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Michael Kremer
Daniel Chen

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ABSTRACT

Developing countries with highly unequal income distributions, such as Brazil or South Africa, face an uphill battle in reducing inequality. Educated workers in these countries have a much lower birthrate than uneducated workers. Assuming children of educated workers are more likely to become educated, this tends to increase the proportion of unskilled workers, reducing their wages, and thus their opportunity cost of having children, creating a vicious cycle. A model incorporating this effect generates multiple steady-state levels of inequality, suggesting that in some circumstances, temporarily increasing access to educational opportunities could permanently reduce inequality. Empirical evidence suggests that the fertility differential between the educated and uneducated is greater in less equal countries, consistent with the model.

Michael Kremer
Harvard University
Department of Economics
Littauer Center
Cambridge, MA 02138
and Brookings Institution
and NBER
mkremer@fas.harvard.edu

Daniel Chen
Oxford and Harvard College
Cambridge, MA 02138

Guide to Notation

Y	output
α	share of output going to skilled labor
L_S	quantity of skilled labor
L_U	quantity of unskilled labor
w_S	wage of skilled labor
w_U	wage of unskilled labor
V	utility
X	consumption
n	number of children
ϕ	time commitment of each child
C_S	children of skilled labor
C_U	children of unskilled labor
θ	proportion of children with unskilled parents with low cost $\tilde{L}$ of education.
$\tilde{L}$	units of time for children of skilled labor and a proportion θ of children of unskilled labor to become skilled
$\tilde{H}$	units of time for a proportion $1 - \theta$ of children of unskilled labor to become skilled
D	wage differential between skilled and unskilled labor
R	ratio of skilled labor to unskilled labor
γ	proportion of children of unskilled labor who become skilled
$R_{equal}*$	low-inequality stable steady state
$R_{unequal}*$	high-inequality stable steady state
R_+*	intermediate unstable steady state
R_-*	intermediate stable steady state
θ_L	cut-off value of θ for which $R_{equal}*$ is admissible
θ_H	cut-off value of θ for which $R_{unequal}*$ is admissible
$\theta_{critical}$	cut-off value of θ at which $R_+* = R_-*$
T	value of L where θ_L attains its maximum, $\theta_{critical}$
G	Gini coefficient

I. Introduction

In developing countries, fertility typically falls with education. For example, in Brazil, women with no education have three times as many children as women with ten or more years of education (United Nations, 1995). Since children of the uneducated are less likely to become educated themselves, this threefold difference in fertility creates a major demographic force increasing the proportion of unskilled workers.

One plausible hypothesis for why fertility declines with education is that because educated women command higher market wages, they face higher opportunity costs of time spent rearing children. If substitution effects outweigh income effects, then educated women have fewer children.

This paper examines the implications of combining three assumptions: (i) skilled and unskilled workers are complements in production; (ii) children of the unskilled are more likely to be unskilled; and (iii) higher wages reduce fertility because substitution effects outweigh income effects. A model incorporating these features implies that an initial increase in the proportion of unskilled workers will reduce wages of unskilled workers. Since lower wages decrease the opportunity cost of raising children, unskilled workers will increase their fertility. Under the assumption that children of unskilled workers are more likely to be unskilled themselves, the proportion of unskilled workers in the next generation will therefore increase. An initial increase in the fraction of unskilled workers thus produces a multiplier effect in subsequent generations, suggesting that improving educational opportunities for even small numbers of children of unskilled workers could lead to large changes in the steady-state distribution of skill.

The model also generates multiple steady-state levels of inequality. If the initial proportion of skilled workers is great enough, wage and fertility differentials between skilled and unskilled workers will be small, allowing the economy to converge to a steady state with low inequality. However, if the initial proportion of skilled workers is too low, inequality will be self-reinforcing and the economy may approach a steady state with a low proportion of skilled workers and great inequality between the skilled and unskilled. Increasing the probability that children of unskilled parents will become skilled, for example, by expanding access to educational opportunities, reduces the basin of attraction of the unequal steady state and may even eliminate it. Some countries may face a brief window of opportunity in which small and temporary increases in the probability that children of unskilled parents become skilled can move them into the basin of attraction for the equal steady state. As time passes, however, and the economy approaches the unequal steady state, larger or longer-lasting increases in the probability that children of unskilled parents become skilled will be necessary to move to the more equal steady state.

We find empirical evidence that the fertility differential between educated and uneducated women is greater in countries with more income inequality. Using data on differential fertility by education from the World Fertility Surveys (United Nations, 1987; Jones, 1982) and Demographic and Health Surveys (United Nations, 1995; Mboup and Saha, 1998), we find a statistically significant, positive, and economically sizeable relationship between differential fertility and inequality for most specifications, consistent with the model.

Our model is most applicable to middle-income countries. At very low wages, wage increases may increase the number of surviving children by reducing infant mortality and infertility due to disease and malnutrition. At very high wages, further wage increases are likely to reduce fertility only modestly if fertility asymptotes to a positive level. In fact, the positive relation between inequality and fertility differentials is strongest in middle-income countries.

Literature Review

Several writers have explored one direction of the feedback mechanism–the impact of differential fertility on the distribution of income or socio-economic status (David Lam, 1986; C. Y. Cyrus Chu and Hui-Wen Koo, 1990; Samuel Preston and Cameron Campbell, 1993; Robert D. Mare, 1997). These papers use a Markovian framework in which fertility in each group (for example, skilled and unskilled) and the probability that a child born to parents in one group will transit to another group are both independent of the distribution of the population across groups. Many other papers discuss fertility and income inequality more generally (Robert Repetto, 1978; Oded Galor and Hyoungsoo Zang, 1997; Marc Nerlove, Assaf Razin, and Efraim Sadka, 1984; and Galor and Joseph Zeira, 1993). None of these papers, however, capture the other direction of causality. As informally discussed by Nancy Birdsall (1988), an increase in income inequality, measured by a greater number of unskilled workers relative to skilled workers, is likely to suppress the wages of the unskilled. If fertility depends inversely on wages, this increases the fertility of the unskilled and thus increases fertility differentials, creating a positive feedback. On the other hand, increasing income inequality implies higher wage differentials, which in turn increase the incentive for children of the poor to become educated and transit to a higher income group. This may create a negative feedback that stabilizes the positive feedback between differential fertility and inequality.

Momi Dahan and Daniel Tsiddon (1998) incorporate this positive feedback in a paper modeling the demographic transition and Kuznets curve, focusing on transition dynamics. In their model, poor dynasties initially do not invest in education and therefore stay poor, whereas rich dynasties invest in education and stay rich. Thus, there is initially no intergenerational mobility between rich and poor. Due to greater fertility among poor, the proportion of poor increases, leading to greater inequality. Once income inequality reaches a certain threshold, wage differentials and thus incentives to obtain education are great enough for some poor to obtain education. The number of uneducated people then falls, which increases their wages and reduces income inequality. At this point, inequality moves to its steady-state level.

Whereas Dahan and Tsiddon focus on transition dynamics in a model with a single steady state, we show that the positive feedback between fertility differentials and income inequality may lead to multiple steady states and multiplier effects. Dahan and Tsiddon obtain a single steady state because they assume all poor people are identical rather than varying in their cost of education.

The remainder of this paper is organized as follows: Section 2 presents the model, solves for the steady states, explores the transition path to the steady state from various initial conditions, and discusses how the dynamic system changes in response to changes in parameters. Section 3 describes the data, discusses the methodology, and presents the empirical results. Section 4 argues that the substitution effect through which wage increases reduce fertility are likely to be important at moderate income levels, and presents evidence that the empirical relationship we document is concentrated in middle-income countries. Section 5 argues that the basic results are robust to various generalizations and extensions of the model and concludes.

II. Theory

This section is organized as follows. Subsection A describes the model. Subsection B solves for the steady states. Subsection C discusses stability of the steady states and explores the transition path to the steady state from various initial conditions. Subsection D examines the admissibility of the steady states as a function of the underlying parameters. Subsection E explains how the basin of attraction and the wage differentials at the steady state change in response to changes in the parameters.

A. Model

Suppose the production technology is

$$Y = A L_S^{\alpha} L_U^{1-\alpha} \tag{1}$$

where L_S and L_U are the number of skilled and unskilled workers respectively[3]. Assuming competitive factor markets, the wages of skilled and unskilled workers will be

$$w_S = A\alpha\left(\frac{L_U}{L_S}\right)^{1-\alpha} \textit{and } w_U = A(1-\alpha)\left(\frac{L_S}{L_U}\right)^{\alpha}. \tag{2}$$

[3]Note that the Cobb-Douglas production form implicitly assumes that the elasticity of substitution between skilled and unskilled workers is 1. However, there is literature that suggests that the elasticity of substitution is close to 1; see Krusell et. al (1997) and the references within for further detail.

Consider the utility function $V = \ln(n - \epsilon) + X$, where n is the number of children and X is consumption. Raising each child requires a time commitment of ϕ, and the total time endowment of each individual is 1. Thus the budget constraint is $X = w(1 - n\phi)$. Substituting X into the utility function yields $V = \ln(n - \epsilon) + w(1 - n\phi)$. For low enough wages ($w < 1 / (1 - \epsilon\phi)$), a corner solution with no consumption is optimal. However, we will assume A is large enough that $w > 1 / (1 - \epsilon\phi)$, so that some consumption is optimal. The first order condition for optimal fertility implies $n = \epsilon + 1 / (w\phi)$. Under the assumed quasi-linear utility function, higher wages lead people to have fewer children. As w increases, the number of children asymptotes to ϵ. We focus on the case where $\epsilon = 0$ for most of the paper, although in Section 4, we speculate on the case in which $\epsilon > 0$.

The assumption that substitution effects outweigh income effects is consistent with the negative correlation between wages and fertility and between education and fertility, both across countries and within countries, although assumption of quasi-linearity, which yields tractability, is clearly extreme.[4] As discussed in Section 4, the inverse relationship between fertility and wages is likely to be a more acceptable approximation over the moderate wage levels

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[4]An alternative explanation for the negative relationship between education and fertility is that parents substitute quality of children for quantity. Educated parents may have a lower shadow price of child quality, for instance, through easier access to schooling and health care; this raises demand for child quality and reduces demand for child quantity. While this may also play a role, there is empirical evidence for the view that substitution effects are important. Since women usually bear most of the responsibility for childcare, the opportunity cost of having children for women is higher than the opportunity cost of having children for men. Assuming that education is a satisfactory proxy for lifetime wage rates, this implies that the fertility differential between educated and uneducated women should be higher than the fertility differential between educated and uneducated men. Schultz (1985) and Razzaz (1998) both cite evidence confirming that female education has a strong negative effect on fertility while male education has a smaller, less statistically significant, and sometimes positive effect on fertility (United Nations, 1987 also has corroborating evidence).

characteristic of middle-income countries, than at very low or very high wages.

The number of children of unskilled and skilled workers is given by the number of adults in each group multiplied by the number of children per adult:

$$C_U = \frac{L_U}{A\,\phi\,(1-\alpha)\left(\frac{L_S}{L_U}\right)^{\alpha}} \quad and \quad C_S = \frac{L_S}{A\,\phi\,\alpha\left(\frac{L_U}{L_S}\right)^{1-\alpha}} . \tag{3}$$

To complete the model, it is necessary to specify the process governing each individual's education decision. We assume that (i) educational decisions are responsive to the incentives provided by wage premia, and (ii) children of unskilled parents face higher costs of education than children of skilled parents, due to either differences in home environments or lack of access to capital markets. To capture these features, consider a model in which all children of skilled parents, along with a proportion θ of children of unskilled parents, need $\tilde{L}$ units of time to become skilled, but a proportion 1 - θ of children of unskilled parents need $\tilde{H}$ units of time to become skilled, where $\tilde{L} < \tilde{H}$.[5] Children who only require $\tilde{L}$ units of time to become skilled do so when the lifetime income from obtaining education is greater than the lifetime income from not obtaining education, that is, when $w_S (1 - \tilde{L}) > w_U$. This expression is equivalent to $1 / (1 - \tilde{L}) < w_S / w_U$. Let $D = w_S / w_U$, where D is the anticipated wage differential when children become adults. Analogously, children who require $\tilde{H}$ units of time to become skilled do so if 1 /

[5]If children of skilled parents require $\epsilon < \tilde{L}$ units of time to obtain education, the steady state proportions of skilled workers and the steady state levels of inequality are identical. If a proportion of children of skilled parents also require $\tilde{H}$ units of time to become skilled, but the proportion is less than 1 - θ, the proportion of children of unskilled who require $\tilde{H}$ units of time, the basic story is similar but (5) becomes a cubic equation instead of a quadratic equation and we no longer get closed form solutions such as those of Proposition 1.

$(1 - \tilde{H}) < D$. To simplify the algebra below, let $L = 1 / (1 - \tilde{L})$ and $H = 1 / (1 - \tilde{H})$. Note that both $\tilde{L}$ and $\tilde{H}$ are bounded by the total time endowment, 1, and by 0, so L and H are unbounded above and bounded below by 1. Note also that D is similarly unbounded above and bounded below by 1 (skilled workers should make more than unskilled workers).[6]

B. Steady States

Define a steady state as a triplet (R*, D*, γ*), such that if the ratio of skilled to unskilled workers at time t is R*, the wage differential would then be D*. If fertility and education decisions are taken optimally, the proportion of children of unskilled workers who become skilled will be γ*, and the ratio of skilled to unskilled workers in the next generation will remain at R*.

