses upon investment in human capital.[5] The existing literature has shown that, when credit markets are imperfect, more inequality implies that less people are able to invest in human capital, which in turn lowers growth. We extend this by incorporating endogenous fertility. Throughout the paper, we postulate that fertility is jointly determined with investment in human capital by the individuals' optimising behaviour.[6] Therefore, in our theoretical model, inequality has implications for growth through both investment in human capital and endogenous fertility.[7]

In incorporating endogenous fertility, we employ an overlapping generations model that follows Ehrlich and Lui (1991) (hereafter E&L). A representative agent in their model maximises her utility by choosing how much to invest in quality and quantity of human capital, caring about current and future consumption, as well as "companionship" by her children in the future. In contrast to E&L, who look only at the representative agent, we look at heterogeneous dynasties that comprise an economy. By allowing education to have external effects, we can define an economy as follows—an economy consists of dynasties who can affect one another through externality in education. It turns out that a dynasty's behaviour differs according to the human capital stock it inherits, as well as the economy's average level of human

[1]Although some studies have recently found a positive or non-monotonic relationship between inequality and growth (Barro, 2000, Forbes, 2000, Li and Zou, 1998), their focus is the effect in the short run (5–10 years).

[2]Perotti (1996) provides a comprehensive survey on this issue.

[3]Persson and Tabellini (1994) and Bertola (1993).

[4]Alesina and Rodrik (1994), Grossman and Kim (1996), Benhabib and Rustichini (1996).

[5]Galor and Zeira (1993), Galor and Zang (1997), and Galor and Tsiddon (1997).

[6]This idea stems from Becker (1960). Theoretical application of this idea to endogenous growth can be found in Becker, Murphy and Tamura (1990).

[7]There exist only few theoretical studies that deal simultaneously with inequality, investment in human capital, endogenous fertility, and growth of an economy, where Dahan and Tsiddon (1998) and Morand (1999) are the notable exceptions.

capital. Hence, the initial distribution of human capital in an economy has strong implications for subsequent growth.

One of our main interests in this paper is to test implications from our theoretical model regarding the effect of inequality upon *long run* growth, say, over 25 years. However, deriving empirical implications from our theoretical model is a little tricky—since we use a three-period OLG model, 25 years correspond to only one generation. Because an economy comprises heterogeneous dynasties who affect each other via educational externality effects, assessing the growth rate of the economy over one generation requires us to keep tracking human capital and fertility levels of all the dynasties in the economy.[8] We have conducted numerical simulations to resolve this matter, which has suggested that the relationship between inequality and long run growth (for the subsequent 25 years) in an economy depends upon an economy's demographic stage of development: whilst in high fertility economies, inequality enhances growth, in low fertility economies, inequality hinders growth.

Turning to the empirical side, a large literature finds a negative relationship between inequality and growth. Typically, it conducts a reduced form growth regression where growth is regressed upon various economic variables including inequality. However, there is little literature that estimates a system of equations. Regarding the literature that looks at endogenous fertility in explaining the effect of inequality upon growth, only one empirical study by Perotti (1996) estimates a system of equations, which has suggested that the relationship between inequality and growth is negative.

This study is similar to Perotti (1996) but is different in the following respects. We modify his econometric specification in order for it to be consistent with our theoretical model. Since our model suggests that the effect of inequality depends upon an economy's demographic stage of development, we specify a system of equations so that we can identify the effects of inequality upon different types of economies. Some empirical studies such as Barro (2000) and Deininger and Squire (1998) also suggest the non-monotonic effects of inequality upon growth (for different reasons from ours). They separate their samples into two according to some criteria, such as an income level or a degree of democracy.[9] In this paper, however, we use a

[8]In a similar set up to ours, Morand (1999) analyses the effect of inequality upon growth in the *long run* of his theoretical model. One crucial difference from Morand (1999) in terms of theoretical modelling is that the utility function in our model explicitly includes the number of children as we postulate that parents enjoy "companionship" by their children as in E&L, whilst in Morand (1999) the number of children does not enter the parents' utility function so children could be interpreted as financial assets that yield returns in the next period. Hence our study generalises Morand (1999) in this respect, and unsurprisingly, our results include those in Morand (1999) as a special case.

[9]The results of these studies are not of interest here. Barro (2000) looks at the short-run effects of inequality on growth and also has a problem in his estimation technique. The random effect panel estimation is used on panel data, but since the data are actually dynamic that include initial income, the random effect estimation produces an inconsistent estimator; see Arellano and Bond (1991). Deininger and Squire (1998) look at the long run story, but separate sample according to whether a country is democratic or not. Their study finds that the effect of inequality does not exist in democratic societies.

different method in order to identify the development-stage-dependent effects. We also utilise an inequality data set compiled by Deininger and Squire (1996), which was not available when Perotti (1996) conducted his study. This data set could be called industry standard by now (Forbes, 2000, Barro, 2000, Deininger and Squire, 1998, and Li and Zou, 1998). The use of this data set alleviates estimation bias from possible measurement error.

The rest of the paper is structured as follows. Section 2 describes a model in which investment in human capital and fertility are determined jointly by individuals. An economy is characterised by a set of dynasties who interact with each other through an educational externality. Section 3 describes the dynamics of economies. We discuss the relationship between initial distribution and subsequent growth and also conduct numerical simulations in order to assess how different initial distributions affect growth in the short run of the model. It is shown that the effects of inequality upon growth are different according to an economy's demographic stage of development. Our empirical model is specified in Section 4. Section 5 reports estimations and analyses results. Section 6 concludes.

2 The model

An extended version of the E&L model can be summarised as follows. There are two-sectors: consumption goods and human capital. Instead of looking at a representative agent, we look at heterogeneous agents who live for three periods in overlapping generations. Let us consider an agent of dynasty i who is born in Period $t-1$. She is born as a child, becomes a young parent, and becomes an old parent before she dies. When she is a child, she is dependent upon her parent and receives education from her parent. Let us denote the level of human capital she receives from her parent by H_t^i at Period t.

When she is a young parent, she is no longer dependent upon her parent and can produce a perishable consumption good Q_t, subject to the following production function:

$$Q_t^i = AH_t^i l_t^i, \tag{1}$$

where A is a positive productivity parameter and l_t^i denotes the time that is spent to produce this good.

She produces this good since she gets utility from consuming it when she is a young parent, but she also takes her future consumption into account in making her production decision. In Period $t+1$ she will become an old parent. She will be dependent upon her children at this stage of life.[10] That is, she is no longer able to

[10]Not only are individuals unable to store a consumption good, but also they are assumed to have no access to credit markets. The assumption of imperfect credit markets is commonly imposed in the existing literature in the similar research area.

produce anything, but instead she can expect support from her children. The amount of support depends upon both how much she has invested in her children's education and how many of her children survive to become a young parent. We will come back to this issue shortly.

A young parent has T units of time. It is assumed that child rearing costs v units of time per child. Hence, she faces the following time constraint:

$$l_t^i = T - vn_t^i - h_t^i n_t^i, \tag{2}$$

where h_t^i is the time she devotes to educating each child and n_t^i is the number of children.

A young parent may have an incentive to invest in education of her children as she can expect more support from them in the future. We assume that there is a custom that people will follow, in which a young parent gives her (old) parent an amount of the consumption good equivalent to a certain ratio w of the education that she received, *i.e.*, the level of human capital H_{t+1}. Let us assume the following human capital production function as in Morand (1999):

$$H_{t+1}^i = (1 + H_t^i h_t^i)^\beta \bar{H}_t, \tag{3}$$

where $0 < \beta < 1$ and H_{t+1}^i is the level of human capital that a child receives from her (young) parent. $\bar{H}_t$ is the average level human capital of all the young parents of an economy, showing that there is the externality effect in education. Note that even if $h_t^i = 0$, *i.e.*, a parent does not devote time on her children's education, they are able to enjoy an externality benefit so that $H_{t+1}^i > 0$.

Dynasties within an economy interact through this externality effect. Suppose Dynasties A and B affect each other through externality in human capital production but Dynasty C is not affected by these dynasties (and they are not affected by Dynasty C, either). We can regard that the former two dynasties reside in the same economy whilst the latter one does not. More formally, we define an economy as follows:

Definition 1 *An economy consists of a set of dynasties that affects one another through educational external effects.*

The material support that an old parent can get and the support that a young parent has to give are $n_t^i w H_{t+1}^i$ and wH_t^i, respectively. Aside from material support, an old parent may find "companionship" by her children worthwhile. This "companionship" function is specified as follows:

$$M_{t+1}^i = (n_t^i)^\gamma (H_{t+1}^i)^\alpha, \tag{4}$$

where $\gamma \in (0, 1]$ and $\alpha \in [0, 1]$. This equation shows that "companionship" by children is subject to diminishing returns to the number of children unless $\gamma = 1$. It also shows that an old parent enjoys more "companionship" by children who are more educated unless $\alpha = 0$.

Each individual gets utility from consumption when she is a young parent, and from consumption and "companionship" by her children when she is an old parent. Specifically, we assume the following log-linear utility function:

$$u_t^i = \ln c_{1,t}^i + \delta(\ln c_{2,t+1}^i + \ln M_{t+1}^i), \tag{5}$$

where c_1^i and c_2^i are consumption when she is a young parent and an old parent, respectively. The utility of consumption when she is old is discounted for the rate of time preference ρ, with $\delta \equiv 1/(1+\rho)$.