To solve for steady states, we look for fixed points of $R_{t+1}(R_t)$. At time t, $L_{S,t}$ is the number of skilled workers and $L_{U,t}$ is the number of unskilled workers. Skilled and unskilled workers have $C_{S,t}$ and $C_{U,t}$ children respectively, who then choose whether or not to become educated at time t + 1 (Figure 1 diagrams the dynamics of these variables). If all the children of skilled workers and a fraction γ of children of unskilled workers become skilled workers, then

$$R_{t+1} = \frac{C_{S,t} + \gamma_t C_{U,t}}{(1 - \gamma_t) C_{U,t}} = \frac{1}{1 - \gamma_t}\left(\frac{1 - \alpha}{\alpha}\right) R_t^2 + \frac{\gamma_t}{1 - \gamma_t} . \tag{4}$$

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[6]Note that ideally we would be looking at differential number of surviving infants between educated and uneducated women; however, data for differential infant mortality is scarce and in any case, differential infant mortality is small relative to differential fertility (see Section 4).

Setting $R_{t+1} = R_t$ in (4) implies that any steady state must satisfy the following quadratic equation:

$$\frac{1}{1-\gamma^*}\left(\frac{1-\alpha}{\alpha}\right) R^{*2} - R^* + \frac{\gamma^*}{1-\gamma^*} = 0 . \tag{5}$$

The assumption that all the children of skilled workers and a fraction γ of children of unskilled workers become skilled workers can be proved. In equation (4), a positive number of people are switching to become skilled in each generation. There cannot be a steady state in which a non-positive number of people switch to become skilled, or equivalently, all the children of unskilled workers and a proportion of children of skilled workers become unskilled (that is, if the γ-arrow in Figure 1 points in the opposite direction). Consider the borderline case where each generation inherits the skill level of the previous generation. In this case, $\gamma = 0$. Then $R_{t+1} = R_t^2(1 - \alpha) / \alpha = R_t / D_t$ (using equations (4) and (2)). Since the wage differential, D_t, is always greater than 1, $R_{t+1} < R_t$ so the ratio of skilled workers to unskilled workers falls in the next time period. The ratio of skilled workers to unskilled workers must fall even further if some positive number of children of skilled workers become unskilled. Hence $\gamma > 0$ for any steady state and the number of children becoming skilled must be greater than $C_{S,t}$.[7]

Equation (5) has three possible types of solutions, each corresponding to a steady state.

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[7]Note that some children of skilled workers can actually become unskilled as long as a greater number of children of unskilled workers become skilled and the net number of children becoming skilled is greater than $C_{S,t}$ (that is, there can be an additional arrow in Figure 1 that points in the opposite direction of the γ-arrow as long as the net movement is from unskilled to skilled). This indeterminancy about exactly who is getting educated does not affect any of the results. If children of skilled workers have some cost less than $\tilde{L}$ of obtaining education, the children of unskilled workers with low cost of education and the children of skilled workers would no longer be interchangeable.

(i) If the steady-state ratio of skilled to unskilled workers, R*, induces a wage differential of exactly L, then among the children of unskilled workers, all those with a high cost of education will choose no education and some or all of those with a low cost of education will choose education. That is, the steady state fraction of children of unskilled workers who become skilled, γ^*, will be less than or equal to θ, the proportion of children of unskilled parents with a low cost of education. (ii) Similarly, if R* induces a wage differential of H, then $\gamma^* \geq \theta$. (iii) Finally, if R* induces a wage differential between L and H, then $\gamma^* = \theta$. All the children with a low cost of education will become educated and all the children with a high cost of education will not become educated. No other solutions are possible since the wage differential can never be expected to be above H or less than L. (Otherwise everyone or no one would become skilled, which would not be consistent with rational expectations.) Note that the quadratic equation in (5) yields more than two solutions because while there is a maximum of two solutions for a given γ^*, there may be more than one γ^*, which depends on the steady state as well.

An example when all three steady states are admissible is given in Figure 2, where R_{equal}^*, $R_{unequal}^*$, and R_+^* are the steady states corresponding to (i), (ii), and (iii) respectively. (For notational convenience, we will generally refer to a steady state by its ratio of skilled to unskilled workers, R*. We will also henceforth refer to R_{equal}^* as the equal steady state and $R_{unequal}^*$ as the unequal steady state.) We consider each of these three types of steady states in turn.

At the equal steady state, the unskilled have more children than the skilled, but enough children of the unskilled become skilled in each period to maintain the skilled–unskilled ratio at R_{equal}^* and the wage differential at L. Given $R_t = R_{equal}^*$, let γ_{equal}^* be the proportion of children of unskilled workers who become skilled at t + 1. The proportion γ_{equal}^* cannot be greater than the proportion θ of children of unskilled workers that have a low cost of education since the wage differential is L. If fewer than $\gamma_{equal}{}^*$ children of unskilled become skilled, the wage differential at t + 1 would be greater than L, and hence all θ children of the unskilled with a low cost of education would have become skilled. On the other hand, if more than $\gamma_{equal}{}^*$ children of unskilled become skilled, the wage differential at t + 1 would be less than L, and hence no one would become skilled. Neither of these is an equilibrium.

For the equal steady state to be admissible, however, the proportion of children of unskilled who have a low cost of education cannot be too small relative to the fertility differential between skilled and unskilled. If the proportion of children of unskilled who have a low cost of education is too small, then too few children of unskilled will become skilled and the proportion of skilled adults in the population will shrink. Thus, in this situation there cannot be a steady state where the equilibrium wage differential is L. If the proportion of children of unskilled who have a low cost of education is large enough, then a sufficient number of children of unskilled can become skilled to maintain the equilibrium wage differential at L. This implies

PROPOSITION 1: *$R_{equal}{}^*$ is an admissible steady state where*

$$[R^*_{equal}, D^*_{equal}, \gamma^*_{equal}] = \left[\frac{\alpha}{(1-\alpha)L}, L, \frac{L\alpha - \alpha}{L^2 - \alpha L^2 + \alpha L}\right], \tag{6}$$

if and only if

$$\theta \geq \frac{L\alpha - \alpha}{L^2 - \alpha L^2 + \alpha L} \equiv \theta_L . \tag{7}$$

PROOF:

Equation (2) implies $D_t = \alpha / [(1 - \alpha) R_t]$, which implies $D^* = L \Leftrightarrow R^* = \alpha / [(1 - \alpha) L]$. Substituting $R_{equal}{}^*$ into (5) yields the expression for $\gamma_{equal}{}^*$ in (6). The condition $D^* = L$ is equivalent to saying that the children of unskilled workers with a low cost of education are indifferent to obtaining education. Since these children are represented by the fraction θ, this last statement, in turn, is equivalent to saying $\gamma_{equal}{}^* \leq \theta$, which is the inequality in (7).

■

At the unequal steady state, the wage differential is H, and hence all children who have a low cost of education become skilled and some children with a high cost of education may do so as well. Let $\gamma_{unequal}{}^*$ be the proportion of children of the unskilled who obtain education at t + 1 given $R_t = R_{unequal}{}^*$. The proportion $\gamma_{unequal}{}^*$ must be at least as large as the proportion θ of children of unskilled workers that have a low cost of education, since the wage differential is H. If more than $\gamma_{unequal}{}^*$ children of unskilled become skilled, the wage differential at t + 1 would be less than H, and hence only the θ children of the unskilled with a low cost of education would have become skilled. If less than $\gamma_{unequal}{}^*$ children of unskilled become skilled, the wage differential at t + 1 would be greater than H, and hence everyone would become skilled. Neither of these is in equilibrium.

The unequal steady state is admissible if the proportion of children of unskilled workers with a low cost of education is low enough relative to the fertility differential between skilled and unskilled. In this case, even if all θ children become skilled, the ratio of skilled to unskilled workers in the next period does not increase and the wage differential does not fall below H.

PROPOSITION 2: $R_{unequal}$* *is an admissible steady state where*

$$[R^*_{unequal}, D^*_{unequal}, \gamma^*_{unequal}] = \left[\frac{\alpha}{(1-\alpha)H}, H, \frac{H\alpha - \alpha}{H^2 - \alpha H^2 + \alpha H}\right], \tag{8}$$

if and only if

$$\theta \le \frac{H\alpha - \alpha}{H^2 - \alpha H^2 + \alpha H} \equiv \theta_H . \tag{9}$$

PROOF: The proof is similar to that of Proposition 1 except H replaces L.

Note that the income distribution at the unequal steady state second-order stochastically dominates the income distribution at the equal steady state. This can be shown as follows. Normalize the two income distributions to the same mean by fixing the overall output and number of workers in the economy. Then the Cobb-Douglas formulation fixes the total income going to the educated and uneducated and is independent of the proportion of educated and uneducated. At the unequal steady state, there are fewer educated workers than at the equal steady state, so each educated worker necessarily gets a larger income. To get to the new income distribution, income must necessarily be transferred from the poorer people to the richer people.[8]

The last case to consider is when the wage differential is between the low and high cost of education, in which case children obtain education if and only if they have a low cost of doing so.

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[8]This proof implies that the steady states are not Pareto rankable.

PROPOSITION 3: *R_+^* is a steady state if and only if D_+^* is between L and H and R_-^* is a steady state if and only if D_-^* is between L and H, where*

$$R_{\pm}^{*} = \frac{1 \pm \sqrt{1 - \dfrac{4(1-\alpha)\theta}{\alpha(1-\theta)^2}}}{\dfrac{2(1-\alpha)}{(1-\theta)\alpha}} , \tag{10}$$

and the wage differential at R_-^* is at least as high as the wage differential at R_+^*.

PROOF:

$D_{\pm}^*$ is between L and H if and only if $\gamma^* = \theta$. Equation (10) follows immediately from solving for the roots of (5) and substituting $\gamma^* = \theta$. $D_-^* \geq D_+^*$ follows from (2) and the fact that $R_+^* \geq R_-^*$.

■

Proposition 3 leads immediately to the following lemma, where we derive the value of θ for which $R_-^* = R_+^*$.

LEMMA 1: *$R_-^* = R_+^*$ if and only if $\theta = \theta_{critical}$, where*

$$\theta_{critical} = \frac{2 - \alpha - 2\sqrt{1-\alpha}}{\alpha} . \tag{11}$$

If $\theta > \theta_{critical}$, R_+^* and R_-^* do not exist. If $\theta < \theta_{critical}$, $R_{\pm}^*$ exist and R_-^* does not equal R_+^*.

PROOF:

$R_-^* = R_+^*$ if and only if the discriminant of (10) is zero, which simplifies to a quadratic equation in θ and can be solved. The positive root is too large while the negative root is admissible, thus the negative root is $\theta_{critical}$, the value of θ for which $R_-^* = R_+^*$. If $\theta > \theta_{critical}$, the term under the square root in (10) is negative. Hence neither R_-^* nor R_+^* exist. If $\theta < \theta_{critical}$, the term under the square root in (10) is positive, so R_-^* and R_+^* must be different.

■

C. Admissibility

Here, we discuss how changes in the underlying parameters affect the admissibility of R_{equal}^*, $R_{unequal}^*$, R_+^*, and R_-^*. Figure 3 shows how the dynamics of $R_{t+1}(R_t)$ depend on the values of θ, L, and H (It will be helpful to refer to Figure 3 frequently). On the two X-axes, θ varies from 0 to 1. On the Y-axis, L and H vary from 1 to infinity. The axes are discussed below. First note the following lemma.

LEMMA 2: *(i) θ_L and θ_H are between 0 and 1.*

(ii) θ_L and θ_H attain their maximum, $\theta_{critical}$, when L and H = T, where

$T = 1 + [1 / (1 - \alpha)]^{0.5}$. θ_L and θ_H have no other local maxima.

(iii) $\theta_L < \theta_H$ implies $L < T$. $\theta_H < \theta_L$ implies $H > T$.

PROOF: The proof follows from straightforward algebraic manipulation and is omitted.[9]

Figure 4 shows $\theta_L(L)$ and is helpful to understand the axes in Figure 3. On Row 1 in Figure 3, L < H < T so $\theta_L < \theta_H$. On Row 2, L < T < H but H is sufficiently close to T such that $\theta_L < \theta_H$. On Row 3, L < T < H but this time L is sufficiently close to T such that $\theta_H < \theta_L$. On Row 4, T < L < H so $\theta_H < \theta_L$.

Since it seems plausible that improving the education system or subsidizing education could increase θ or decrease L and H, it is useful to discuss how the dynamics depend on θ, L, and H. The intuition is clearest for the lowest and highest values of θ (Columns A and D). If the proportion of children of unskilled with a low cost of education is very low, the economy converges to $R_{unequal}$* (proved in Proposition 4 below). Recall the argument that for R_{equal}* to be admissible, the proportion of children of unskilled who have a low cost of education cannot be too small relative to the fertility differential between skilled and unskilled. If the proportion of children of unskilled who have a low cost of education is too small, then too few children of unskilled will become skilled and the proportion of skilled adults in the population will shrink. Thus, there cannot be a steady state where the equilibrium wage differential is L.

For very high proportions of children of unskilled with a low cost of education, the economy converges to R_{equal}*. $R_{unequal}$* is inadmissible when the proportion of children of unskilled who have a low cost of education is too high relative to the fertility differential between skilled and unskilled. If θ is greater than $\theta_{critical}$, then sufficiently many children of unskilled will

[9]Due to space limitations, intermediate steps in many of the subsequent proofs are also omitted; the reader can refer to Chen (1999) for more detail.

become skilled so that the proportion of skilled adults in the population will rise.

Figure 3 broadly confirms the intuition that lower costs of education and a higher proportion of children of unskilled with a low cost of education may help reduce inequality. As the cost of education falls, the economy moves up along the Y-axis towards Row 1. As the proportion of children of unskilled parents with low cost of education increases, the economy moves right along the X-axis. As both the cost of education falls and the proportion of children of unskilled with low cost of education increases, the economy goes from a single unequal steady state to multiple steady states to a single equal steady state. The lowest values of L and H (Row 1) have the largest region of θ over which only the equal steady state is admissible (Columns C and D). As H increases beyond T (Row 2), this region shrinks (Column D). For even larger values of L and H (Row 3), the region over which only an unequal steady state is admissible increases (Columns A and B). The largest values of L and H (Row 4) have one steady state for all values of θ but the wage differentials at all the steady states are high.

To prove the relationships shown in Figure 3, we need the following lemma:

LEMMA 3: *(i) If $\theta < \theta_H$, then $R_-^* < R_{unequal}^*$.*[10]

(ii) If $\theta < \theta_H$, then $R_+^* > R_{unequal}^*$.

(iii) If $\theta_H < \theta < \theta_{critical}$ and $H > T$, then $R_-^* > R_{unequal}^*$.

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[10]An equivalent necessary and sufficient condition for admissibility of $R_\pm^*$ in Proposition 3 is $R_{unequal}^* \leq R_\pm^* \leq R_{equal}^*$. This is because equation (2) and the expressions in Propositions 1 and 2 imply $D_\pm^*$ between L and H $\Leftrightarrow$ $R_\pm^*$ between $R_{unequal}^*$ and R_{equal}^*. In other words, for a steady state to be admissible, the skilled-to-unskilled ratio must be between the skilled-to-unskilled ratios at the equal and unequal steady states. Thus Lemma 3 can be interpreted as saying if $R_{unequal}^*$ is admissible, then R_-^* is inadmissible.

(iv) If $\theta_H < \theta < \theta_{critical}$ *and* $H < T$, *then* $R_+^* < R_{unequal}^*$.[11]

(v) If $\theta < \theta_L$, *then* $R_-^* < R_{equal}^*$.

(vi) If $\theta < \theta_L$, *then* $R_+^* > R_{equal}^*$.[12]

(vii) If $\theta_L < \theta < \theta_{critical}$ *and* $L > T$, *then* $R_-^* > R_{equal}^*$.[13]

(viii) If $\theta_L < \theta < \theta_{critical}$ *and* $L < T$, *then* $R_+^* < R_{equal}^*$.

PROOF:

Re-expressing $\theta < \theta_H$ yields

$$1 - \frac{4}{H(1-\theta)} + \frac{4}{H^2(1-\theta)^2} < 1 - \frac{4(1-\alpha)\theta}{\alpha(1-\theta)^2} \quad . \tag{12}$$

Since both sides of this inequality are positive, taking the square root (note that either the positive or negative root of the left-hand side can be chosen) leads to the statements in (i) and (ii).

If $\theta_H < \theta < \theta_{critical}$, ">" replaces "<" in (12). The right-hand side is the term under the square root for R_-^* and is positive since $\theta < \theta_{critical}$ (recall the proof of Lemma 2). Taking the square root implies

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[11]Hence, neither R_+^* nor R_-^* are admissible.

[12]In other words, if R_{equal}^* is inadmissible, then so is R_+^*.

[13]Hence neither R_+^* nor R_-^* are admissible.

$$\left|1 - \frac{1}{H}\frac{2}{1-\theta}\right| > \sqrt{1 - \frac{4(1-\alpha)\theta}{\alpha(1-\theta)^2}} \ . \tag{13}$$

If H > T, then 1 - 2 / [H(1 - θ)] is positive, and (iii) follows. If H < T, then 1 - 2 / [H(1 - θ)] is negative, and (iv) follows. The proofs of (v) - (viii) are similar to those of (i) - (iv), respectively, where L replaces H.

■

Proving the relationships in Figure 3 is a straightforward application of Propositions 1 and 2 and Lemmas 1-3.

PROPOSITION 4:

(Column A) *If θ is less than both θ_H and θ_L, only $R_{unequal}$* is admissible.*

(Column D) *If $\theta > \theta_{critical}$, only R_{equal}* is admissible.*

(1B and 2B) *If $\theta_L < \theta < \theta_H$, then only R_{equal}*, R_+*, and $R_{unequal}$* are admissible.*

(3B and 4B) *If $\theta_H < \theta < \theta_L$, then only R_-* is admissible.*

(1C) *If $L < H < T$ and $\theta_H < \theta < \theta_{critical}$, then only R_{equal}* is admissible.*

(2C and 3C) *If $L < T < H$ and $\theta_L < \theta_H < \theta$, then only R_{equal}*, R_+*, and R_-* are admissible. Or, if $L < T < H$ and $\theta_H < \theta_L < \theta$, then only R_{equal}*, R_+*, and R_-* are admissible.*

(4C) *If $T < L < H$ and $\theta_L < \theta < \theta_{critical}$, then only R_{equal}* is admissible.*

PROOF:

(Column A) Proposition 1 implies $R_{unequal}*$ is admissible. Proposition 2 implies $R_{equal}*$ is inadmissible. Lemma 3.i implies R_-* is inadmissible. Lemma 3.vi implies R_+* is inadmissible.

(1B and 2B) Propositions 1 and 2 imply $R_{equal}*$ and $R_{unequal}*$ are admissible. Lemma 3.i implies R_-* is inadmissible. Lemma 4 implies $R_+* > R_{unequal}*$. Lemma 2 implies $L < T$. Lemma 3.viii implies $R_+* < R_{equal}*$. Hence $R_{unequal}* < R_+* < R_{equal}*$ so R_+* is admissible.

The remainder of the proof is similar.

■

Note that the relationships at the cut-off values along the X- and Y-axes in Figure 3 follow immediately from the fact that Lemma 3 can also be proved with non-strict inequality.

D. Stability

When $R_{equal}*$, $R_{unequal}*$, R_-* are admissible, they are generically stable as well. When R_+* is admissible, it is generically unstable. For certain proportions of children of unskilled with low cost of education, some of the steady states become saddle points; but this occurs with measure zero. The intuition is as follows.

Consider the case in which the initial ratio of unskilled to skilled, and hence the initial fertility differential between the unskilled and the skilled, is sufficiently great so that even if a proportion θ children of unskilled workers obtain education the proportion of unskilled workers will rise in the next generation. In this case, the unskilled wage in the next generation will fall. The proportion of unskilled will keep growing until the wage differential between the groups becomes H. On the other hand, if the initial ratio of unskilled to skilled, and hence the fertility differential between the unskilled and the skilled is small enough, then the proportion of unskilled in the next generation will fall, and the economy will approach a steady state in which the wage differential is L. R_+* is the critical population ratio that is on the borderline between these cases and is an unstable steady state. For certain values of the underlying parameters, R_-* replaces $R_{unequal}$* as the unequal, stable steady state. This implies the following two propositions.

PROPOSITION 5: *If R_+* and R_-* are admissible then they are generically unstable and stable, respectively. When $\theta = \theta_{critical}$, R_+* and R_-* are saddle points.*

PROOF:

Taking the derivative of (4) and substituting $R_t = R_+^*$ and $\gamma^* = \theta$ yields

$$\frac{\delta R_{t+1}}{\delta R_t} = 1 + \sqrt{1 - \frac{4(1-\alpha)\theta}{\alpha(1-\theta)^2}} \geq 1 , \qquad \textbf{(14)}$$

which means R_+* is unstable or a saddle point. R_+* is a saddle point when the term under the square root is zero. Since this is the discriminant of equation (10), this is the same as saying $\theta = \theta_{critical}$ (recall the proof of Lemma 1), which occurs with measure zero.

Substituting R_-* instead of R_+* leads to the same expression as (14), except "+" becomes "-" and "≥" becomes "≤". Thus R_-* is generically a stable steady-state and a saddle point only when $\theta = \theta_{critical}$.

■

PROPOSITION 6: *If R_{equal}* and $R_{unequal}$* are admissible then they are generically stable as well. If $\theta = \theta_L$ and $L < T$, then R_{equal}* is a saddle point. If $\theta = \theta_H$ and $H < T$, then $R_{unequal}$* is a saddle point.*

PROOF:

Consider R_{equal}*. Suppose the ratio of skilled workers to unskilled workers is perturbed to $R_{equal}* + \epsilon$ at time t. At time t + 1, the ratio of skilled to unskilled must fall or else the wage differential is less than L, which is inconsistent with rational expectations since no one would have become educated in the first place.

Suppose the ratio of skilled to unskilled is perturbed to $R_{equal}* - \delta$ at time t. Assume towards contradiction that the ratio of skilled to unskilled does not rise at time t + 1, in which case the wage differential will be greater than L. Then all θ children of unskilled workers with low cost to education would have become educated. But for R_{equal}* to be admissible, $\theta \geq \gamma_{equal}*$, which means at least as many children become skilled at $R_{equal}* - \delta$ as at R_{equal}*. For δ small enough, if more people are becoming educated at $R_{equal}* - \delta$ than at R_{equal}*, this means the ratio of skilled to unskilled workers actually increases at $R_{equal}* - \delta$, which is our contradiction.

If, however, the same proportion of people are becoming educated at $R_{equal}* - \delta$ as at R_{equal}* and $L < T$, then the ratio of skilled to unskilled falls at $R_{equal}* - \delta$. $L < T$ and the fact that $\gamma_{equal}* = \theta_L$ imply $R_{equal}* = R_+*$ (using Lemma 3.vi and viii with non-strict inequality), which is generically unstable. Hence R_{equal}* is a saddle point. If, however, $\theta = \gamma_{equal}$* and $L \geq T$, then R_{equal}* = R_-*, which is also stable. The bottom line is that R_{equal}* is stable or a saddle point that occurs with measure zero.

Note that we can rule out exotic dynamics such as cycles or chaotic dynamics. For ratios of skilled workers to unskilled workers that are greater than R_{equal}*, the slope of the function $R_{t+1}(R_t)$ is necessarily zero because of rational expectations. For ratios that are less than and arbitrarily close to R_{equal}*, γ is set under rational expectations so that $R_{t+1} = R_{equal}$*. For ratios that are sufficiently less than R_{equal}*, γ is a constant and taking the derivative of (4) yields an expression that is positive.

The proof for $R_{unequal}$* is similar.

■

E. Comparative Statics

In general, as the proportion of children with low cost of education increases, as the cost of education falls, or as the proportion of output that goes to skilled workers decreases, wage differentials fall and the basin of attraction to the unequal steady state shrinks, possibly becoming eliminated. In this section, we first consider how the basin of attraction of the stable steady states and the wage differentials at those steady states are affected by changes in the underlying parameters θ, L, H, and α; that is, we consider how R_{equal}*, $R_{unequal}$*, R_+*, and R_-* themselves change as the underlying parameters change. We then discuss how changes in the same parameters affect the cutoff values for the admissibility of R_{equal}*, $R_{unequal}$*, R_+*, and R_-*.

When there are multiple steady states as in Figure 2, the system converges to the unequal steady state if R_0, the initial ratio of skilled to unskilled workers, is less than R_+*, and to the equal steady state if R_0 is greater than R_+*. The only parameters that effect R_+* and thus the basin of attraction from which the system approaches either the unequal steady state or the equal steady state are θ and α. Increases in θ, the proportion of children of unskilled parents who have a low cost of education, reduce R_+*, and expand the basin of attraction of the equal steady state. To see this, note that

$$\frac{\delta R_+^*}{\delta \theta} = \frac{-\alpha}{2(1-\alpha)}\left(1 + \sqrt{1 - \frac{4(1-\alpha)\theta}{\alpha(1-\theta)^2}}\right) + \frac{(1-\theta)\alpha}{2(1-\alpha)} \frac{1}{2\sqrt{1 - \frac{4(1-\alpha)\theta}{\alpha(1-\theta)^2}}} \frac{-4(1-\alpha)}{\alpha}[(1-\theta)^{-2} + 2\theta(1-\theta)^{-3}] \,, \tag{15}$$

which is negative since θ and α are less than 1. Since R_+* exists, the term under the square root is positive. Decreases in α, the share of output going to skilled workers, reduce R_+*, and also expand the basin of attraction from which the system approaches the equal steady state. To see this, note that R_+* can be written as

$$R_+^* = \frac{\frac{\alpha}{1-\alpha} + \sqrt{\frac{\alpha}{1-\alpha}\left(\frac{\alpha}{1-\alpha} - \frac{4\theta}{(1-\theta)^2}\right)}}{\frac{2}{1-\theta}} \,. \tag{16}$$

Since $\alpha / (1 - \alpha)$ increases as α increases, R_+* also increases as α increases.

The model thus suggests that countries with R_0 just under R_+* may face a brief window of opportunity in which small and temporary increases in θ or small and temporary decreases in α

can move them into the basin of attraction for the equal steady state. As time passes, and R falls, larger or longer-lasting increases in θ or decreases in α would be necessary to move to the more equal steady state.