The consumption of a young parent and an old parent are as follows, respectively:[11]

$$c_{1,t}^i = AH_t^i(T - vn_t^i - h_t^i n_t^i) - wH_t^i, \tag{6}$$
$$c_{2,t+1}^i = n_t^i w H_{t+1}^i. \tag{7}$$

Now let us analyse optimal decisions by the representative of dynasty i. Note we also impose a non-negative condition on both n_t^i and h_t^i, *i.e.*:

$$n_t^i \geq 0, \tag{8}$$
$$h_t^i \geq 0. \tag{9}$$

Given H_t^i, a young parent of dynasty i in Period t chooses the optimal values of n_t^i and h_t^i in order to maximise her utility function (5) subject to Equations (4), (6), (7), (8), and (9). The first order conditions are as follows:

$$\frac{c_{2,t+1}^i}{c_{1,t}^i} \geq \frac{\delta w(1+\gamma)H_{t+1}^i}{A(v+h_t^i)H_t^i} \equiv \delta R_{t,n}^i, \tag{10}$$
$$\frac{c_{2,t+1}^i}{c_{1,t}^i} \geq \frac{\delta w\,(1+\alpha)}{AH_t^i}\frac{\partial H_{t+1}^i}{\partial h_t^i} \equiv \delta R_{t,h}^i, \tag{11}$$

where δR_n^i and δR_h^i represent discounted rates of return on investment in quantity (n_t^i) and quality (h_t^i) of children, respectively.

From these equations we can obtain the following relationship:

$$R_{t,h}^i \gtreqless R_{t,n}^i \iff \frac{\beta(1+\alpha)}{1+\gamma} \gtreqless \frac{1+H_t^i h_t^i}{H_t^i(v+h_t^i)}. \tag{12}$$

This equation provides us with many theoretical implications. We summarise them in the following lemmas.

[11]Note that for $c_{1,t}^i$ to be positive, $AT > w$. We assume that it holds throughout the analysis.

Lemma 1 *When H_t^i is sufficiently small and $\beta(1+\alpha) < 1+\gamma$, the return on quantity of children $R_{t,n}^i$ exceeds the return on quality of children $R_{t,h}^i$, i.e., a parent does not educate her children.*[12]

Proof. Suppose not. Then h_t^i should be positive. But Equation (12) implies:

$$\begin{aligned} \frac{\beta(1+\alpha)}{1+\gamma} &\geq \frac{1+H_t^i h_t^i}{H_t^i(v+h_t^i)} \\ h_t^i &\leq \left(v-(H_t^i)^{-1}\right)(1+\gamma)\left[(1+\gamma)-\beta(1+\alpha)\right]^{-1} \end{aligned}$$

When H_t^i approaches zero, the RHS of this inequality approaches negative infinity. Contradiction. ■

This lemma shows that a corner solution in which a parent invests only in quantity of children exists. It turns out that a parent finds it most profitable just to rely upon externality in education and not to invest in her children's education at all when her level of human capital is below the threshold, which we explain next.

Lemma 2 *For any $H_t^i > \widehat{H} = \frac{1+\gamma}{v\beta(1+\alpha)}$, the returns on quantity and quality of children are the same. Investment in human capital is given as $h_t^i = \frac{H_t^i - \widehat{H}}{H_t^i(\widehat{H}-v^{-1})}$, and is increasing in H_t^i.*

Proof. First we argue that $R_{t,h}^i > R_{t,n}^i$ can be ruled out, *i.e.*, the return on quality of children will never be greater than the return on quantity of children.

Suppose it is the case, *i.e.*, $h_t^i > 0$ and $n_t^i = 0$. This implies that an old parent gets neither material nor mental support. She never chooses this option, which gives her negative infinity utility, so $h_t^i > 0$ and $n_t^i = 0$ cannot happen.[13]

Having ruled out the case where $R_{t,h}^i > R_{t,n}^i$, from Equation (12), $R_{t,h}^i \leq R_{t,n}^i$ implies:

$$\begin{aligned} \frac{\beta(1+\alpha)}{1+\gamma} &\leq \frac{1+H_t^i h_t^i}{H_t^i(v+h_t^i)} \\ h_t^i &\geq \frac{H_t^i - \widehat{H}}{H_t^i(\widehat{H}-v^{-1})}. \end{aligned}$$

[12] The second order condition for the interior optimal solution requires that $(1+\gamma)(1+\alpha\beta) > \beta^2(1+\alpha)^2$. It is necessarily the case that if $\beta(1+\alpha) < 1+\gamma$, then this condition holds. We assume this condition on parameters holds throughout the rest of the paper. The derivation of this condition is available upon request.

[13] This result sounds a little unrealistic, as in reality, many people choose not to have children. It is driven by the fact that, in our model, the only way for a young parent to secure future consumption is to have children.

The denominator of the RHS of this inequality is always positive given this restriction on the parameters. Suppose $H_t^i > \widehat{H}$ and $R_{t,h}^i < R_{t,n}^i$. Then $h_t^i = 0$. But the above inequality shows that $h_t^i > 0$ as the numerator of the RHS of it is also positive. Contradiction. So we must have an interior solution for any $H_t^i > \widehat{H}$, which means that the above inequality will hold as an equality, that is, $h_t^i = \frac{H_t^i - \widehat{H}}{H_t^i(\widehat{H} - v^{-1})}$. Differentiating this with respect to H_t^i concludes the proof:

$$\frac{\partial h_t^i}{\partial H_t^i} = \frac{\widehat{H}(\widehat{H} - v^{-1})}{\left[H_t^i(\widehat{H} - v^{-1})\right]^2} > 0.$$

Investment in human capital increases as the level of human capital increases. ■

This lemma shows that for a parent whose human capital is above $\widehat{H}$, it is profitable to invest in her children's education, and the greater her level of human capital is, the more she invests in her children's education. We call $\widehat{H}$ the *threshold* level of human capital hereafter.

We can show that the number of children is decreasing in the level of human capital when the returns on quality and quantity of children are the same.

Lemma 3 *For any interior solution, the number of children is given as* $n_t^i = \frac{\delta(1+\gamma)(T - wA^{-1})}{(v + h_t^i)[1 + \delta(1+\gamma)]}$ *and is decreasing in* H_t^i*.*

Proof. Using Equations (6), (7), and (10) leads to the result. Note that from Lemma 2 $h_t^i = \frac{H_t^i - \widehat{H}}{H_t^i(\widehat{H} - v^{-1})}$ and is increasing in H_t^i. It is apparent that the number of children for any interior solution is decreasing in h_t^i, therefore is decreasing in H_t^i as well. ■

In passing, note that n_t^i approach a constant, $\bar{n} = \frac{\delta(T - wA^{-1})[1 + \gamma - \beta(1+\alpha)]}{v[1 + \delta(1+\gamma)]}$, when H_t^i approaches infinity.[14]

The relationship between the number of children and human capital is not, however, negative when the level of human capital is below the threshold where $h = 0$. It turns out that a young parent chooses to have the same number of children regardless of the level of human capital.[15]

Lemma 4 *For any corner solution, the number of children is given as* $n_c = \frac{\delta(1+\gamma)(T - wA^{-1})}{v[1 + \delta(1+\gamma)]}$.[16]

[14] This follows Lemmas 2 and 3. This information is used when we conduct numerical simulations.

[15] The non-continuous nature of our human capital production function in the sense any children without having education can obtain the average level of human capital of their parents is crucial to this result.

[16] Note also that this lemma is consistent with Lemma 3, *i.e.*, $n_t^i = n_c$ if and only if $h_t^i = 0$. This information is also used when we conduct numerical simulations.

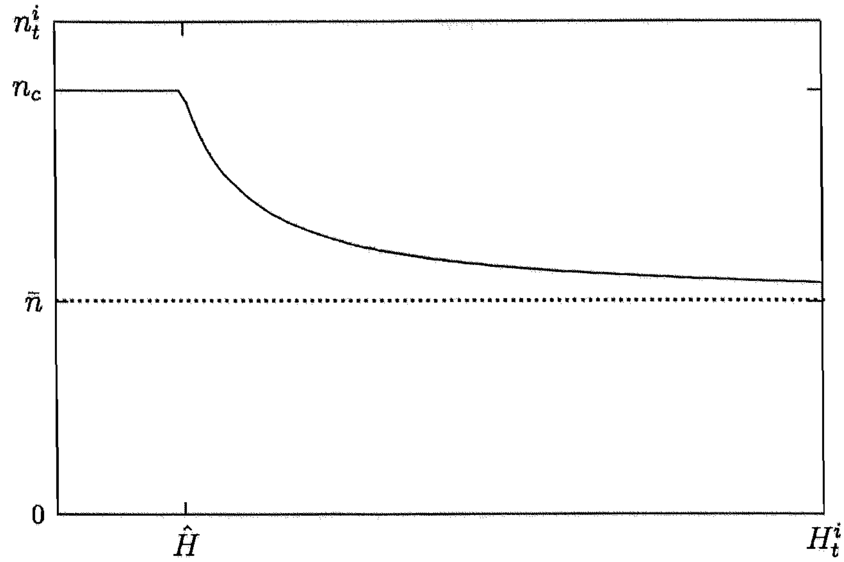

Figure 1: The number of children

Proof. Equation (10) holds as an equality in this case. Using Equations (6), (7), and (10) setting $h_t^i = 0$ leads to the result. ∎

Figure 1 depicts the relationship between fertility and human capital derived from our model. Barro (1991) has stylised an inverse relationship between human capital and fertility across countries. Our theoretical model appears to explain this stylised fact.

Let us summarise the important results from our analysis so far in the following proposition.