If a country wishes to reduce the steady-state wage differential at its current steady state, the model suggests reducing $\tilde{L}$ or $\tilde{H}$, the cost of education for different segments of the population, suffices to reduce the corresponding steady-state wage differential, L and H, and the equal and unequal steady states. For some parameter values, however, R_-^* replaces $R_{unequal}^*$ as the unequal steady state, in which case changes in α and θ may also affect the steady-state wage differential. Decreases in α reduce the wage differential at R_-^*. Using equation (2), the wage differential D_-^* can be written as

$$D_-^* = \frac{\frac{2}{1-\theta}}{1 - \sqrt{1 - \frac{1-\alpha}{\alpha}\frac{4\theta}{(1-\theta)^2}}} \ . \tag{17}$$

As α falls, $(1 - \alpha) / \alpha$ increases, so the denominator of D_-^* increases and D_-^* itself falls. Moreover, increasing θ, the proportion of children of unskilled with low cost of education, results in a lower wage differential D_-^*. To see this, refer back to the quadratic equation in (5). Note that increases in θ increase the coefficient of R^2 and the constant term. This means the upwards-pointing parabola narrows and moves strictly upwards and does not cross the original parabola. Thus if R_+^*, one root of the quadratic equation, decreases as θ increases, as shown in equation (15), then the other root, R_-^*, must increase, which implies θ and D_-^* are inversely related.

The comparative statics for the cutoff values, T, θ_L, θ_H, and $\theta_{critical}$, in Figure 3 are less straightforward. For low values of L, increases in L can eliminate the equal steady state if increasing L causes θ_L to increase beyond θ. The intuition behind this is that higher L means that it becomes more difficult for people to become skilled and thus it becomes more difficult to maintain the equal steady state. Analogously, reductions in H can eliminate the unequal steady states, $R_{unequal}^*$ and R_-^*, if H is reduced to below T and θ_H falls below θ. Lower H means it becomes easier for some people to become skilled and thus unequal steady states become more difficult to maintain.[14]

Reductions in α, the share of output going to skilled workers, reduce $\theta_{critical}$ and thus can eliminate the unequal steady state. To see this, note that the following relationship can be derived:

$$\frac{\delta\,\theta_{critical}}{\delta\,\alpha} = \frac{2 - \alpha - 2\sqrt{1-\alpha}}{\alpha^2\sqrt{1-\alpha}}\,, \tag{18}$$

which is positive since this is just $\theta_{critical}/(1-\alpha)^{0.5}$. Reductions in α also reduce θ_L and θ_H and thus moves the system towards greater equality and to the right on the X-axis. To see this, note that

[14]For large values of L, however, increases in L can eliminate R_-^* and expand the region of θ over which only the equal steady state is admissible, if increasing L causes θ_L to decrease below θ. This is because $\theta_L(L)$ is increasing in L until L = T and then decreasing thereafter (Lemma 2). This may seem counter-intuitive. However, recall that increasing L and H increase the wage differential at the equal and unequal steady states, respectively. For example, it may seem odd that increasing L from 3C to 4C in Figure 3 removes the unequal steady states. Or it may seem odd that increasing L so that θ_L falls below θ may move the system from 4B to 4C, from R_-^* to R_{equal}^*. But for R_-^* to be admissible in the first place, its wage differential must have been between L and H. Thus, increasing L increases the lower bound of admissibility for R_-^*. When increases in L cause R_-^* to become inadmissible, the economy then shifts to R_{equal}^* but the wage differential, L, at R_{equal}^* is now greater than it was at R_-^*. A similar phenomenon occurs when increases in H cause the system to shift from 4A to 4B by lowering θ_H below θ.

θ_L can be rewritten as

$$\theta_L = \frac{\alpha(L - 1)}{L^2 + \alpha(1 - L)L} . \tag{19}$$

Since the numerator increases with α and the denominator decreases with α, θ_L is positively related with α. On the other hand, reductions in α move us down on the Y-axis since T is positively related to α. Note that $T = 1 + 1/(1-\alpha)^{0.5}$ decreases as α decreases. Except for this last case, reductions in α is associated with greater equality, as measured by wage differentials.

In summary, our model suggests that if a country is at an unequal steady state, a temporary increase in the probability that children of unskilled parents become skilled, due, for example, to temporary expansion of educational opportunities, may induce a shift into the basin of attraction of the more equal steady state and permanently move the country to greater equality. This temporary increase must last long enough for the country to move near the equal steady state so that when the push ends, the country is still in the basin of attraction of the equal steady state. For some parameter values, a temporary decrease in the cost of education for children with a high cost of education has a similar effect.

III. Empirical Evidence

We find some evidence that the fertility differential between educated and uneducated women is greater in countries with more inequality[15]. However, since causality runs in both directions in the feedback model, the evidence is not conclusive; if only one direction of the causality exists, there would still be a positive association between differential fertility and inequality.

The model predicts that there should be a positive relationship between differential fertility and Gini coefficients[16] as well as a positive relationship between differential fertility and wage differentials, measured by the return to education.

The remainder of the section is organized as follows. Subsection A discusses the sources for the data (Table 1 summarizes the available data).[17] Subsection B describes the methodology and empirical models. Subsection C reports the results.

A. Data

To measure differential fertility, we use data on total fertility rates (TFR) by women's educational attainment from four comparative studies (United Nations 1987, Jones 1982, United Nations 1995, and Mboup and Saha 1998)[18]. The four comparative studies calculate TFR by

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[15]We did not try to look directly at the impact of ratio of educated to uneducated people on fertility differentials because of the difficulty in defining "educated" people cross-nationally.

[16]Recall that the income distribution at the unequal steady state second-order stochastically dominates the income distribution at the equal steady state.

[17]For an in-depth discussion of how the data sets were put together, see Chen (1999).

[18]For United Nations 1987 and 1995, length of attendance to formal schooling was grouped into four categories: 0 years, 1-3 years, 4-6 years, and 7 years or over. Women with 1-3 years of schooling have typically attended but not completed the primary level, those with 4-6

summing age-specific fertility rates. Thus, we can interpret the total fertility rate as the expected number of children a woman would have should she live until the end of her reproductive years and experience the age-specific fertility schedule. Table 2 reports the available data. Data on income inequality comes from Deininger and Squire (1996). Most of these Gini coefficients are calculated based on gross household income. Bils and Klenow (1998) report Mincer coefficients, a measure of returns to education, for 52 countries.[19] GDP data comes from Summers and Heston (1994), who report real GDP per capita in constant dollars (Chain index) expressed in international prices, base 1985.

B. Methodology

To measure differential fertility for each country, we regress ln(TFR) as reported in Table 2 on years of education. We weight observations in this regression by the percentage of women in the education category.[20] Weights are used because in some countries there are very few

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years of schooling have usually completed a significant portion of the primary level, and those with 7 or more years of schooling are likely to have progressed to secondary school. Collapsing years of schooling into a few categories tends to reduce the response error. For certain data, the educational group 7 years or over is divided into two categories, 7-9 years and 10 years or over, because of the recent upward trend in female education and thus to provide more detail at the upper end of the educational spectrum. For Mboup 1998 and Jones 1982, the education categories reported are descriptive, for example, no school, primary, and secondary+.

[19] Mincer coefficients are coefficients from semi-log OLS regressions of log earnings on years of schooling with potential years of labor market experience and its square as additional independent variables. The correlation between Mincer coefficients and Gini coefficients is positive and significant at the 1% level.

[20] Note that the percentage distribution of women is only available for data from United Nations (1987) and United Nations (1995).

women with extreme levels of educational attainment, which increases the noise with which fertility is measured at these levels. We report the negative of the coefficient in this regression, so a positive number implies uneducated women have more children then educated women. We typically assume that all women in an education category have the average of the range of years of education in the category.

We test the model using data on total fertility rates by women's educational attainment, Gini coefficients, and Mincer coefficients.[21] Total fertility rates (TFR) by women's educational attainment and Gini coefficients of inequality could be obtained for 88 observations in 62 countries from 1974 to 1994. TFR by women's educational attainment and Mincer coefficients of returns to education could be obtained for 30 countries.

We use a model that specifies the total fertility rates by women's educational attainment are independent across observations from different countries but not necessarily independent for observations within countries. Because the data covers three decades, the data set includes some countries up to three times. Since income inequality is likely to be correlated for observations of the same country due to unobservable characteristics of the environment, failing to account for these correlations would lead to underestimation of the standard errors of the coefficients. More specifically, the model is:

$$F_{ct} = a + bG_{ct} + cX_{ct} + u_c + \epsilon_{ct}$$

where c indexes countries and t indexes time. F_{ct} is the fertility differential, which is

[21] In an attempt to use data as consistent as possible across countries and across time, we avoid using individual country censuses, which presumably would vary significantly in definitions and measurement. To reduce measurement error, we use data sources, such as the World Fertility Survey and Demographic and Health Surveys, that have already standardized definitions and measurements across many countries.

approximated as the coefficient from the weighted least squares regression described earlier; *a* is a constant; *b* reflects the relationship between the fertility differential and the Gini coefficient; G_{ct} is the Gini coefficient; X_{ct} is a vector of country and time variables such as ln(GDP), continent dummy variables, and the year of survey; u_c is a country-specific error term; and ϵ_{ct} is the residual.

We also take into account the fact that ϵ_{ct} is heteroskedastic. The noise in the approximation of F_{ct}, the fertility differential, varies across observations. The earlier regressions that provide the measurements of differential fertility, however, also provide an estimate of their noise–the standard errors of the same regression. In this case, where the standard errors are given by h_{it} and the variance of the error term is given by $var(\epsilon_{ct}) = h_{it}^2\sigma^2$, we define $F_{ct}^* = F_{ct}/h_{it}$, $G_{ct}^* = G_{ct}/h_{it}$, $X_{ct}^* = X_{ct}/h_{it}$, $1^* = 1/h_{it}$, and $\epsilon_{ct}^* = \epsilon_{ct}/h_{it}$ and we estimate the model:

$$F_{ct}^* = a1^* + bG_{ct}^* + cX_{ct}^* + \epsilon_{ct}^*$$

In effect, this regression puts more weight on observations with low variance.

Where applicable (Tables 3 and 5), we report the results from using i) only clustering by country, ii) only weights, and iii) both clustering by country and weights. Since under the Kuznets hypothesis, Gini coefficients may be higher among middle-income countries than among either low-income or high-income countries, we control for linear and nonlinear income effects by adding ln(GDP) and ln(GDP)^2 as additional covariates.

C. Results

For most specifications, differential fertility seems positively correlated with Gini coefficients and Mincer coefficients. Table 3 and Chart 1 refer to the sample of countries for which observations on TFR by women's educational attainment and Gini coefficients of inequality could be obtained. Table 4 and Chart 2 refer to the sample of countries for which TFR by women's educational attainment and Mincer coefficients of returns to education could be obtained.

Table 3 -- Fertility Differential Regressed on Gini Coefficient, 1974-1995

Fertility differentials are significantly and positively correlated with Gini coefficients under the cluster and weighted specifications with or without controls for log per capita income and its square. Using both clustering by country and weights to correct for heteroskedasticity, the coefficient of the fertility differential regressed on the Gini coefficient is 0.121 and significant at the 5% level (see column (ix)), once one controls for the level and square of log per capita income. This indicates that going from a relatively equal country like Indonesia with a Gini coefficient of 0.320 in 1987 to a relatively unequal country like Brazil with a Gini coefficient of 0.545 in 1986 increases the fertility differential by 0.027. A fertility differential increase of 0.027 means, for example, the ratio of the expected number of children between a woman with no schooling and a woman with ten years of schooling is 1.31 times children greater in a country like Brazil than it is in a country like Indonesia[22]. Another interpretation is that increasing by two standard deviations of the Gini coefficient (two standard deviations is 0.188) increases the fertility differential by 0.023. Or, going from the 25th percentile of the Gini coefficients, 0.349, to the 75th percentile, 0.490, increases the fertility differential by 0.017. (Of course, these

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[22]This factor is calculated by calculating e^(10*fertility differential increase).

associations are not necessarily causal.)

There is some evidence that fertility differentials may be greatest among middle-income countries. The coefficient on ln(GDP) in column (ix) of Table 3 is positive and significant at the 1% level, while the coefficient on ln(GDP)^2 is negative and significant at the 1% level; for the range of income levels in this data set, fertility differentials initially rise among low to middle-income countries and then fall among middle to high-income countries, all else equal.

The results are reasonably robust to adding continent dummies. When we include a continent dummy for Latin America, the relationship between fertility differentials and the Gini coefficient is positive, but statistically insignificant; but when we include continent dummies for Latin America, sub-Saharan Africa, and Asia, the relationship is statistically significant at the 5% level.

Table 4 -- Fertility Differential Regressed on Returns to Education

In the second data set, since only one Mincer coefficient is available per country, we do not worry about data being correlated for observations within countries and only use weights to correct for heteroskedasticity. The coefficient on the Mincer coefficient is positive and significant at the 5% level for the specification in column (iii). The coefficient of 0.228 implies that an increase of two standard deviations in returns to education increases the fertility differential by 0.021 (two standard deviations is 0.09). This implies a 1.23 increase in the ratio of the number of children women with no schooling have to women with 10 years of education. Note that in Chart 2, the line of best fit between differential fertility and Mincer coefficients is flat, while the line of predicted values from the variance-weighted least squares regression is upwards-sloping. This is because many of the outliers in the chart have relatively high standard deviations. Consequently, as mentioned earlier, these observations have less weight in the regression. Furthermore, note that as in Table 3, column (iii) suggests that fertility differentials are greatest among middle-income countries. The coefficient on ln(GDP) is positive and significant at the 1% level, while the coefficient on ln(GDP)^2 is negative and significant at the 1% level.[23]

Ideally we would have wanted to use an instrument to shed light on the direction of causality. But in the absence of a good instrument, it is interesting to consider the example of Taiwan. During the communist takeover of China, Taiwan had exogenous increases in the proportion of skilled workers due to the exodus of educated people fleeing China. Since then, Taiwan has had a fairly equal wage distribution. Moreover, in Taiwan, there is no tendency for less educated women to have more children. In fact, women with some post-secondary education actually have twice as many children as women with primary school education or less[24] (Taiwan-Fukien demographic fact book, 1996).

IV. A More General Relationship Between Fertility and Wages

[23]We also find a positive relationship between differential fertility and income inequality in a United States time-series data set consisting of 13 observations for the United States from 1925 to 1989. The relationship is positive though somewhat weaker than the relationship in the other two data sets. That the relationship is less significant than in the other data sets can perhaps be explained by the small size of the US time-series sample. Furthermore, as Section 4 notes, the relationship may be hard to pick up in general for a high-income country such as the US. Since fertility levels are generally very low, measurement noise may cover up the true association between differential fertility and income inequality.

[24]To compare with Table 2, the weighted OLS coefficient measuring differential fertility is -0.107.

In Sections 2 and 3, we considered the case in which $\epsilon = 0$ (so that as income grows, fertility falls to zero) and A, productivity, is large enough to create an interior solution for fertility. Under these conditions, fertility is inversely proportional to wages. This may be an acceptable approximation over the moderate wage levels characteristic of middle-income countries, but it is not likely to fit as well at very low or very high wages. At very low wages, wage increases may increase the number of surviving children by reducing infant mortality and infertility due to disease and malnutrition. In fact, among the poorest African countries, fertility initially increases with education. Child survival is also more important to model in the poorest countries In middle-income countries, the under-5 mortality rate in 1997 was only 42 per 1000 (World Bank, 1999), so it may be acceptable to neglect infant mortality, as we have done so far, and approximate differences in the number of surviving children of educated and uneducated workers by differences in fertility rates between these groups. The under-5 mortality rate was higher in low-income countries at 97 per 1000 in 1997 (excluding China and India, the rate was 130 per 1000; World Bank, 1999). Thus, in the very poorest countries, a high proportion of children of the unskilled may not survive, so increases in wages may have a strong positive effect on survival rates. Barro and Sala-i Martin (1995) find that among the very poorest countries, fertility rises with income. At very high wages, further wage increases are likely to reduce fertility only modestly. This suggests that the relationship between fertility differentials and income inequality would be greatest among middle-income countries, negative among low-income countries, and weak among high-income countries.

The weaker relationship between fertility and wages at high wage levels can be captured by the utility function we employ if we let $\epsilon > 0$, in which case fertility asymptotes to a positive level as wage increases without bound. Suppose also that at very low wages, wage increases lead to more surviving children by reducing infertility and infant mortality. In this case, the relationship between the number of surviving children and wages may be shown in Figure 5.

In this case, the effect of inequality on fertility differentials depends on the general level of wages, and hence on the productivity parameter A. If wages are in region 1, then skilled workers have more children than unskilled workers. If wage differentials increase, then the fertility differential, as defined in Sections 2 and 4, falls. If a low-income country is in region 2, then the relationship between inequality and fertility differentials is ambiguous.

The model applies best for middle-income countries around region 3. For these countries, fertility differentials, as measured in Section 3, should be the greatest relative to low and high-income countries. Consequently, the relationship between differential fertility and inequality should also be the strongest.

Among high-income countries, the fertility of both skilled and unskilled labor is small as shown in region 4. However, since fertility asymptotes to ϵ, fertility differentials are small. Hence, measurement noise may obscure the relationship between differential fertility and inequality.

We find that the positive relationship between inequality and differential fertility is primarily found in the sample consisting of middle-income countries, while among high-income countries the relationship is weaker, and among the low-income countries the relationship is weakest (See Table 5.) Following the World Bank, we take the cut-off between middle-income and low-income developing countries as \$1640 GDP per capita while the cut-off between middle-income and high-income countries as $7170 GDP per capita.[25]

Among middle-income countries, the association between differential fertility and the Gini coefficient has a larger magnitude than the coefficient for the sample of all countries and is statistically significant at the 5% level. The number 0.193 in column (ii) can be interpreted as increasing the fertility differential by 0.043 when inequality increases from the 1987 Indonesian level (with a Gini coefficient of 0.320) to the 1986 Brazilian level (with a Gini coefficient of 0.545). A fertility differential increase of 0.043 means, for example, the ratio of the expected number of children of a woman with no schooling to a woman with 10 years of education is 1.54 times greater in a country like Brazil than it is in a country like Indonesia.

For low-income countries the association between differential fertility and Gini coefficient is close to zero. Among high-income countries, the association between differential fertility and Gini coefficients is positive, though weaker than among middle-income countries in most specifications. Note, however, that the strength of this association in rich countries is mainly driven by the oil-rich outliers, Venezuela and Trinidad and Tobago, in this sub-sample of mainly European and North American countries. Indeed, the cut-off values for middle-income and high-income countries are arbitrary. If we use cut-off values of $950 and $9500 GDP per capita for middle and high-income countries then the relationship between differential fertility and Gini coefficients in high-income countries is not significant, and the relationship among low-income countries is negative and statistically significant.

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[25]Note that $1639 is the World Bank cutoff between lower middle-income countries and upper-middle income countries.

V. Conclusion

The large fertility differentials between educated and uneducated workers found in developing countries, together with intergenerational persistence in education levels, make it difficult to reduce inequality in these countries. Differential fertility tends to increase the proportion of unskilled workers, reducing their wages. Since wage reductions lower the opportunity cost of having children, there may be a positive feedback. A model incorporating this effect generates multiple steady-states with varying levels of inequality.

Consistent with the model, we find positive relationships between Gini and Mincer coefficients on the one hand and fertility differentials between educated women and uneducated women on the other. The relationship between differential fertility and inequality is strongest for middle-income countries, weaker for the richest group of countries, and negative for the poorest countries.

Our model suggests that if a country is in an unequal steady state, a temporary increase in the probability that children of unskilled parents become skilled, due, for example, to an expansion of access to educational opportunities, may permanently move the country to a more equal steady state.

The analysis can be generalized and extended in several ways.[26] In the model, we assume a two-point form for the distribution of the cost of education. This discrete form of the distribution of cost implies that the supply of skilled labor is infinitely elastic at wage premiums

[26]The empirical investigation of the model can also be expanded but evidence is limited by the available data.

of L and H and completely inelastic for wage premiums in between. If the wage premium ever falls below L, no children would invest in education; if the wage premium rises above L, all children of skilled workers and a fraction θ of children of unskilled workers would invest in education. In between L and H, the ratio of children of unskilled workers who become skilled is θ. Consequently, between L and H, the demographic force for instability explored in this paper dominates any effect of wage premia on incentives for education. Once the wage premium reaches L or H, the traditional, stabilizing force by which increasing wage differentials increase incentives for education dominates. With a more general, continuous distribution of cost of education, either force could locally dominate in different areas. We conjecture that, with a more general distribution of cost of education, the R_{t+1} (R_t) curve could cross the $45°$ line an arbitrary number of times, generating an arbitrary number of stable steady states.

More generally, with a continuous distribution of cost, the response of fertility differentials to wages should make R_{t+1} increase more steeply in R_t than if fertility were exogenous. The steady-state distribution of skill would therefore be more sensitive to changes in parameters with endogenous fertility. For example, suppose a public program educates an additional 1,000,000 children in each generation. Unskilled wages will rise, raising the opportunity cost of childbearing among the unskilled and reducing their fertility, which will further increase wages among the unskilled, creating a multiplier effect on inequality. Figure 6 shows, in a local neighborhood of a stable steady state, that a permanent increase in the function $R_{t+1}(R_t)$ leads to a larger steady-state proportion of skilled workers when there is endogenous fertility than when there is not. This is because endogenous fertility creates a positive feedback, which makes the reaction function steeper. Note that this effect does not arise in the simple model with a two-point distribution of cost since at the stable steady states with L and H as wage premiums, the supply of skilled labor is infinitely elastic. The traditional force of children choosing education when wage differentials are high has an infinite weight relative to the demographic force and hence the slope of the response function $R_{t+1}(R_t)$ is zero.

Another limitation of the analysis is that we approximate relative wages as depending on the skilled-to-unskilled ratio of the population, rather than on the skilled-to-unskilled ratio of market labor time, which also depends on the proportion of time each group spends on education and raising children. Moreover, the value of education should depend on the amount of time people expect to spend in the labor market, not on the total amount of time people spend outside of school, at least under our assumption that education does not affect productivity in child-rearing. Dispensing with these approximations would make the problem more complicated. During the time when young people are in school learning rather than working, the supply of unskilled labor will be lower. Moreover, the greater fertility of the unskilled will also reduce their time in the market. This will tend to increase the wage of the unskilled for every level of R. Solving the dynamic model becomes much more difficult, because the choice of whether to become educated depends on people's expectations of fertility of the skilled and unskilled when they become adults since this will affect wage rates. Thus R_t would depend not only on R_{t-1} but also on R_{t+1}, which takes into account fertility rates, and thus time spent in the labor market, in period t. We conjecture that most of the intuition would go through in such a model.

We focus on a tractable case of quasilinear utility but conjecture that the results in this paper still hold for more general forms of utility as long as (i) skilled and unskilled workers are complements in production; (ii) children of the unskilled are more likely to be unskilled, and (iii) higher wages reduce fertility because substitution effects outweigh income effects.

References

Barro, Robert and Sala-i-Martin, Xavier. *Economic Growth.* New York: McGraw-Hill, 1995.

Bils, M. and P. Klenow, "Does Schooling Cause Growth or the Other Way Around?" NBER Working Paper No. 6393, 1998.

Birdsall, N. "Economic Approaches to Population Growth," in Chenery, H. and Srinivasan, T.N., ed., *Handbook of Development Economics*, Vol. 1. Amsterdam: Elsevier Science Publishers, 1988, pp. 477-542.

Chen, Daniel L. "Income Distribution Dynamics with Endogenous Fertility," senior thesis Harvard University, 1999.

Chu, C. Y. Cyrus. and Koo, Hui-Wen. "Intergenerational Income-Group Mobility and Differential Fertility." *American Economic Review*, December 1990, *80*(5), pp. 1125-38.

Chung-hua min kuo Tai Min ti chu jen kou tung chi. Taiwan-Fukien demographic fact book, Republic of China, Tai-pei, Nei cheng pu, 1996.

Dahan, Momi and Tsiddon, Daniel. "Demographic Transition, Income Distribution, and Economic Growth." *Journal of Economic Growth* , March 1998, *3*(1), pp. 29-52.

Deininger, K. and Squire, L. "Measuring Income Inequality: A New Data-base." Development Discussion Paper No. 537, Harvard Institute for International Development, Harvard University, 1996.

Galor, O., and J. Zeira. "Income Distribution and Macroeconomics." *Review of Economic Studies*, January 1993, *60*(1), 35-52.

Galor, O. and Zang, Hyoungsoo. "Fertility, Income Distribution, and Economic Growth: Theory and Cross-Country Evidence." *Japan and the World Economy*, May 1997, *9*(2), pp. 197-229.

Jones, E. *Socio-economic Differentials in Achieved Fertility*. World Fertility Survey Comparative Study No. 21, ECE Analyses, Voorburg, The Netherlands: International Statistical Institute, 1982.

Krusell, P., L. Ohanian, V. Rios-Rull, G. Violante, *Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis.* Federal Reserve Bank of Minnesota Staff Report #239, 1997.

Lam, David. "The Dynamics of Population Growth, Differential Fertility, and Inequality." *American Economic Review*, December 1986, *76*(5), pp. 1103-16.

Mare, Robert D. "Differential Fertility, Intergenerational Educational Mobility, and Racial Inequality." *Social Science Research,* September 1997, *26*(3), pp. 263-291.

Mboup, G. and Saha, T. *Fertility Levels, Trends, and Differentials: Demographic and Health Surveys*, Comparative Study No. 28, Calverton, Maryland: Macro International, 1998.

Nerlove, M., Razin, A., and Sadka, E. "Income Distribution Policies with Endogenous Fertility." *Journal of Public Economics*, July 1984, *24*(2), 221-230.

Preston, Samuel and Campbell, Cameron. "Differential Fertility and the Distribution of Traits: the Case of I.Q." *American Journal of Sociology*, March 1993, *98*(5), pp. 997-1019.

Razzaz, Susan. "Fertility and Growth: The Significance of Gender Differences in Human Capital." Unpublished Ph.D. dissertation, Brown University, 1998.

Repetto, Robert. "Interaction of Fertility and Size Distribution of Income." *Journal of Development Studies*, July 1978, *14*(4), pp. 22-39.

Schultz, T. Paul. *Economics of Population*. Massachusetts: Addison-Wesley, 1981.

Summers, Robert and Heston, Alan. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988," *Quarterly Journal Of Economics*, May 1991, *106*(9).

United Nations. *Fertility Behavior in the Context of Development: Evidence from the World Fertility Survey.* Population Studies No. 100, New York: United Nations, 1987.

________. *Women's Education and Fertility Behavior: Recent Evidence From the Demographic and Health Surveys.* New York: United Nations, 1995.

World Bank. *World Development Report 1999/2000.* Oxford: Oxford University Press, 1999.