Proposition 1 *There exists a threshold level of human capital $\widehat{H}$ below which parents will not invest in their children's education. If parents' human capital is above the threshold, they invest in their children's education. The higher is the parents' human capital, the higher their investment in children's education and the lower the rate of fertility.*

Proof. This is another presentation of the above lemmas. ∎

3 The dynamics of an economy

The dynamics of dynasty i of an economy in our model can be summarised as follows:

$$H_{t+1}^i = \bar{H}_t \left\{ 1 + (\widehat{H} - v^{-1})^{-1} \max \left[H_t^i - \widehat{H}, 0 \right] \right\}^{\beta}, \tag{13}$$

$$n_t^i = \frac{\delta(1+\gamma)(T - wA^{-1})}{\left(v + \max\left[\frac{H_t^i - \widehat{H}}{H_t^i(\widehat{H} - v^{-1})}, 0\right]\right)[1 + \delta(1+\gamma)]}. \tag{14}$$

The dynamics of human capital and the number of children for dynasties are governed by Equations (13) and (14), respectively. As we can see, human capital stock of young parents of dynasty i in Period $t+1$ depends not only upon their parents' level of human capital in Period t, but it also depends upon the economy's average level of human capital (of young parents) in Period t. We first consider a benchmark case where every dynasty is identical and then extend the analysis to heterogeneous dynasties.[17]

3.1 Identical dynasties

First we analyse the benchmark economy where all dynasties are identical. Suppose initially every young parent in an economy has a level of human capital equivalent to H_0^i, hence the average level of human capital will be $\bar{H}_0 = H_0^i$. We can consider two situations. If $H_0^i < \widehat{H}$, our discussion in the previous section implies that every young parent in the next period will have a level of human capital equivalent to the average level of human capital in this period, so $H_1^i = \bar{H}_0$. In turn, this implies that the average level of human capital will be unchanged, *i.e.*, $\bar{H}_1 = \bar{H}_0$. By the same token, $\bar{H}_t = \bar{H}_0$ hence $H_{t+1}^i = H_t^i$ for any t. In summary:

Proposition 2 *An economy that consists of identical dynasties whose level of human capital is below the threshold will stagnate.*[18]

In the case where $H_0^i > \widehat{H}$, from our discussion in the previous section, every young parent in the next period will have received education of $h_0^i = \frac{H_0^i - \widehat{H}}{H_0^i(\widehat{H} - v^{-1})}$ from their parents, and their level of human capital will be $H_1^i = \bar{H}_0\left(1 + \frac{H_0^i - \widehat{H}}{\widehat{H} - v^{-1}}\right)^\beta > \bar{H}_0$. This implies that the average level of human capital will be increasing, *i.e.*, $\bar{H}_1 > \bar{H}_0$. By the same token, $\bar{H}_{t+1} > \bar{H}_t$ hence $H_{t+1}^i > H_t^i$ for any t. In summary:

Proposition 3 *In an economy that consists of identical dynasties whose level of human capital is above the threshold, all dynasties will keep accumulating human capital.*

[17] This analysis follows Morand (1999).

[18] This conforms to the stylised fact—more than 10 per cent of the countries in the Penn World Table experienced negative growth during the period 1960-1989.

3.2 Heterogeneous dynasties

There are three cases we can consider when an economy consists of heterogeneous dynasties. First, we consider the case in which an economy's average level of human capital exceeds the threshold, *i.e.*, $\bar{H}_0 > \widehat{H}$. Call this Case I. We show that regardless of initial distribution, an economy's level of human capital will be increasing over time. Equation (13) implies that all the young parents in Period 1 will inherit a level of human capital at least $\bar{H}_0$, so the average level of human capital in Period 1 will be greater than that in Period 0, *i.e.*, $\bar{H}_1 > \bar{H}_0$. By the same token, $\bar{H}_{t+1} > \bar{H}_t > \widehat{H}$ for any t. That is:

Proposition 4 *In an economy that consists of heterogeneous dynasties whose average level of human capital is above the threshold, all dynasties will keep accumulating human capital.*

Second, consider the case where an economy's average level of human capital is below the threshold, and so are all dynasties' levels of human capital. That is, $H_0^i < \widehat{H}$ for all i, so $\bar{H}_0 < \widehat{H}$. Call this Case II. The scenario is simple. Equation (13) implies that all the young parents in Period 1 will inherit a level of human capital equal to $\bar{H}_0$, which is below the threshold level, *i.e.*, $H_1^i = \bar{H}_0$. This implies that all the young parents in periods following this will inherit $\bar{H}_0$, *i.e.*, $H_t^i = \bar{H}_0 < \widehat{H}$ for all $t > 1$. This finding is summarised as follows.

Proposition 5 *In an economy that consists of heterogeneous dynasties all of whose levels of human capital are below the threshold, all dynasty will stagnate with a constant level of human capital.*

Finally, we consider the case where an economy's average level of human capital is below the threshold, but there are some dynasties whose levels of human capital are above the threshold. The outcome is ambiguous. Dynasties above the threshold will contribute to increasing the economy's average level of human capital as young parents who belong to them will educate their children, but the dynasties below the threshold will contribute to lower it as these young parents will not educate their children at all but choose to have many children, which will drive the economy's average level of human capital down. If the contribution of the former is large enough, the economy's average level of human capital may jump above the threshold at some stage $\widehat{t}$, *i.e.*, $\bar{H}_{\widehat{t}} > \widehat{H}$. From Proposition 5, we know that thereafter all the dynasties in this economy will accumulate human capital over time (same as Case I). In contrast, there exists a situation where all the young parents inherit human capital below the threshold at some stage $\widetilde{t}$, *i.e.*, $\bar{H}_{\widetilde{t}} < \widehat{H}$. This happens when an economy comprises a number of poor dynasties and few rich dynasties whose human capital levels are just above the threshold. From Proposition 4, we know that all the dynasties in this economy will stagnate (Case II).

3.3 Demographic transition

The dynamics we have seen have relevance to the *demographic transition.*[19] If the economy happens to jump from Case II to Case I, it corresponds to a decline in the rate of fertility. In Case II where an economy stagnates, every dynasty invests only in quantity of children, and the optimal number of children is n_c. We could thus regard an economy of this type as a pre-transition economy. In contrast, in Case I, every individual eventually comes to invest in quality of children and the optimal number of children declines as the level of human capital increases. Therefore, we would regard an economy of this type as a post-transition economy.

3.4 Initial inequality and growth

Note that our analysis is based upon the overlapping generations model. One period in our model corresponds to around 25–30 years, in which case the short run of our model corresponds to what we usually call the long run in empirical analysis. Therefore our interest in this paper is to see how initial inequality will affect *growth in the short run of the model.* Morand (1999) only conducts the long run analysis pointing out that conducting this short run analysis is difficult because we need to keep tracking human capital and fertility levels for all the dynasties simultaneously. We attempt this step by resorting to numerical simulations.[20]

Let us assume that initial human capital is lognormally distributed over 10,000 dynasties, *i.e.*, $\log H \sim N(\mu_H, \sigma_H^2)$. This distribution is often used since it is skewed to the right and takes only positive values. We create two economies, one with $\sigma_H = 0.2$ and the other with $\sigma_H = 0.8$. We control μ_H in order to make $\bar{H}_0$ the same. We analyse the case where $\bar{H}_0 > \widehat{H}$, restricting our analysis to the situation in which an economy is guaranteed to exhibit positive growth in the long run.

Figure 2 summarises our results. The difference between the growth rates is taken on the vertical axis. If the difference is positive, a more equal economy grows faster. As we can observe, this is the case for economies with high $\bar{H}_0$. In contrast, it appears that a more unequal economy exhibits higher growth when the initial average level of human capital is low. Recalling that the rate of fertility declines as the level of human capital increases, we can put it another way: in an economy where fertility is high, inequality enhances growth, but in a low fertility economy, inequality impedes growth.

Let us introduce two figures in order to provide intuition as to what is happening. Figures 3 and 4 depict the distribution of human capital for a high fertility (low human

[19]Note that this model is not explaining all aspects of what demographers call the demographic transition, which has to do with both the birth and death rates.

[20]Parameter values used here are $v = 0.1$, $\delta = 0.7$, $\gamma = 2/3$, $\alpha = 1/9$, $w = 0.2$, $T = 2$, $A = 1/3$, $\beta = 3/4$. These parameters yield $\bar{n} \approx 2.15$ and $n_c \approx 4.31$, which are close to the average fertility values of the lower and higher thirds of our 57 country sample, respectively. The threshold level of human capital $\widehat{H}$ is 20, given these parameters.

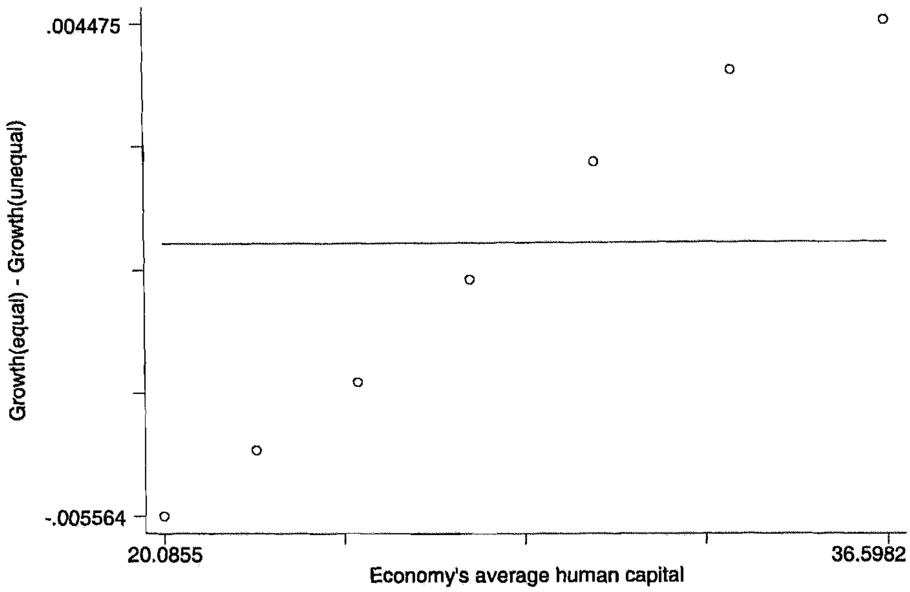

Figure 2: Comparison of growth rates in the short run

capital) economy and a low fertility (high human capital) economy, respectively. The distribution of a relatively unequal economy is shaded in each figure. In both figures, the important differences between an equal economy and an unequal one are that, in the latter there exist more young parents at the upper end as well as the lower end of the distribution of human capital.