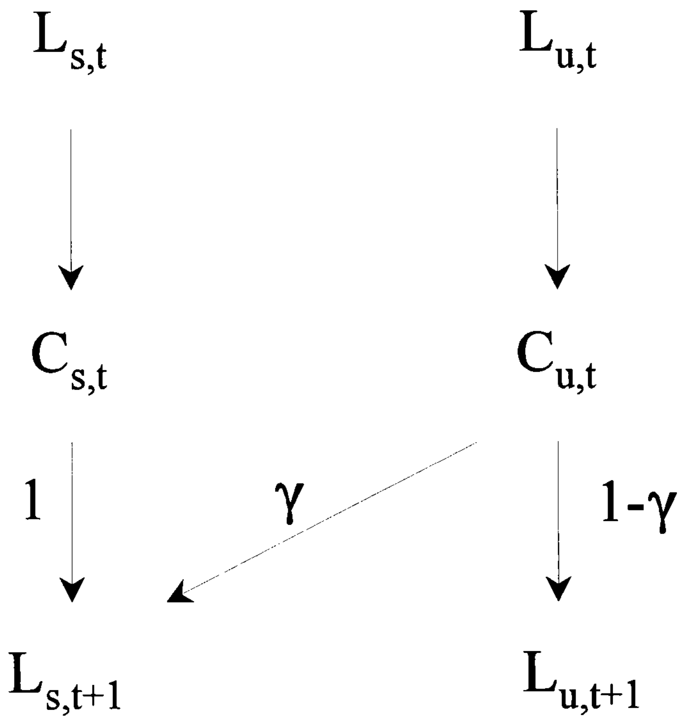


Figure 1 -- Dynamics of $C_{S,t}$, $C_{U,t}$, $L_{S,t}$, and $L_{U,t}$.

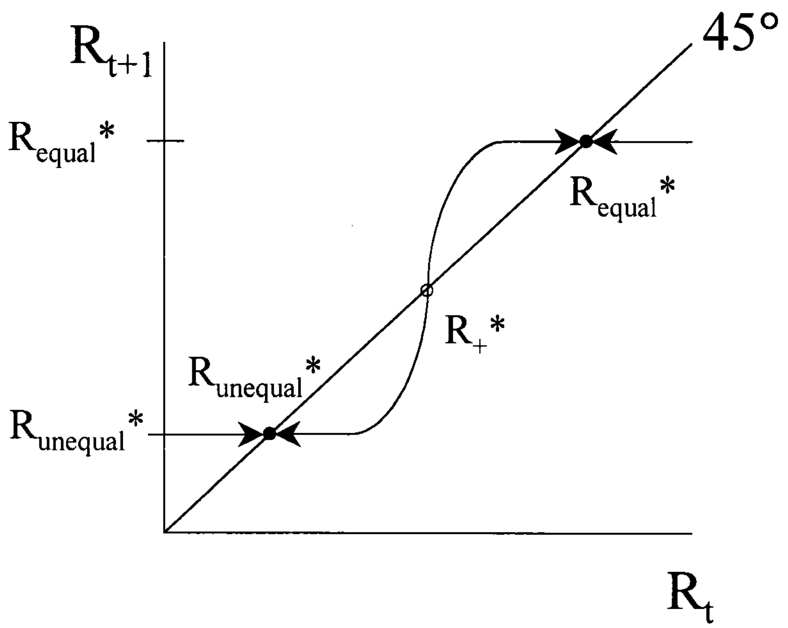


Figure 2: Multiple steady states

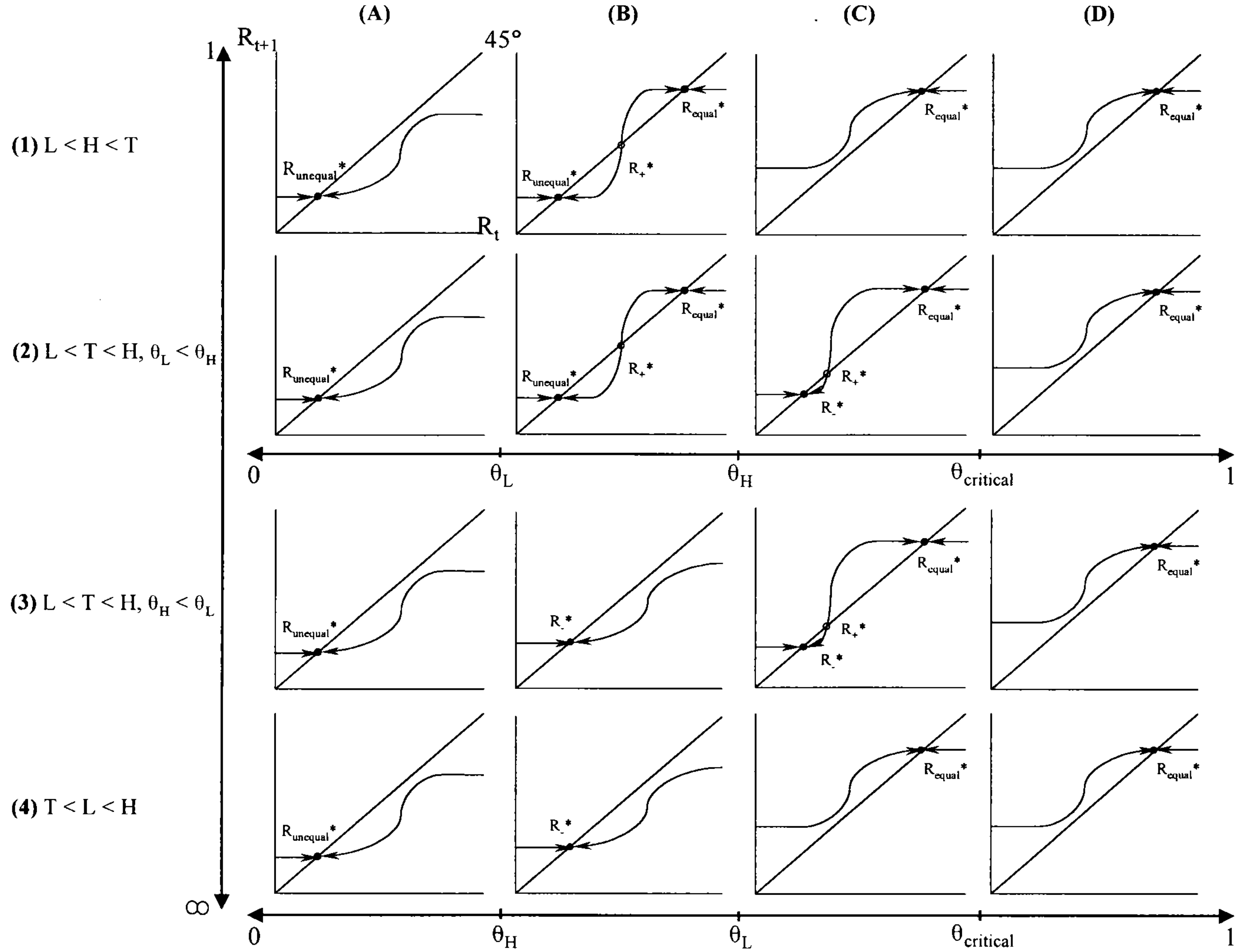


Figure 3 -- Dynamics of $R_{t+1}(R_t)$ as θ, L, and H vary

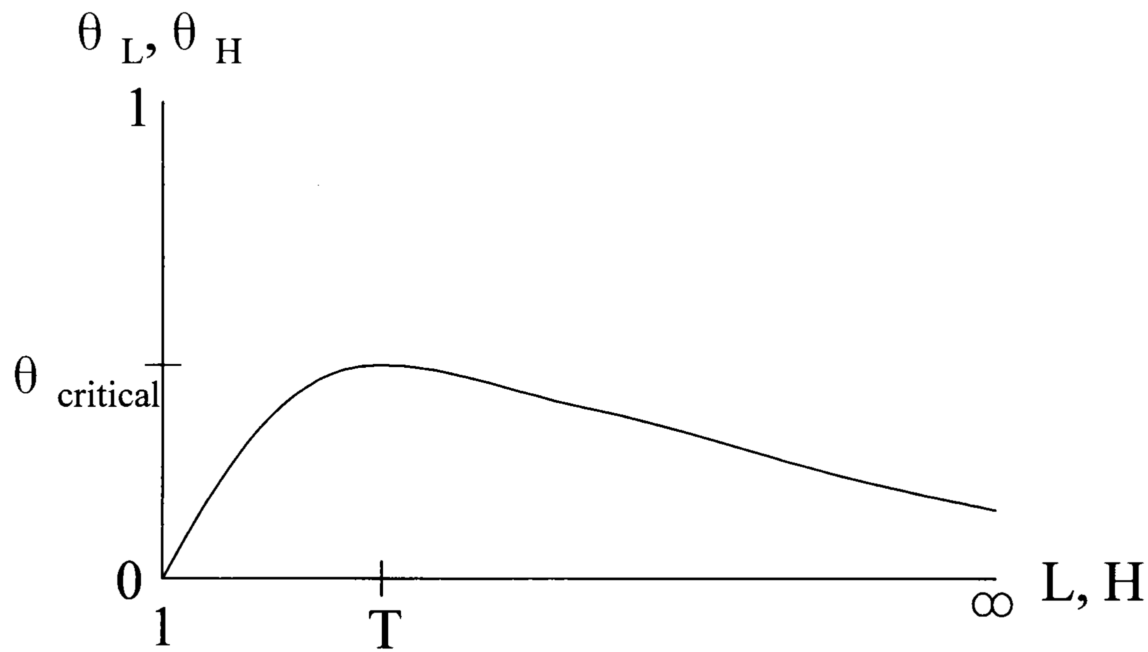


Figure 4: $\theta_L(L)$ and $\theta_H(H)$

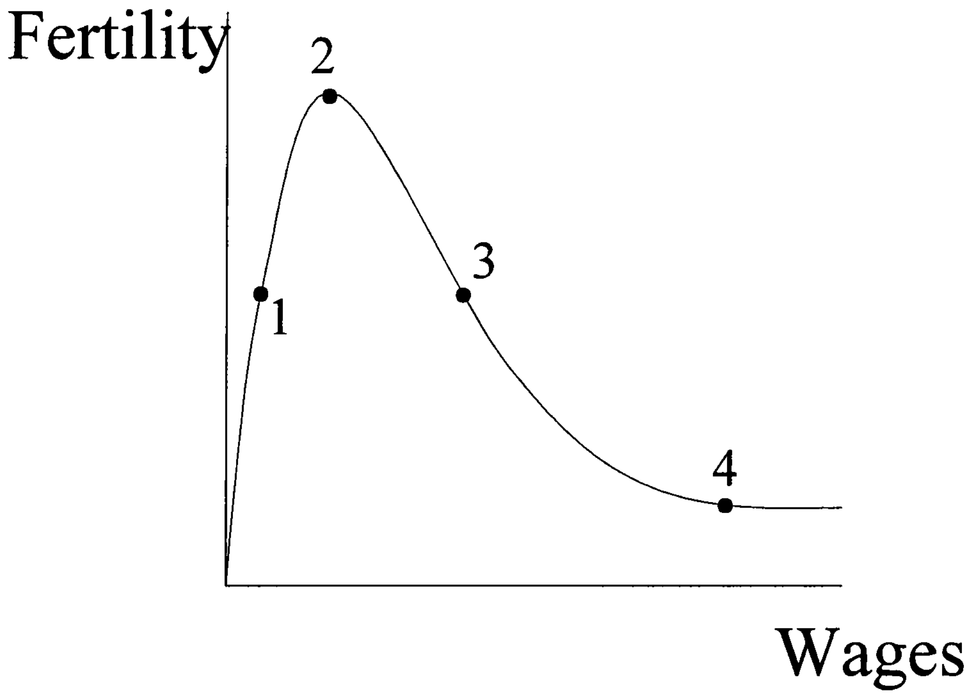


Figure 5: Fertility vs. Wages

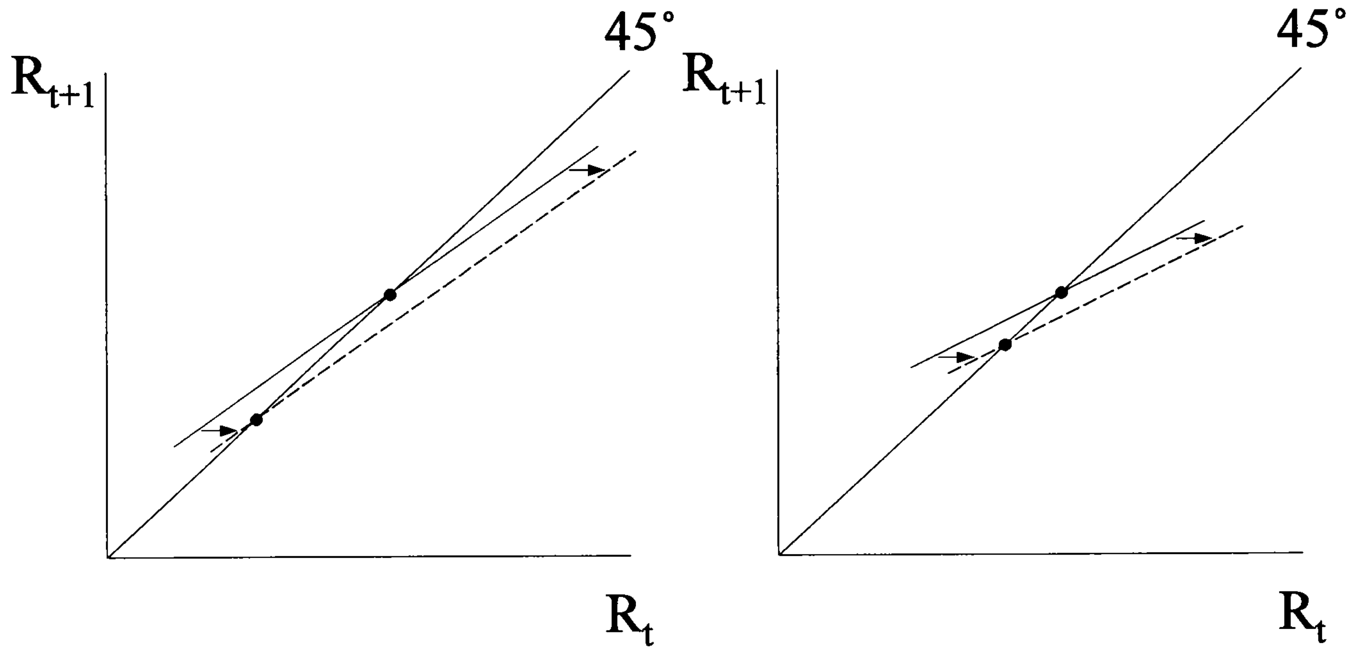


Figure 6: Multiplier effect in a local neighborhood of a stable steady state with and without endogenous fertility