In Figure 3, we set the average level of young parents' human capital equivalent to the threshold $\widehat{H}$ for both economies. Roughly speaking, when we make an equal economy unequal, young parents who lie in Areas B and D stretch out to Areas A and F, respectively. Do these differences in distributions matter to the growth rate of output per worker? In order to think about this, let us look at the differences in the distribution above and below the average level of human capital $\bar{H}_t$.

Regarding the difference above the average, making the distribution more unequal appears to have a positive effect upon the growth rate of output per worker. The reasons are that 1) young parents in F invest more in their children's education than those in D; and 2) they choose to have less children. In turn, making the distribution more unequal creates more young parents at the lower end of the distribution, *i.e.*, young parents in B stretch out to A. Note however, unlike young parents who lie above the threshold, these young parents behave in the same way regardless of their levels of human capital, *i.e.*, they have the same number of children and do not invest in their children's education. Thus in the next period, the same number of young parents who have the same level of human capital will exist in both economies. Hence making the distribution more unequal appears to have a positive effect upon growth

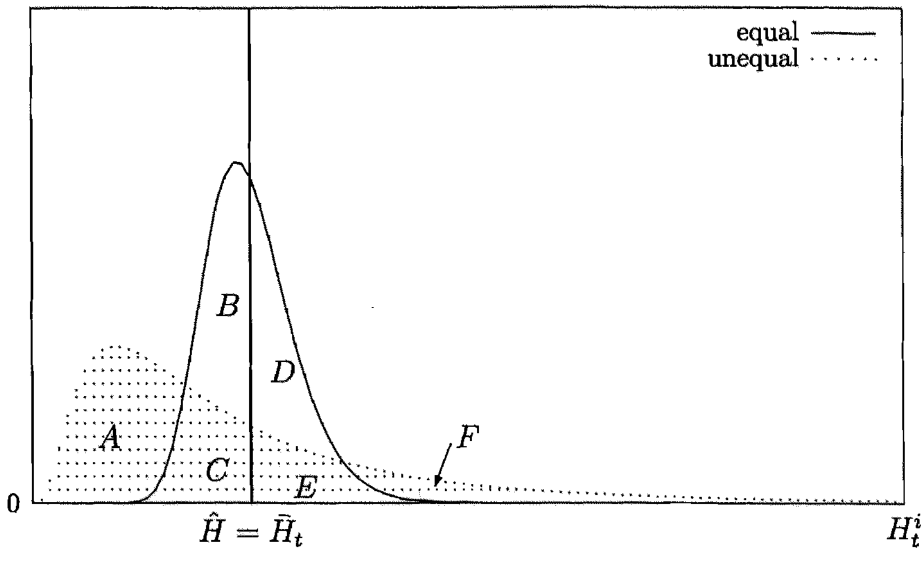

Figure 3: Initial distribution for high fertility (low human capital) economies

(there are more dynasties catching up faster in a more unequal economy). These together explain the positive effect of inequality upon growth, but why should the story be different for a low fertility (high human capital) economy?

In order to think about this, note that in Figure 3, many young parents lie below the threshold in both economies. In contrast, it is not the case in Figure 4 where the average level of human capital is set high above the threshold. Under this situation, in a more equal economy, there exist only few young parents (Area J) who lie below the threshold. When we make the distribution more unequal, it will create many more young parents who lie below the threshold (Area G). These young parents contribute *against* increasing the growth rate of output *per worker* as they choose to have many (maximum in our model, n_c) least-productive children. In Figure 4, when we look above the average, making the distribution more unequal appears to have a positive effect upon growth, as in Figure 3. However, a more unequal economy has many more young parents below the threshold (Area G) than a more equal economy does, and their behaviour of having the maximum number of children who are not educated more than offsets the positive effect of inequality above the average. In other words, in having a net positive effect of inequality upon growth in Figure 3, the fact that the average level of human capital is low is important as it ensures that many young parents exist in a more equal economy.[21]

The above analysis leads us to posit the following conjecture about a relationship

[21] By nature of the log-normal distribution, there exist more young parents in Area A than in Area B, so there is some negative effect of inequality in Figure 3 as well. However, what is important is that the negative effect is relatively small compared with that in Figure 4.

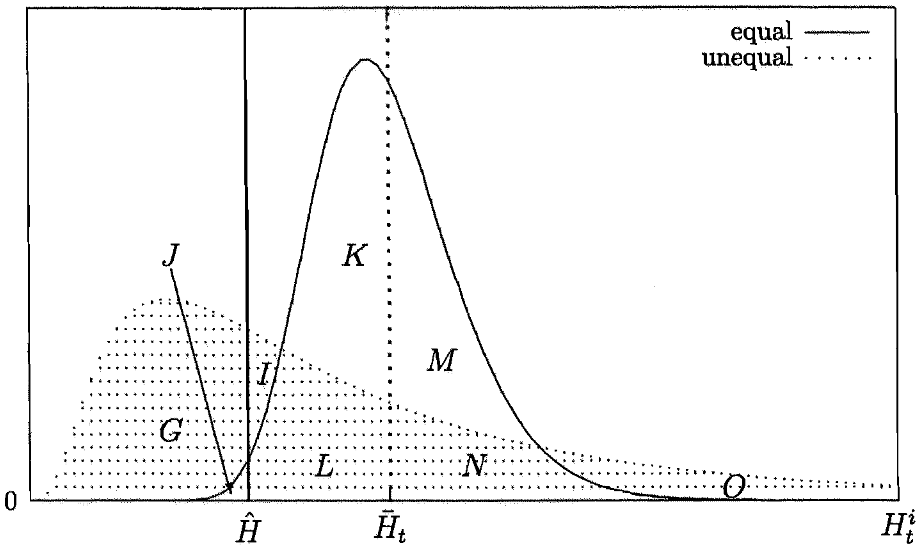

Figure 4: Initial distribution for low fertility (high human capital) economies

between initial inequality and subsequent growth.

Conjecture 1 *The implication of inequality for the per-worker growth rate depends upon an economy's demographic stage of development. In a high fertility economy, inequality enhances growth, whereas in a low fertility economy, inequality impedes growth. For an economy in between, the effect of inequality upon growth is ambiguous and trivial.*

4 The empirical model and data

The previous conjecture is obtained using the numerical example, hence it is important that we test it against real data. To begin with, we specify the empirical model as follows:

$$\begin{cases} g_{65-90} & = f(\ln y_{65}, PPPI_{65}, FEDU_{65-90}), \\ FEDU_{65-90} & = g(FERT_{65-90}, GINI_{65}, FHC_{65}), \\ FERT_{65-90} & = h(FEDU_{60}, FERT_{60}, FHC_{60}, POP_{65}), \end{cases} \tag{15}$$

where g_{65-90} is the average annual growth rate of real GDP per worker 1965–1990, $\ln y_{65}$ is a logarithm of real GDP per worker in 1965 that captures convergence, $PPPI_{65}$ is the PPP value of the investment deflator as an indication of price distortion, relative to that of the United States in 1965, $FERT_{65-90}$ is the net fertility rate,[22] average of 1960 and 1990 values, $GINI_{65}$ is the Gini coefficient in or around 1965,[23] $FEDU_{65-90}$ is the female gross enrolment ratio for secondary education, average of 1960 and 1990 values, and FHC_{65} is average years of secondary schooling in the female population over age 25 in 1965.[24] $FEDU_{60}$, $FERT_{60}$, and FHC_{60} are the 1960 values of $FEDU_{65-90}$, $FERT_{65-90}$, and FHC_{65-90}, respectively, and POP_{65} is total population in 1965. The descriptive statistics that are relevant in the subsequent discussion are given in Table 1.

System (15) consists of three equations. The first is a growth equation where the growth rate of real GDP per worker is explained by the initial level of real GDP per worker, the degree of price distortion in the economy, and investment in education.[25] In turn, the second equation shows that investment in education depends upon various variables including the net fertility rate, which is jointly determined with investment in education. This equation is derived from the results of the previous sections, a point we will come back to shortly. In order to complete the system, we need an equation that explains cross-country variations in fertility. There appear to be many factors that explain differences in the fertility rate across countries, such as the difference in child rearing costs, the differences in religious and social norms, the difference in knowledge of contraception, *etc.*, and estimating this equation per se will be worth a paper. Since our main objective is to uncover the effect of inequality upon growth, we will not attempt to estimate the whole system. Instead, we postulate in the third equation in(15) that fertility is explained by the initial population and lagged fertility and education variables, *i.e.*, we will instrument fertility by these variables. Issues regarding the choice of instruments will be discussed in the next section.

Two other issues regarding this system of equations should be discussed. First, most of the empirical studies that relate education to growth use both male and female education variables or an aggregated one, whereas in this paper, we use only the female education variable. A rationale for doing this is that the female education appears more relevant in relation to our theoretical model. The crucial aspect of our model is that individuals make a joint decision over fertility and investment in human capital. Evolution of population and stock of human capital—which are crucial in determining the growth rate of output per worker—rely upon that decision made by individuals. In our model, there is no gender, but in reality, it is much more likely to be the female that faces the decision.

In fact, the issue about coefficients on male and female education variables has been controversial. Barro and Lee (1994), using cross-country estimation, find that male education contributes positively to growth but female education retards growth, and therefore stress the importance of male education. In contrast, Caselli *et al.*

[22]Net fertility rate is defined as total fertility rate multiplied by (1 - infant mortality rate in the first year of life).

[23]Details on how we have compiled the Gini coefficient are available in Appendix.

[24]See Appendix for the data sources of these variables.

[25]We also include regional dummies in this equation but will omit them until Section 5 for brevity.