Table 1 -- Available Data

	Number of Observations	Mean	Standard Deviation
Fertility differentials vs. Gini coefficients			
Countries with fertility differentials	88		
Country-Years with fertility differentials	96		
Fertility differentials	96	0.058	0.034
Gini coefficients	88	0.423	0.094
GDP	96	2851	2829
Fertility differentials vs. Mincer coefficients			
Countries with Mincer coefficients	52		
Mincer coefficients	52	0.096	0.047
Gini coefficients	52	0.407	0.099
Fertility differentials	30	0.063	0.034
GDP	52	5510	4538

Table 2 -- Total Fertility Rate by Women's Years of Education

Data is taken from World Fertility Survey [United Nations, 1987 and Jones, 1982] and Demographic and Health Surveys [United Nations, 1995 and Mboup, 1998]. For the last two groups of surveys, no data on percentage distribution of women is available. Weighted OLS coefficients are calculated by regressing TFR on proxy years representing the education categories and using % of Women in category as weights where available. If not available, % of Women is assumed as uniform. Standard errors are from the OLS regression. Proxy years are: 0, 2, 5, and 8 for non-European/USA surveys from 1974-1982; 0, 2, 5, 8, and 11 for 1985-1989 surveys; 0, years in primary, primary+2 for 1990-1994 surveys; 3, 6, 9, 12, and 14 for European/USA surveys.

World Fertility Survey, 1974-1982, Developing countries [United Nations, 1987]

Country	Survey Year	Wtd OLS	Std Error	TFR for Education category 0	1-3	4-6	7+	% of Women in category 0	1-3	4-6	7-9	10+
BANGLADESH	1975	0.003	0.019	6.1	6.4	6.7	5.0	78	8	11	2	1
BENIN	1982	0.052	0.016	7.4	8.5	5.8	4.3	88	3	6	2	1
CAMEROON	1978	0.018	0.015	6.4	7.0	6.8	5.2	68	7	19	4	2
COLOMBIA	1976	0.126	0.017	7.0	6.0	3.8	2.6	16	38	29	11	5
COSTA RICA	1976	0.088	0.013	5.0	5.0	3.6	2.7	8	25	41	9	13
COTE D'IVOIRE	1980	0.022	0.010	7.4	8.0	6.4	5.8	84	4	8	3	2
DOMINICAN REP.	1975	0.110	0.037	7.0	7.3	5.4	3.0	16	38	28	12	7
ECUADOR	1979	0.141	0.032	7.8	7.2	5.3	2.7	14	25	35	11	14
GHANA	1979	0.024	0.006	6.8	6.7	6.7	5.5	60	3	7	9	20
GUYANA	1977	0.039	0.005	6.6	7.0	5.6	4.8	4	3	23	60	6
HAITI	1977	0.093	0.008	6.0	4.8	4.1	2.8	70	15	9	3	2
JAMAICA	1975	0.043	0.015	6.2	5.9	5.8	4.8	2	3	18	67	10
JORDAN	1976	0.073	0.009	9.3	8.6	7.0	4.9	50	6	21	13	9
KENYA	1977	0.010	0.010	8.3	9.2	8.4	7.3	53	12	18	12	4
KOREA, REP.	1974	0.063	0.014	5.7	5.5	4.3	3.4	21	8	42	17	12
LESOTHO	1977	0.021	0.021	6.2	5.6	6.0	4.8	8	13	55	23	2
MALAYSIA	1974	0.048	0.022	5.3	5.3	4.8	3.2	35	18	34	7	6
MEXICO	1976	0.105	0.027	8.1	7.5	5.8	3.3	22	33	27	13	4
MOROCCO	1979	0.070	0.010	6.4	5.2	4.4	4.2	88	2	6	2	2
PAKISTAN	1975	0.075	0.028	6.5	5.4	6.1	3.1	87	2	5	2	2
PANAMA	1975	0.122	0.024	7.0	6.9	5.0	3.0	6	14	40	18	22
PARAGUAY	1979	0.130	0.004	8.2	6.6	4.6	2.9	7	31	41	9	12
PERU	1977	0.100	0.016	7.3	6.8	5.1	3.3	31	24	23	8	14
PHILIPPINES	1978	0.082	0.045	5.4	7.0	6.2	3.8	6	12	48	9	24
SENEGAL	1978	0.051	0.019	7.3	9.4	6.3	4.5	90	2	5	2	1
SUDAN	1978	0.078	0.011	6.5	5.6	5.0	3.4	81	7	7	2	2
SYRIA	1978	0.100	0.005	8.8	6.7	5.6	4.1	67	4	18	7	5
TRINIDAD&TOBAGO	1977	0.037	0.016	4.6	3.4	4.1	3.2	4	2	12	67	15
VENEZUELA	1977	0.122	0.023	7.0	6.4	4.6	2.6	14	16	43	16	11
YEMEN	1979	0.100		8.6	5.4	5.4	5.4	98	0	1	0	0
Averages	1977	0.072	0.017	6.9	6.5	5.5	4.0	42.5	12.6	22.7	14.0	7.7

Demographic and Health Surveys, 1985-1989, Developing countries [United Nations, 1995]

Country	Survey Year	Wtd OLS	Std Error	TFR for Education category 0	1-3	4-6	7-9	10+	% of Women in category 0	1-3	4-6	7-9	10+
BOLIVIA	1989	0.081	0.016	6.2	6.4	5.3	4.2	2.8	17.5	21.6	19.9	15.4	25.7
BOTSWANA	1988	0.054	0.012	5.9	5.6	5.1	4.5	3.1	24.1	7.7	16.7	34.5	17.0
BRAZIL	1986	0.092	0.012	6.7	5.2	3.4	2.8	2.2	7.4	22.3	31.6	16.0	22.6
BURUNDI	1987	0.008	0.014	7.0	7.4	6.7	6.6	4.2	80.2	6.8	10.8	1.1	0.8
COLOMBIA	1986	0.102	0.008	5.6	4.5	3.6	2.5	1.8	6.9	23.9	31.3	21.0	16.8
DOMINICAN REP.	1986	0.068	0.008	5.8	5.0	4.4	3.5	2.6	5.9	20.9	24.7	21.0	27.6
ECUADOR	1987	0.084	0.004	6.4	6.3	4.7	3.5	2.6	7.8	14.8	32.7	16.1	28.6
EGYPT	1988	0.055	0.009	5.7	5.3	4.2	3.4	3.4	52.0	13.5	17.3	11.4	5.9
EL SALVADOR	1985	0.075	0.008	6.0	5.2	3.9	3.5	2.5	21.3	24.6	24.6	13.4	16.0
GHANA	1988	0.032	0.008	7.1	6.6	6.4	6.8	4.9	39.7	5.8	10.4	15.9	28.0
GUATEMALA	1987	0.091	0.009	6.9	5.6	4.2	2.8	2.7	41.7	24.1	19.6	6.2	8.4
INDONESIA	1987	0.031	0.015	3.8	4.0	3.6	2.8	2.6	23.2	20.8	39.1	8.6	8.2
KENYA	1988	0.038	0.013	7.2	7.5	7.5	6.2	4.6	25.1	7.4	20.2	34.2	12.8
LIBERIA	1986	0.034	0.016	6.8	7.1	7.5	5.7	4.2	63.0	6.9	11.1	9.2	9.7
MALI	1987	0.021	0.009	7.0	6.7	6.6	5.7	4.7	85.4	3.4	6.3	3.8	1.1
MEXICO	1987	0.104	0.013	6.4	6.3	4.0	2.7	2.4	11.6	16.6	31.4	26.4	14.0
MOROCCO	1987	0.095	0.010	5.5	3.9	2.9	2.4	2.2	82.7	3.6	7.1	3.1	3.3
PERU	1986	0.098	0.005	7.4	6.1	4.6	3.7	2.5	10.9	17.8	24.3	17.0	29.9
SENEGAL	1986	0.050	0.005	7.0	6.4	5.5	4.3	3.6	77.4	3.5	10.1	4.1	4.8
SRI LANKA	1987	0.007	0.007	2.8	3.0	2.9	2.7	2.7	11.1	12.6	23.6	29.6	23.0
THAILAND	1987	0.078	0.007	3.5	2.8	2.5	2.1	1.5	9.7	5.0	70.9	2.9	11.5
TOGO	1988	0.050	0.013	7.2	7.1	6.0	3.9	4.8	58.7	10.1	19.0	7.2	4.9
TRINIDAD&TOBAGO	1987	0.030	0.017	2.3	4.3	3.6	3.8	2.9	1.1	3.8	22.9	21.4	50.8
TUNISIA	1988	0.060	0.005	5.1	4.7	3.7	2.8	2.6	56.7	7.6	23.5	5.2	7.0
UGANDA	1988	0.015	0.010	7.7	7.4	7.0	7.2	5.3	39.8	18.0	25.8	13.2	5.2
ZIMBABWE	1988	0.071	0.013	7.3	7.2	6.3	5.0	3.3	13.6	10.5	23.6	35.1	17.0
Averages	1987	0.059	0.010	6.0	5.7	4.9	4.0	3.2	33.6	12.8	23.0	15.1	15.4

Demographic and Health Surveys, 1990-1994, Developing countries [Mboup, 1998]

Country	Survey Year	Veighte OLS	Std Error	TFR for Education category no school	primary	secondary+	Years in Primary
BANGLADESH	1993	0.048	0.025	3.64	3.24	2.49	5
BOLIVIA	1993	0.063	0.060	5.84	5.62	3.05	6
BURKINA FASO	1993	0.080	0.048	6.06	4.97	2.86	6
CAMEROON	1991	0.019	0.029	5.78	6.02	4.44	7
CENTRAL AFR.R.	1994	0.020	0.030	4.73	4.94	3.74	6
COLOMBIA	1990	0.097	0.030	4.66	3.36	2.24	5
DOMINICAN REP.	1991	0.049	0.019	4.80	3.71	2.75	8
EGYPT	1992	0.058	0.013	4.82	3.66	2.94	6
GHANA	1993	0.055	0.040	5.36	4.56	2.69	8
INDONESIA	1994	0.023	0.024	3.12	3.14	2.47	6
JORDAN	1990	0.031	0.013	6.31	5.62	4.74	6
KENYA	1993	0.033	0.026	5.40	5.08	3.75	7
MADAGASCAR	1992	0.030	0.042	5.88	6.21	4.19	6
MALAWI	1992	0.040	0.033	6.11	5.81	4.08	6
MOROCCO	1992	0.119	0.013	4.16	2.15	1.85	5
NAMIBIA	1992	0.040	0.030	5.64	5.26	3.80	6
NIGER	1992	0.048	0.048	6.42	6.37	3.92	6
NIGERIA	1990	0.037	0.037	5.67	5.66	3.91	6
PAKISTAN	1990	0.035	0.013	4.69	4.23	3.61	5
PARAGUAY	1990	0.074	0.046	6.06	5.03	3.00	6
PERU	1991	0.122	0.060	6.49	4.80	2.48	5
PHILIPPINES	1993	0.020	0.052	4.31	5.13	3.25	6
RWANDA	1992	0.049	0.029	5.98	5.25	3.78	6
SENEGAL	1992	0.066	0.034	5.85	4.79	3.19	6
TURKEY	1993	0.107	0.014	4.00	2.30	1.65	6
ZAMBIA	1992	0.028	0.026	6.39	6.18	4.55	7
ZIMBABWE	1994	0.031	0.024	4.68	4.36	3.28	7
Averages	1992	0.053	0.032	5.29	4.72	3.29	6

World Fertility Survey, 1975-1979, Europe/USA [Jones, 1982]