(1996), using dynamic panel GMM estimation, find the exact opposite—female education contributes to growth but male education has negative effects upon growth. Some studies such as Mankiw *et al.* (1992) use the average enrolment ratio for all working-age population and find the contribution to growth positive and significant. We will stick to our interpretation of the model and use female education, but given this lack of robustness of the estimates, we will check the sensitivity of the result using the education variables for the entire working-age population.

Second, if we look at the growth equation in (15), it is the flow of education that influences growth. In some studies, however, it is the stock of education that counts for growth. It depends upon the theoretical model as to which of these two variables is used. If endogenous growth is postulated, it is the level of human capital stock that matters to growth in the long run, so the initial stock of education enters the growth equation (Barro and Lee, 1994). On the other hand, if the Solow-Swan growth model is behind the empirical model, it is investment in human capital that matters during transition (since long-run growth is given exogenously), so the flow of education is employed (Mankiw *et al.*, 1992).

Our system has both of these flavours. As we have seen, growth is directly dependent upon the flow of human capital in our specification. This comes from the fact we are looking at growth between two consecutive periods in the short run (although it is 25 years). Note, however, that in turn, the flow of human capital is dependent upon the stock of human capital, and that our system can be reduced as follows:

$$g_{65-90} = f(\ln y_{65}, PPPI_{65}, g(FERT_{65-90}, GINI_{65}, FHC_{65})). \tag{16}$$

Therefore, indirectly the level of human capital stock is important in determining growth, which is consistent with the theoretical framework underlying this empirical system, which is an endogenous growth model.

Now, given that fertility is instrumented by the predetermined variables, we try to estimate the following econometric model similar to Perotti (1996):

$$\begin{cases} g_{65-90} & = \alpha_1 + \alpha_2 \ln y_{65} + \alpha_3 PPPI_{65} + \alpha_4 FEDU_{65-90} + \epsilon_1, \\ FEDU_{65-90} & = \beta_1 + \beta_2 GINI_{65} + \beta_3 FHC_{65} \\ & \quad +\beta_4 FERT_{65-90} + \beta_5 FERT_{65-90} GINI_{65} + \epsilon_2. \end{cases} \tag{17}$$

What are the expected signs of the coefficients? Regarding the growth equation, we expect $\alpha_2 < 0$ if there is a convergence effect, $\alpha_3 < 0$ as price distortion in the market is considered to retard economic performance, and $\alpha_4 > 0$ because investment in education contributes to economic growth. As for the second equation, note that we can rewrite it as follows:

$$FEDU_{65-90} = \beta_1 + \beta_3 FHC_{65} + \beta_4 FERT_{65-90} + (\beta_2 + \beta_5 FERT_{65-90}) GINI_{65} + \epsilon_2. \tag{18}$$

Due to the analysis in the previous sections, we can expect that $\beta_3 > 0$ and $\beta_4 > 0$. In an economy with higher stock of human capital, the return on investment in human

Table 1: The relevant descriptive statistics for 57 countries

Variable	Obs	Mean	Std. Dev.	Min	Max
g_{65-90}	57	.0182755	.0171273	-.0165344	.0662873
$GINI_{65}$	57	42.97968	9.107882	24.3	61.88
$PPPI_{65}$	57	.7538105	.2979437	.194	2.1101
$\ln y_{65}$	57	8.732098	.9049669	6.74052	10.24178
FHC_{65}	57	.6433684	.7145447	.003	3.253
$FEDU_{65-90}$	57	.4411403	.2719671	.015	.935
$FERT_{65-90}$	57	3.961862	1.494163	1.852062	7.164125

capital is higher, given any distribution of human capital, and therefore the investment in education is higher. Fertility is endogenously determined with investment in human capital and the relationship is postulated negative, which is emphasised in the previous sections. The focus of this paper is more upon the coefficient on $GINI_{65}$. As we can see, the coefficient on $GINI_{65}$ is sum of β_2 and $\beta_5 FERT_{65-90}$. Therefore, the effect of inequality upon investment in education depends upon these two things. We first postulate that the whole effect is negative according to the existing empirical work—more inequality will lead to less investment in education, which leads to lower economic growth. In which case, β_2, which shows the common negative effect of inequality upon growth, is anticipated to be negative. In turn, we expect β_5 to be positive. In high fertility economies, negative effect of inequality represented by the first term may be more than offset by positive β_5 together with high $FERT_{65-90}$ so that the overall effect is positive.

5 The estimation results

We estimate System (17) using the method of two-stage least squares (2SLS). g_{65-90} $FEDU_{65-90}$, $FERT_{65-90}$, and $FERT_{65-90}GINI_{65}$ are the four endogenous variables to the system, and exogenous variables are $\ln y_{65}$, $PPPI_{65}$, $GINI_{65}$, FHC_{65}, and the regional dummies, $ASIAE$, $LAAM$, and $SAFRICA$. As we have discussed in the previous section, we use 1960 values of $FEDU_{65-90}$, $FERT_{65-90}$, and FHC_{65} as well as POP_{65}, as instruments. The Breusch-Pagan LM test is employed in order to check heteroskedasticity of the error term. Throughout the analysis, heteroskedasticity-robust t statistics will be reported if we reject the null hypothesis of homoskedasticity of the error term at 5 per cent.

5.1 The non-monotonic effects of inequality upon growth

Column (a) in Table 2 presents the estimation results for (17). First, let us look at a growth equation in Column (a). The estimate of coefficients on $\ln y_{65}$ is statistically significant at 1 per cent and the estimate of coefficient on $FEDU_{65-90}$ is statistically significant at 5 per cent. We observe the anticipated signs on coefficients, *i.e.*, a negative coefficient on $\ln y_{65}$ that captures the convergence effects, a negative coefficient on $PPPI_{65}$, albeit statistically insignificant, showing that price distortion in an economy is harmful to growth, and a positive coefficient on $FEDU_{65-90}$ implying that investment in education fosters economic growth. Regional dummies are also statistically significant at 1 per cent, Asian economies being estimated to have higher growth than Latin American and Sub-Saharan African economies.

In turn, let us look at the other equation in Column (a). All variables are estimated statistically significant at at least 5 per cent. Coefficients on FHC_{65} and $FERT_{65-90}$ are in expected signs as we have discussed in Section 4. Most interestingly and strikingly, the coefficient on $GINI_{65}$ is negative and that on $FERT_{65-90}GINI_{65}$ is positive as we have anticipated.

Column (b) shows the estimation results when no additional instruments are used to control for fertility in the system. We observe drastic changes. In particular, note that estimates of coefficients on fertility, inequality, and the interactive term of those two are not significant. This result may be suggesting that the instruments we have used could be appropriate. In fact, the Durbin-Wu-Hausman test reject the null hypothesis that both $FERT_{65-90}$ and $FERT_{65-90}GINI_{65}$ are exogenous to the system at 10 per cent.[26] Hence, our strong prior belief that fertility is endogenously determined with investment in human capital is statistically supported, although the level of significance is at 10 per cent. As we have discussed in Section 4, the use of aggregated education instead of female education may change the results. Column (c) shows that it is not the case in terms of both magnitude of coefficients and the statistical significance, which is rather surprising given examples from existing studies.[27]

These results appear to support Conjecture 1: the effect of inequality upon growth through human capital accumulation is statistically significant, and that the effect is non-monotonic. Let us check next if the effect is, at all, important in terms of economics,[28] and try to interpret the results in line with the implication from the previous sections.

[26] An F statistic for this test is 2.75 and a p-value is 0.0738. See Davidson and MacKinnon (1993, Chapter 7) for the Durbin-Wu-Hausman test.

[27] Sensitivity analysis is provided in an appendix to this paper (separate text). Our empirical model appears to provide us with much clearer interpretation of the estimated coefficients than other ones do.

[28] We want to compare the magnitude of the inequality effect with that of the existing empirical studies.

Table 2: Estimation results

	Our specification	(a)	No instruments	(b)	Aggregated education	(c)
Dependent variable	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	EDU_{65-90}
$\ln y_{65}$	-0.012		-0.009		-0.011	
	(-3.263)		(-1.517)		(-3.086)	
$PPPI_{65}$	-0.005		-0.005		-0.004	
	(-0.846)		(-1.046)		(-0.804)	
$FEDU_{65-90}$	0.025		0.011			
	(2.018)		(0.494)			
EDU_{65-90}					0.024	
					(1.770)	
$FERT_{65-90}$		-0.443		-0.145		-0.426
		(-3.135)		(-0.990)		(-3.456)
FHC_{65}		0.094		0.099		
		(3.334)		(3.671)		
HC_{65}						0.074
						(2.801)
$GINI_{65}$		-0.030		0.002		-0.031
		(-2.080)		(0.139)		(-2.462)
$FERT_{65-90}GINI_{65}$		0.007		-0.0001		0.007
		(2.163)		(-0.033)		(2.407)
$ASIAE$	0.012		0.012		0.013	
	(2.568)		(1.761)		(2.784)	
$LAAM$	-0.013		-0.015		-0.012	
	(-3.296)		(-3.660)		(-2.830)	
$SAFRICA$	-0.027		-0.029		-0.026	
	(-4.326)		(-4.590)		(-4.051)	
constant	0.121	2.108	0.100	0.884	0.112	2.142
	(4.422)	(3.684)	(2.482)	(1.486)	(4.347)	(4.316)
Number of observations	57	57	57	57	58	58
R^2	0.6751	0.8231	0.6587	0.8564	0.6697	0.8250

NB: Values in the parentheses are t statistics, but for those in the second equation of Column (b), which are heteroskedasticity-robust t statistics. EDU_{65-90} and HC_{65} are the total gross enrolment ratio for secondary education and average years of secondary schooling in the total working population. In addition to $FERT_{60}$ and POP_{65}, HC_{60}, average years of secondary schooling in the total working population in 1960, and EDU_{60}, the 1960 value of the total gross enrolment ratio for secondary schooling are used as additional instruments for Column (c) estimation, instead of FHC_{60} and $FEDU_{60}$.