Country	Survey Year	Veighte OLS	Std Error	TFR for Education category elementary incomplete	elementary complete	low secondary	high secondary	post-secondary
BULGARIA	1976	0.046	0.010	2.41	1.74	1.55	1.50	1.37
CZECHOSLOVAKIA	1977	0.035	0.006	2.35	2.35	2.08	1.80	1.62
DENMARK	1975	0.019	0.005	2.20	2.20	1.87	1.86	1.85
FINLAND	1977	0.020	0.003	2.01	2.01	1.80	1.74	1.64
FRANCE	1977	0.034	0.006	2.51	2.03	1.86	1.79	1.66
ITALY	1979	0.024	0.004	2.45	1.96	1.74	1.65	1.48
NORWAY	1977	0.043	0.006	2.40	2.40	2.11	1.95	1.86
POLAND	1977	0.026	0.004	2.70	2.32	1.95	1.71	1.55
ROMANIA	1978	0.050	0.001	2.25	2.25	1.68	1.52	1.39
SPAIN	1977	0.048	0.008	2.63	2.28	2.42	2.27	2.41
U.K.	1976	0.007	0.007	2.15	2.15	1.90	1.73	1.72
U.S.A.	1976	0.040	0.006	2.76	2.76	2.34	2.07	1.82
YUGOSLAVIA	1976	0.045	0.01	2.43	1.81	1.57	1.57	1.40
Averages	1977	0.034	0.006	2.40	2.17	1.91	1.78	1.67

Table 3 -- Fertility Differentials Regressed on Gini Coefficient, 1974-1995

Dependent variable: Weighted OLS coefficient of TFR on years of education

	Cluster[1]			Weights[2]			Both[3]		
Independent Variable	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
Gini coefficient	0.101**	0.112***	0.092***	0.074**	0.066*	0.121***	0.074	0.066	0.121**
	(0.044)	(0.039)	(0.034)	(0.034)	(0.035)	(0.028)	(0.067)	(0.062)	(0.050)
Year	-0.001	-0.00003	-0.0001	0.001	0.001	-0.0003	0.001	0.001	-0.0003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ln(GDP)		0.010*	0.315***		-0.005	0.394***		-0.005	0.394***
		(0.006)	(0.062)		(0.005)	(0.054)		(0.008)	(0.068)
ln(GDP)^2			-0.020***			-0.025***			-0.025***
			(0.004)			(0.003)			(0.004)
Constant	1.130	0.010	-1.002	-1.740	-0.950	-1.501	-1.740	-0.950	-1.501
	(1.000)	(1.190)	(1.188)	(1.442)	(1.612)	(1.260)	(2.046)	(2.595)	(2.160)
N	88	88	88	88	88	88	88	88	88

Notes:

GDP is real GDP per capita in constant dollars (Chain index) expressed in international prices, base 1985.

[1]These regressions correct standard errors for random effects (grouped errors by country).

[2]These regressions use weighted least squares (to weight for the precision of the first stage estimates).

[3]These regressions correct standard errors for random effects (grouped errors by country) and use weighted least squares (to weight for the precision of the first stage estimates).

Standard errors are in parantheses.

* Significant at 10% level

** Significant at 5% level

*** Significant at 1% level

Table 4 -- Fertility Differential Regressed on Returns to Education

Dependent variable: Weighted OLS coefficient of TFR on years of education

	Weights[1]		
Independent Variable	(i)	(ii)	(iii)
Mincer coefficient	0.288***	0.171	0.228**
	(0.104)	(0.113)	(0.096)
Year	0.0004	0.001	0.001
	(0.001)	(0.001)	(0.001)
ln(GDP)		-0.015**	0.390***
		(0.007)	(0.116)
ln(GDP)^2			-0.024***
			(0.007)
Constant	-0.799	-1.435	-3.143**
	(1.750)	(1.680)	(1.487)
N	88	88	88

Notes:

Mincer Coefficients are coefficients from semi-log OLS regression of ln(earnings) on years of schooling on potential years of labor market experience and its square as independent variables.

[1]These regressions use weighted least squares (to weight for the precision of the first stage estimates).

Standard errors are in parantheses.

* Significant at 10% level

** Significant at 5% level

*** Significant at 1% level

Table 5 -- Fertility Differentials Regressed on Gini Coefficient, 1974-1995

Dependent variable: Weighted OLS coefficient of TFR on years of education									
	Cluster[1]			Weights[2]			Both[3]		
Independent Variable	Low (i)	Middle (ii)	High (iii)	Low (iv)	Middle (v)	High (vi)	Low (vii)	Middle (viii)	High (ix)
Gini coefficient	-0.033	0.177***	0.238	0.008	0.193***	0.097	0.008	0.193**	0.097*
	(0.030)	(0.038)	(0.157)	(0.031)	(0.041)	(0.062)	(0.044)	(0.078)	(0.051)
Year	0.0003	-0.001	-0.002	0.001	-0.001	0.0003	0.001	-0.001	0.0003
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.002)
Constant	-0.600	1.446	3.988	-1.116	1.560	-0.528	-1.116	1.560	-0.528
	(1.236)	(1.452)	(3.559)	(1.311)	(1.677)	(5.334)	(1.533)	(2.680)	(3.384)
N	31	46	11	31	46	11	31	46	11

Notes:

Low-Income countries: with GDP measure < 1640 US$.

Middle-Income countries: with GDP measure between 1640 and 7169 US$.

High-Income countries: with GDP measure > 7169 US$.

[1]These regressions correct standard errors for random effects (grouped errors by country).

[2]These regressions use weighted least squares (to weight for the precision of the first stage estimates).

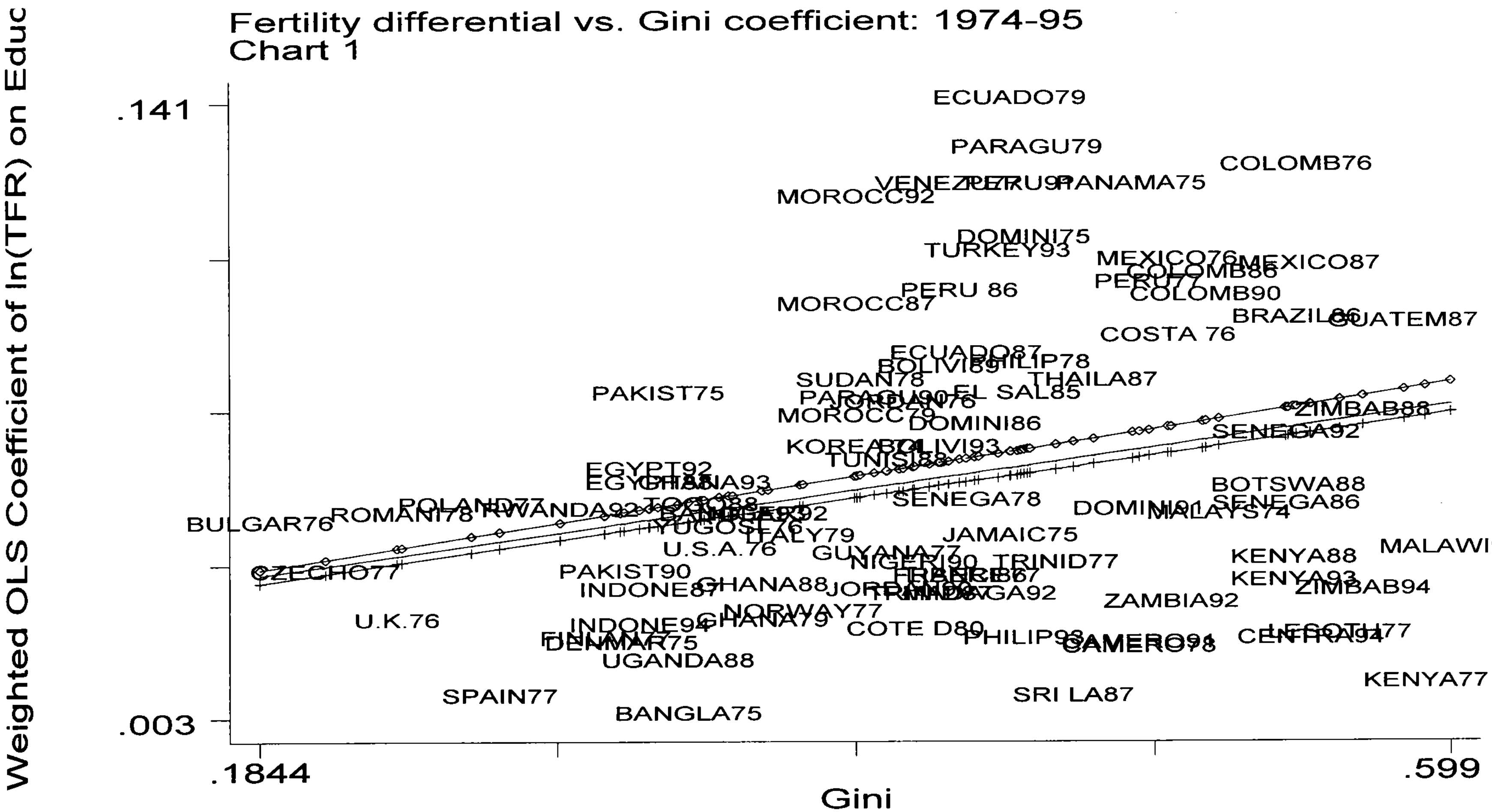
[3]These regressions correct standard errors for random effects (grouped errors by country) and use weighted least squares (to weight for the precision of the first stage estimates).

GDP is real GDP per capita in constant dollars (Chain index) expressed in international prices, base 1985. Standard errors are in parantheses.

* Significant at 10% level

** Significant at 5% level

*** Significant at 1% level

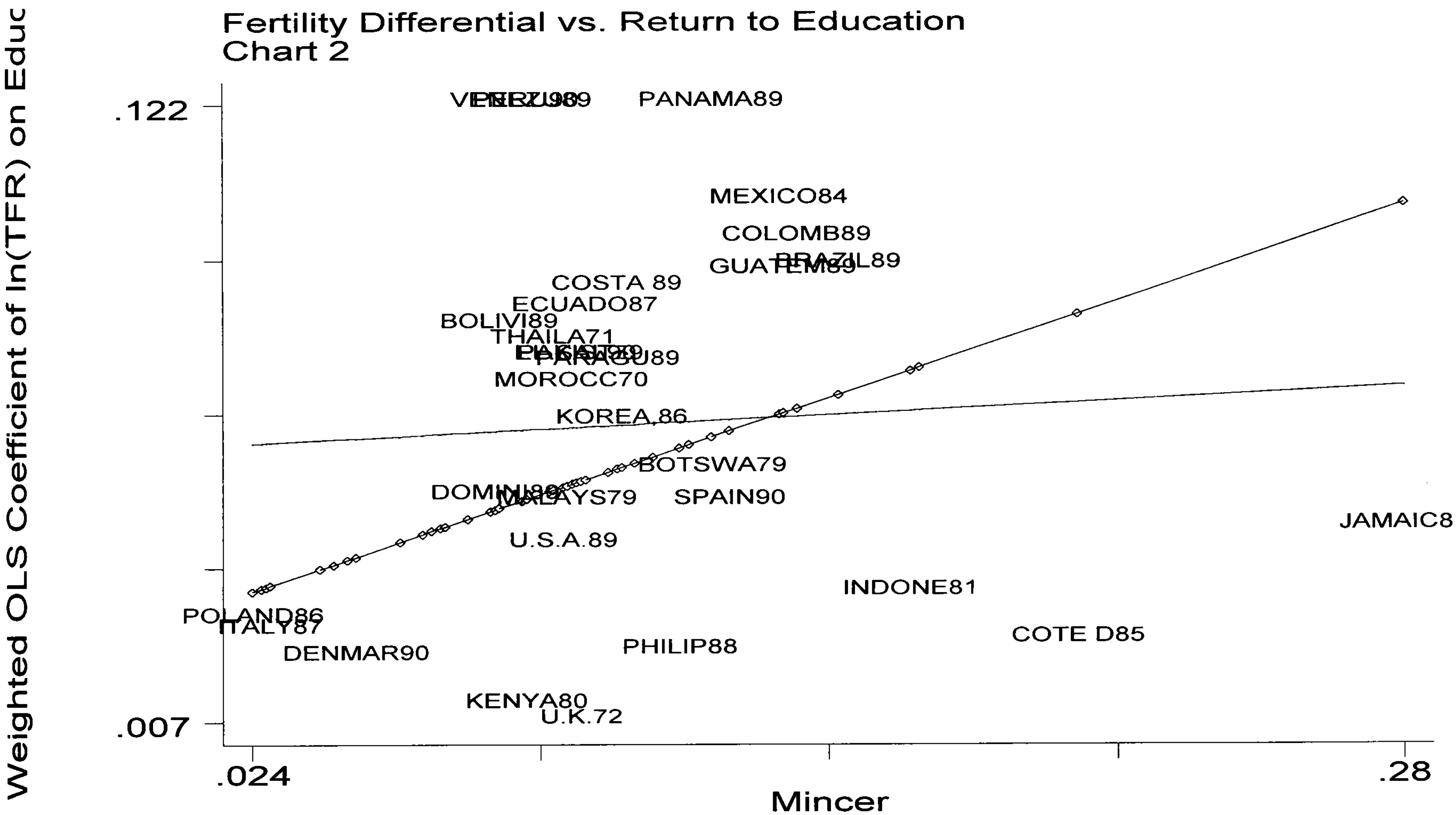


– line – line of best fit

\+ line – predicted values from country random effects regression

◊ line – predicted values from variance-weighted least squares regression

Fertility Differential vs. Return to Education
Chart 2



– line – line of best fit

◇ line – predicted values from variance-weighted least squares regression