5.2 How important is the effect of inequality?

Since the effect of inequality depends upon the level of $FERT_{65-90}$, we need to refer to the descriptive statistics in order to obtain a single magnitude. Results are summarised in Table 3.

When we evaluate the effect at the 57 country sample mean, the coefficient on $GINI_{65}$ in (18) is negative, *i.e.*, more inequality will have a negative effect on investment in human capital, and that will lead to lower growth. A one standard deviation increase in the Gini coefficient will *lower* investment of human capital (the female secondary school enrolment ratio) by about 0.007. This implies a decrease in the growth rate of GDP per worker by around 0.02 percentage points. The effect of inequality upon growth appears significantly small compared with what the existing

Table 3: Effects of a one standard deviation increase in $GINI_{65}$ upon g_{65-90} for different groups of economies

Group of economies	Change in $FEDU_{65-90}$	Change in g_{65-90}
All 57 countries	-0.007	-0.0002
OECD	-0.117	-0.0028
Latin America	0.032	0.0008
Sub-Saharan Africa	0.134	0.0033

NB: Values are evaluated at mean of sample or subsample.

literature has found.[29]

When we evaluate the effect using the OECD country subsample mean, the coefficient on $GINI_{65}$ in (18) is negative as well, *i.e.*, inequality will have a negative impact upon investment in human capital, which will impede growth. However, the magnitude of the effect appears much more important. A one standard deviation decrease in the Gini coefficient will *lower* investment in human capital by about 0.12, and this implies a decrease in the growth rate of GDP per worker by 0.28 percentage points. This magnitude is very similar to what Birdsall *et al.* (1995) has found, which is 0.32 percentage points. The effect of inequality upon growth appears to be sizable, considering that the standard deviation of the annual growth rate of real GDP per worker of our whole sample is around 1.8 per cent.

In turn, if we look at a subsample of Latin American countries, the story looks a little different. For this sub-sample, a one standard deviation increase in the Gini coefficient will *foster* growth. However, the magnitude of this effect is only 0.08 percentage points, which appears to be relatively small. This comparison between the OECD and Latin America appears to support our Conjecture 1 if we regard the former and the latter as regions characterised by low and medium fertility, respectively.

When we focus upon a subsample of Sub-Saharan African countries, we find stronger and seemingly non-negligible inequality effects. For this sample, a one standard deviation increase in the Gini coefficient will *increase* investment in human capital by around 0.13, which increases the growth rate of GDP per worker by 0.33 percentage points. The magnitude is almost the same as that for the OECD but the direction is different. This result appears to be consistent with Conjecture 1.

Figure 5 plots the levels of the stock of human capital in 1965 against the predicted changes in the growth rate of real GDP per worker for each of countries in our 57 country sample, when the Gini coefficient *decreases* by one standard deviation, *i.e.*, when an economy becomes more *equal*. The picture appears to convey the following

[29] The effect ranges between 0.32 (Birdsall *et al.*, 1995) and 2.5 (Clarke, 1995) percentage points in the existing literature.

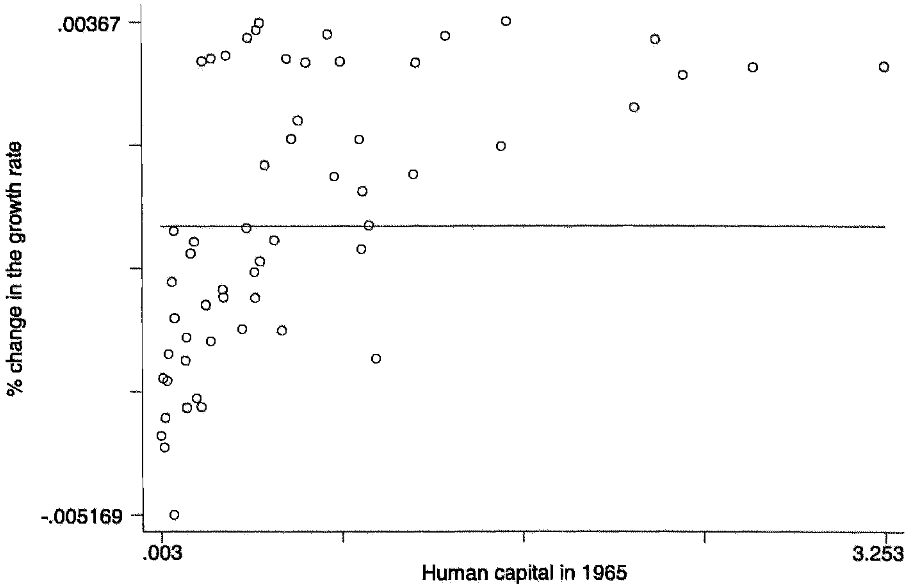

Figure 5: The predicted effects of a fall in inequality upon growth for each country

facts. For either low fertility (high human capital) or high fertility (low human capital) economies, inequality appears to have sizable effects upon growth, although the direction of the effect appears to be different: inequality impedes growth for the former but enhances growth for the latter. In contrast, for economies in between, the effects appear to be trivial.

6 Concluding Remarks

Using slightly different econometric specification from Perotti (1996), we have shown that the effect of inequality upon growth is statistically significant and is not negligible, in line with much of the existing literature. In contrast to the literature, our theoretical model has predicted that the effect of inequality upon growth is non-monotonic, and this prediction has been supported by the real data. In low fertility (high human capital) economies inequality impedes growth whilst in high fertility (low human capital) economies it enhances growth.

This paper has emphasised the importance of endogenous fertility in determining the effect of inequality upon growth. Its importance is confirmed by two facts: our prior belief that fertility is endogenously determined with investment in human capital is supported by real data, and the fact that the effect of inequality upon growth depends upon the demographic stage of development.

Reducing inequality has been of great interest to policy makers. The existing studies have emphasised a "double bonus" from reducing inequality: lower inequality implies higher growth. Our results, in contrast, appear to suggest that for developing economies that typically have high ferility rate, there is no such thing as double bonus. In our model, however, the public sector does not play any role, so we cannot comment much on policy issues. Further research could be directed to introducing a public sector to our model. It would enable us to investigate the effect of reducing inequality by the government's redistributive policy upon growth.

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An appendix to "Inequality and growth: Non-monotonic effects via education and fertility"

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1 Introduction

This is an appendix to the paper "Inequality and growth: Non-monotonic effects via education and fertility." The following section summarises the data we have used in the paper. In Section 3, we report the results of sensitivity analysis. Our empirical model appears to provide us with much clearer interpretation of the estimated coefficients than other ones do. However, the question whether it is statistically preferred to other ones remains unsolved.

2 Description of data

We use an inequality data set compiled by Deininger and Squire (1996) as in the most of the recent empirical literature. Some of the important characteristics of this data set are summarised, whilst more detailed explanation can be found in their original paper.

2.1 Measure of inequality

The Gini coefficient is chosen as a measure of inequality for the empirical analysis. Given from the previous studies that aggregate results are similar for different measures of inequality,[1] it should be best to utilise it since it is most widely reported in official sources that are based upon primary data.

[1] See Anand and Kanbur (1993) for example.

2.2 Quality of this data set

Deininger and Squire (1996) select 682 "high quality" inequality data out of more than 2600 data sources according to three selection criteria. First, they require that inequality data should be based upon actual observation of individual units drawn from household surveys. Therefore, data sets based upon synthetic estimates of inequality using national accounts and some sort of assumed functional form of income distribution will be excluded from this data set.

Second, they require that inequality data should cover all the population. It is well known that differences between Gini coefficients based upon a subset of the population and those based upon a nationally representative sample can be substantial.

Third, comprehensive coverage of different income sources are required. Exclusion of non-monetary income as well as non-wage earnings might have significant effect upon Gini coefficients.

One important thing to note here is the following. Data sets that have been used in the existing literature may be of doubtful quality if we apply these three criteria. Persson and Tabellini (1994) have detected a negative relationship between inequality and growth using their 55 country data set (gathered from various sources). But only 18 out of 55 data are in high quality, and Deininger and Squire (1996) claim that use of this reduced data undermines their finding.

2.3 Characteristics of this data set

This data set has many more observations and covers more economies over longer periods than any other inequality data sets. However, Deininger and Squire (1996) note that we need to be careful when we want to compare one observation with another, because the definition of the coefficient differs across countries and over time. Three important differences are the focus.

First, the inequality measure based upon individuals differs from that based upon households when there are systematic differences in size between rich and poor households. Household-based data give slightly lower inequality than individual-based data, but the difference is not too large (the mean difference of the coefficient is 1.67 percentage points).

Second, use of before-tax income should give a higher inequality measure than use of after-tax income. The quantitative importance of the redistributive tax's effect depends upon the progressivity and effectiveness of the tax system. The data show some difference (the mean difference of about 3 percentage points) for the OECD economies, but this difference might be irrelevant for developing economies where the role of redistributive taxation is smaller.

Finally, inequality in expenditure is usually smaller than inequality in income since it is much easier for individuals to smooth expenditure than to smooth income. The data shows the systematic and significant difference between income-based and expenditure-based inequality measures (the mean difference is 6.6 percentage points).

It is most preferable that we confine our analysis to measures that are defined consistently, *i.e*, use either income-based or expenditure-based measure. However, this will reduce the number of observation. In order to avoid this, Deininger and Squire (1996) suggest that we should correct the difference by adding the mean difference to expenditure-based observations. Of course, they also note the importance of checking the robustness of results to this correction.

This comprehensive data set even allows us to conduct panel estimation, and in fact, some studies have already conducted it (Li and Zou, 1998, Barro, 2000, Forbes, 2000). As Forbes (2000) emphasises, panel estimation is preferred to cross-sectional estimation for various reasons. Panel estimation can capture time-invariant systematic differences between countries that independent variables cannot capture, so the estimation is not as prone to omitted variable problem as in cross-sectional estimation. It also provides us with effects of the independent variables upon dependent variables *within* a country, whereas cross-sectional estimation provides a relationship *across* countries. Bearing in mind these superiority in panel estimation, however, this study does not fully utilise the time dimension of this data set, *i.e.*, we only use data for the Gini coefficient in 1965 (or the year around 1965). This is due to the fact that the empirical implication we test in the paper is related to the short run of our theoretical model, which is around 25 years.

2.4 Compiling the initial Gini coefficient

The following outlines the way the Gini coefficient data we have used in the paper are compiled. The (high quality) Gini coefficients in 1965 are available for only 56 countries. In addition to this, we allow to include the nearest high-quality observation prior to 1965, if there is no observation for 1965. If we cannot find observations prior to 1965, we use the nearest observation after 1965 but no later than 1975. We also follow Barro (2000) in order to increase the number of the observations. Namely, we add observations that are excluded from the high-quality data set because their source was unidentified. The source being unidentified implies that these observations may not satisfy the second criteria—the data should cover all the population—but Barro (2000) argues these observations appear to be based upon representative national coverage. Again we look for the observations for 1965 first. If we cannot find them, we look for nearest observations prior to 1965, and then after 1965 but no later than 1975. If there are multiple observations in the same year, we use the average value of them.

2.5 Other variables

Data sources for other variables used in the paper are as follows. The average annual growth rate of real GDP per worker 1965–1990 and real GDP per worker in 1965 are taken from Penn World Table 5.6a (Summers and Heston, 1995). All the schooling

Table 1: Descriptive statistics for all countries

Variable	Obs	Mean	Std. Dev.	Min	Max
g_{65-90}	105	.0166417	.0175463	-.025103	.0662873
$GINI_{65}$	85	42.23183	9.970333	22.23	61.88
$PPPI_{65}$	118	.9265627	.467477	.194	3.3549
$\ln y_{65}$	125	8.372516	1.019235	6.419995	10.24178
FHC_{65}	107	.4969626	.6127281	0	3.253
$FEDU_{65-90}$	99	.3742273	.2752068	.015	.935
$FERT_{65-90}$	113	4.469705	1.479164	1.766405	7.164125

variables, the net fertility rate, a price distortion variable,[2] total population, and regional dummies are taken from Barro and Lee (1993) data set. For the flow variables, it is common to use the average of initial and terminal periods, but the data for schooling variable (enrolment ratio) for 1990 is unavailable in Barro and Lee (1993), so we use 1985 instead and take the average of that and 1965. We do the same for the net fertility rate. The descriptive statistics for the all observations are shown in Table 1. Table 2 shows the detailed information on the Gini coefficient data for the 57 country sample. Following the suggestion by Deininger and Squire (1996), we have added 6.6 to the Gini coefficient if the data source is expenditure-based, in running all the regressions throughout the paper.[3]

3 Sensitivity analysis

In the paper we have estimated the following system of equations using the method of two-stage least squares (2SLS).

$$\begin{cases} g_{65-90} & = \alpha_1 + \alpha_2 \ln y_{65} + \alpha_3 PPPI_{65} + \alpha_4 FEDU_{65-90} + \epsilon_1, \\ FEDU_{65-90} & = \beta_1 + \beta_2 GINI_{65} + \beta_3 FHC_{65} \\ & \quad + \beta_4 FERT_{65-90} + \beta_5 FERT_{65-90} GINI_{65} + \epsilon_2. \end{cases} \tag{1}$$

The results of sensitivity analysis are presented in Tables 3, 4, and 5. The estimation results for our specification in the paper are presented in Column (a) of Table 3. As in the paper, the Breusch-Pagan *LM* test is employed in order to check heteroskedasticity of the error term, and heteroskedasticity-robust t statistics will be reported if we reject the null hypothesis of homoskedasticity of the error term at 5 per cent.

[2]Following Perotti (1996), we use the PPP value of the investment deflator as an indication of price distortion, relative to that of the United States in 1965.

[3]The Gini coefficient values in Table 2 are after-adjustment values.

Table 2: The Gini coefficient for 57 countries

Economy	Source	$GINI_{65}$	Quality	Economy	Source	$GINI_{65}$	Quality
Argentina	Income	42.00	ps	Mexico	Income	55.50	accept
Australia	Income	32.02	accept	Netherlands	Income	28.60	accept
Bangladesh	Income	37.31	accept	New Zealand	Income	30.05	accept
Benin	Income	42.12	ps	Norway	Income	37.52	accept
Bolivia	Income	49.60	ps	Pakistan	Expenditure	37.16	accept
Brazil	Income	53.00	accept	Panama	Income	57.00	accept
Canada	Income	31.61	accept	Peru	Income	55.00	accept
Chile	Income	45.64	accept	Philippines	Income	51.32	accept
Colombia	Income	52.02	accept	Portugal	Income	40.58	accept
Costa Rica	Income	50.00	accept	Senegal	Income	57.37	ps
Denmark	Income	38.00	ps	Sierra Leone	Income	60.79	accept
Ecuador	Income	35.00	ps	Singapore	Income	41.00	accept
El Salvador	Income	53.00	ps	South Korea	Income	34.34	accept
Fiji	Income	46.00	ps	Spain	Income	31.99	accept
Finland	Income	31.80	accept	Sri Lanka	Income	47.00	accept
France	Income	47.00	accept	Sweden	Income	33.41	accept
Germany	Income	28.13	accept	Thailand	Income	41.28	accept
Greece	Expenditure	41.71	accept	Togo	Income	33.80	ps
Honduras	Income	61.88	accept	Trinidad and Tobago	Income	46.02	accept
Hong Kong	Income	40.90	accept	Tunisia	Expenditure	48.90	accept
India	Expenditure	37.74	accept	Turkey	Income	56.00	accept
Indonesia	Expenditure	39.90	accept	Uganda	Income	40.07	ps
Ireland	Income	38.69	accept	United Kingdom	Income	24.30	accept
Italy	Income	41.00	accept	United States	Income	34.64	accept
Jamaica	Income	54.31	accept	Venezuela	Income	47.65	accept
Japan	Income	34.80	accept	Yugoslavia	Income	31.18	accept
Kenya	Income	48.80	ps	Zambia	Income	51.32	ps
Malawi	Income	46.08	ps	Zimbabwe	Income	46.00	ps
Malaysia	Income	50.00	accept				

NB: ps implies that the data are not included in the Deininger and Squire (1996) high quality data set as there is no clear reference to the primary source.

It is very important to check whether our specification in the paper is preferable to ones in the existing empirical studies. A number of empirical studies estimate the reduced form, *i.e.*, they regress the growth rate of GDP per worker on various economic variables including a measure of inequality. Column (d) in Table 3 presents estimation results of a typical growth regression using our data set. The problem about this kind of estimation is that the interpretation of the coefficient on $GINI_{65}$, *i.e.*, we do not know *how* inequality is affecting the growth rate of output. In any case, the coefficient on $GINI_{65}$ is estimated to be negative but statistically insignificant. Some studies have found that it happens when regional dummies are included in the equation, implicating possible high correlation between inequality and the regional dummies. However, the results in Column (e) shows that this is not the case. Even when regional dummies are excluded from the equation, the estimate of the coefficient on $GINI_{65}$ remains statistically insignificant. Again we observe improvement in a t statistic of the distortion variable, which may imply its possible strong relationship with regional dummies. We conclude that, from this reduced form regression, we find no relationship between inequality and growth.

In passing, Column (j) in Table 5 shows that the estimation results of our preferred specification are fairly robust to the exclusion of regional dummies. The notable change here is that a price distortion variable turns statistically significant once regional dummies are excluded. It may be the case that the degree of price distortion is strongly correlated with regional dummies, and therefore it does not have any explanatory power in our preferred specification (Column (a) in Table 3).

Table 3: Sensitivity analysis

	Our specification		Reduced form		Including direct effects	
	(a)		(d)	(e)	(f)	
Dependent variable	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	g_{65-90}	g_{65-90}	$FEDU_{65-90}$
$\ln y_{65}$	-0.012		-0.014	-0.015	-0.012	
	(-3.263)		(-4.250)	(-4.224)	(-3.242)	
$PPPI_{65}$	-0.005		-0.002	-0.010	-0.003	
	(-0.846)		(-0.485)	(-1.749)	(-0.584)	
$FEDU_{65-90}$	0.025		0.029	0.053	0.022	
	(2.018)		(2.454)	(3.930)	(1.729)	
$FERT_{65-90}$		-0.443				-0.443
		(-3.135)				(-3.135)
FHC_{65}		0.094				0.094
		(3.334)				(3.334)
$GINI_{65}$		-0.030	-0.0002	-0.0003	-0.0001	-0.030
		(-2.080)	(-0.850)	(-1.060)	(-0.554)	(-2.080)
$FERT_{65-90}GINI_{65}$		0.007				0.007
		(2.163)				(2.163)
$ASIAE$	0.012		0.014		0.013	
	(2.568)		(2.499)		(2.605)	
$LAAM$	-0.013		-0.009		-0.012	
	(-3.296)		(-2.272)		(-2.540)	
$SAFRICA$	-0.027		-0.027		-0.028	
	(-4.326)		(-5.766)		(-4.310)	
constant	0.121	2.108	0.142	0.149	0.126	2.108
	(4.422)	(3.684)	(5.830)	(5.283)	(4.312)	(3.684)
Number of observations	57	57	60	60	57	57
R^2	0.6751	0.8231	0.6977	0.3735	0.6763	0.8231

NB: Values in the parentheses are t statistics, but for those in Column (d), which are heteroskedasticity-robust t statistics.

Coming back to reduced-form estimation, one up-side of estimating the reduced form is that we could regard it as if $GINI_{65}$ is capturing every effect of inequality upon growth. That is, although our specification allows us to tell *how* inequality affects growth—through human capital accumulation and the rate of fertility, there might be some other channels through which inequality could affect growth.[4] One way to capture this possible effects of inequality is to introduce $GINI_{65}$ in to the first equation of (1). Column (f) presents the results of this estimation. The estimates for the second equation do not change as we did not introduce new instruments. As for the first equation, in comparison with our specification, note that the magnitude of

[4]Perotti (1996) provides a comprehensive survey on this issue.

Table 4: Sensitivity analysis (continued)

	À la Perotti (1996)		À la Perotti (1996)		Instrumenting $FERT_{65-90}$	
	(g)		(h)		(i)	
Dependent variable	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	$FEDU_{65-90}$
$\ln y_{65}$	-0.018	0.069	-0.013	0.169	-0.012	
	(-4.202)	(2.687)	(-2.480)	(6.507)	(-3.263)	
$PPPI_{65}$	-0.004		-0.004		-0.005	
	(-0.672)		(-0.687)		(-0.846)	
$FEDU_{65-90}$	0.051		0.027		0.025	
	(3.338)		(1.339)		(2.018)	
$FERT_{65-90}$		-0.107				-0.139
		(-6.670)				(-10.27)
FHC_{65}		0.081		0.094		0.108
		(3.212)		(2.792)		(4.458)
$GINI_{65}$		-0.001		-0.007		0.001
		(-0.377)		(-3.518)		(0.444)
$FERT_{65-90}GINI_{65}$						
$ASIAE$	0.011		0.014		0.012	
	(2.329)		(3.043)		(2.568)	
$LAAM$	-0.009		-0.012		-0.013	
	(-1.999)		(-2.681)		(-3.296)	
$SAFRICA$	-0.024		-0.027		-0.027	
	(-3.594)		(-4.024)		(-4.326)	
constant	0.161	0.242	0.124	-0.776	0.121	0.887
	(5.128)	(0.969)	(3.457)	(-3.163)	(4.422)	(10.81)
Number of observations	57	57	59	59	57	57
R^2	0.6420	0.8780	0.6902	0.7629	0.6751	0.8607

NB: Values in the parentheses are t statistics. Column (g) is a quasi-replication of Columns (1) and (8) of Table 13 in Perotti (1996) and Column (h) is a quasi-replication of Columns (1) and (7) of Table 13 in Perotti (1996).

the coefficient on $FEDU_{65-90}$ does not change much. This implies that the effect of inequality upon growth through human capital accumulation and fertility does not change much, either, even when the direct inequality effect is taken into account. The estimates of the coefficient on $GINI_{65}$, which captures direct effects of inequality upon growth, is negative as we have expected, but is statistically insignificant. It appears the direct effect does not exist.

Next, we compare our results with those of Perotti (1996). Column (g) in Table 4 presents estimation results based upon a model specification à la Perotti (1996). The important thing to note here is that Perotti (1996) does not treat $FERT_{65-90}$ as an endogenous variable. Therefore, in estimating Column (g), we do not use instruments to control for $FERT_{65-90}$. Perotti (1996) also includes lny_{65} (he uses GDP_{65}) but does not include the interactive term, $FERT_{65-90}GINI_{65}$, which is crucial to the non-monotonic nature of the effect of inequality upon growth.[5] The estimates of coefficients on $FERT_{65-90}$ and FHC_{65} are quite close to those in Perotti (1996),

[5]Another difference is that Perotti (1996) uses regional dummies in the second equation instead of using them in the first one. All regional dummies turn out to be insignificant for this specification.

confirming that our data are similar to what he has used.

The estimate of the coefficient on $GINI_{65}$ is negative but statistically insignificant, which is identical to what Perotti (1996) has found. Perotti (1996) argues that this is due to the inclusion of $FERT_{65-90}$. That is, Perotti (1996) finds a negative and statistically significant coefficient on $GINI_{65}$ if $FERT_{65-90}$ is not included in the equation. He argues that, since in an endogenous fertility approach, investment in education is mainly dependent upon fertility, income distribution largely affects investment in education through its effects upon the rate of fertility. Therefore, once $FERT_{65-90}$ is controlled for, it is not surprising to see that inequality has no explanatory power. In fact, when we estimate the identical system without $FERT_{65-90}$, we find a negative and significant (at 1 per cent) estimate of the coefficient on $GINI_{65}$. The results are presented in Column (h). However, the estimate of the coefficient on $FEDU_{65-90}$ is statistically insignificant, and so is the effect of inequality through investment in human capital.

In any event, Perotti's (1996) argument sounds a little odd, as on one hand he claims that investment in human capital and fertility are jointly determined, whilst on the other hand he treats the former as endogenous and the latter as exogenous to the system.[6] So in Column (i), we present estimation results when we instrument fertility ($FERT_{65-90}$) in Column (g).[7] This specification is the same as ours in the paper (See Column (a) in Table 3) except that it does not include the interactive term, $FERT_{65-90}GINI_{65}$, which captures the non-monotonic nature of the effects of inequality upon growth we have conjectured.

The estimate of the coefficient on $GINI_{65}$ is positive, against our prediction, but is statistically insignificant. When we include the interactive term as in the paper (See Column (a) in Table 3), estimates of coefficients on both $GINI_{65}$ and $FERT_{65-90}GINI_{65}$ become statistically significant (at 5 per cent), and are in anticipated signs. The fact that inequality is not statistically significant just by itself, but is statistically significant with the interactive term, could be regarded as an indication that inequality has a non-monotonic impact upon growth. Having said so, however, there is no strong evidence that our specification is superior to other specifications on other statistical grounds.

Finally, we test the stability of coefficients across the OECD and the non-OECD subsamples. Column (k) and Column (l) present the estimation results for these two subsamples.[8] As for the OECD subsample, signs of coefficients are estimated as anticipated, but most of the estimates have turned out statistically insignificant including those of coefficients on $GINI_{65}$ and $FERT_{65-90}GINI_{65-90}$. Regarding the

[6] In fact, Perotti (1996) does not state which of these specifications is preferable.

[7] lny_{65} is excluded from the second equation in order to make it similar to our specification.

[8] Note that regional dummies are dropped for the both columns. For Column (k) this is due to the fact that these dummies are all zero for the OECD countries. In order to make it consistent with Column (k), regional dummies are dropped in Column (l) as well. However, we keep using regional dummies as instruments.

Table 5: Sensitivity analysis (continued)

	No regional dummies		OECD only		Non-OECD only	
	(j)		(k)		(l)	
Dependent variable	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	$FEDU_{65-90}$	g_{65-90}	$FEDU_{65-90}$
$\ln y_{65}$	-0.011		-0.023		-0.015	
	(-2.472)		(-5.903)		(-2.923)	
$PPPI_{65}$	-0.017		-0.003		-0.012	
	(-2.608)		(-0.204)		(-1.756)	
$FEDU_{65-90}$	0.040		0.023		0.072	
	(2.706)		(1.796)		(2.433)	
$FERT_{65-90}$		-0.533		-0.696		0.488
		(-2.301)		(-1.039)		(1.265)
FHC_{65}		0.094		0.109		-0.011
		(3.138)		(2.388)		(-0.065)
$GINI_{65}$		-0.040		-0.030		0.078
		(-1.786)		(-0.858)		(1.624)
$FERT_{65-90}GINI_{65}$		0.010		0.011		-0.015
		(1.729)		(0.762)		(-1.579)
$ASIAE$						
$LAAM$						
$SAFRICA$						
constant	0.106	2.482	0.225	2.394	0.132	-2.258
	(3.365)	(2.787)	(7.518)	(1.507)	(3.578)	(1.200)
Number of observations	57	57	19	19	38	38
R^2	0.3435	0.7762	0.7939	0.5850	0.3546	0.3490

NB: Values in the parentheses are t statistics, but for those in the second equation of Column (j) amd in the first equation of Column (l), which are heteroskedasticity-robust t statistics.

non-OECD subsample, all of the estimates in the second equation turn out statistically insignificant and neither of them is in anticipated signs, the results which are difficult to interpret. The estimates of coefficients between the two subsamples appear to be quite different. In fact, the null hypothesis that all coefficients are stable across these subsamples is rejected at 1 per cent for each of the equations.[9]

This result may be suggesting that the OECD subsample contains most of the economies that have already gone through the demographic transition and that the non-OECD subsample contains most of the economies that have not. Recall that the interactive term, $FERT_{65-90}GINI_{65}$, is included in estimation in order to capture (large) variation between economies *across* different demographic development stages for the whole sample. However, if each of the subsamples contains economies in the same stage of demographic development, variation between economies *within* each of

[9]Since we are using 2SLS estimation, the Chow test using an ordinary F statistic (also known as the Chow statistic) is invalid in this case. Therefore, we employ the analog of the ordinary F statistic, which is suggested by Davidson and MacKinnon (1993, Chapter 7). The statistics for the first and second equations are 29.31 ($3.72 < F[4,46] < 3.77$) and 91.81 ($3.41 < F[5,46] < 3.46$), respectively (relevant critical values at 1 per cent are in brackets).

the subsamples might not be so large. This may be the cause of this poor estimation result.

Not much of the empirical growth literature has, in fact, tested the stability of coefficients. Much of the growth literature has not reported anything on this matter (Alesina and Rodrik, 1994, Barro and Lee, 1994, Birdsall, 1995, Caselli *et al.*, 1996, Perotti, 1994), or at most, it splits the sample according to some criteria but does not conduct any formal test to check the stability of coefficients across subsamples (Barro, 2000, Benhabib and Spiegel, 1994, Deininger and Squire, 1998, Galor and Zang, 1997, Mankiw *et al.*, 1992, Perotti, 1996).[10] This issue appears to require further investigation.

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