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Income Inequality, Fertility Choice, and Economic Growth: Theory and Evidence

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Abstract

The growing literature on inequality and economic growth has focused on the adverse effects of income inequality on investment. We focus on the negative relationship between inequality and economic growth, hypothesising that inequality lowers economic growth by raising the fertility rate. Unlike other studies, our analysis does not rely on incomplete markets, or on parental altruism. Instead, it uses the fact that a larger number of children reduces the riskiness of the financial payoff from having children, a factor which is more important for the poor than for the wealthy. Cross country econometric tests using a newly collated dataset of income distribution support the proposition that much of the growth enhancing effects of an equitable income distribution may come from its negative effect on fertility rates.

Keywords*:* fertility, income inequality, growth
JEL Codes*:* J13, O15, O40

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Income Inequality, Fertility Choice, and Economic Growth: Theory and Evidence

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1. Introduction

It is a surprising empirical result that, holding average level of income constant, countries with higher income inequality have slower per capita GDP growth.[1] Part of the reason that it is surprising is that it contradicts the debates in the 1960's and early 1970's where a more equal income distribution had, at best, a neutral impact on economic development. A typical example is the '*Cambridge*' savings function, where only the capitalists (rich) save while the workers (poor) spend all their income. It was perhaps Ranis (1977) who first argued that a more equal distribution could lead to faster growth.

This paper develops a model of fertility choice (presented in *Section 2*) that results in a positive link between income inequality and fertility, a link through which income inequality has a negative effect on growth. Our analysis predicts that the optimal number of children falls as the income of the parents rises. This reduction in fertility from an increase in income becomes smaller as income becomes larger; therefore, a country with a more equal income distribution will have lower population growth, *ceteris paribus*. Thus, greater equality of income leads to higher per capita GDP growth.

As in some previous models, we model fertility choice within a utility maximizing framework. However, our model is restricted to considering the optimum fertility choice for non-altruistic parents. Our innovation is to consider the riskiness of the payoff from children, and in this way to relate fertility choice to income distribution. Little work has been done in the area of income distribution and fertility choice. Our use of risk aversion in a formal model of fertility choice appears unique.

Our empirical results strongly support the proposition that unequal income distribution raises the fertility rate, and that higher fertility reduces the GDP growth rate. Furthermore, our regression results suggest that income distribution does not strongly affect the investment share of GDP. Therefore, fertility appears to be the main channel through which income distribution affects economic

[1] Recent empirical studies, Alesina and Rodrik (1994), Benhabib and Speigel (1996), Deninger and Squire (1995), Galor and Zang (1997), Perotti (1994, 1996), and Persson and Tabellini (1996), have all found a negative relationship between inequality and growth.

growth. The growth enhancing effects of an equitable income distribution come mainly from a lowering of fertility rates.

The Literature on Income Inequality

Past papers trying to explain the negative relationship between inequality and growth have concentrated on the adverse effect of inequality on investment. A negative link between inequality and investment has been derived from three main types of models.[2] The first *type* is political economy models (e.g., Alessina and Rodrik (1994), Bertola (1993), Perrotti (1993), and Persson and Tabellini (1994)), that concentrate on how greater inequality leads to greater (or a higher probability of) redistribution of wealth, and so discourages investment. The second type posits that imperfect capital markets combined with inequality (e.g., Aghion and Bolton (1996), Benabou (1996a), Galor and Zeira (1993), Loury (1981), and Piketty (1996)) can lead to a non-optimal rate of investment. In the *third* type, socio-political insecurity or conflict increase the risk of investment and so lowers capital accumulation (e.g., Benhabib and Rustichini (1996), Grossman and Kim (1996), and Tornell and Velasco (1992).

However, Solow type growth models suggest that income inequality can affect output growth through another channel, namely by increasing fertility and population growth. Higher population growth can decrease output growth rates through classic '*capital dilution*', and through labor supply '*dependency*' effects (either by increasing the dependency ratio directly or by reducing the proportion of women in the labour force). Empirical work on economic growth (e.g., Barro (1991,1996), Brander and Dowrick (1994), Galor and Zang (1997), Mankiw, Romer and Weil (1993) and Perotti (1996)) has in general found a negative relationship between fertility and per capita output growth.[3]

If income inequality increases fertility or population growth rates, as argued by Kocher (1973) and Repetto (1979), then income inequality would adversely affect economic growth through its effect on fertility.[4] Benabou (1996b) and Perrotti (1996) have noted that there is strong empirical evidence to support this link. However, there appears to be a paucity of models explaining the link between

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[2] A comprehensive review of this literature can be found in Benabou (1996).
[3] Growth regressions before 1985 did not find a significant relationship between fertility and economic growth, but this may have been caused by problems that existed in the data.

income distribution, fertility and growth (also noted by Benabou (1996b)). One related paper is Galor and Zang (1997). This paper focuses on human capital accumulation by employing capital market constraints to develop a model where high inequality lowers the economy's rate of human capital accumulation. High fertility also lowers the rate of human capital accumulation in a way similar to classic capital dilution.[5]

There is also a strand in the endogenous growth literature that looks at endogenous fertility choice. Recent papers include Barro and Becker (1989), Becker, et al. (1990), and Wang, et al. (1994). However, those papers are relatively unrelated to the literature on income distribution and growth because they use a representative agent and abstract from income distribution effects.

Our cross-country regressions of income inequality, investment, education and growth use recently collated inequality data from Deninger and Squire (1996). This data set is superior to inequality data used in previous empirical exercises, in both quantity and quality of individual data points. Previous empirical work has used datasets provided by Paukert (1973), Jain (1975) or Fields (1989), but the dataset provided by Deninger and Squire (1996) increases the amount of high quality data available by almost fourfold.

2. Modelling the Choice of Number of Children

Individuals live for three periods in this model: childhood, adulthood, and retirement. As with many other models in this genre, we ignore any complications arising due to the process and costs of marriage or the spacing of children. During childhood (Period 1), individuals are passive recipients of care from their parents. During adulthood (Period 2), they provide for two cohorts. They take care of their retired parents in order to fulfill an implicit contract for the care they received as children. However, in order to arrange for the same provisions in their own old age, they create an implicit contract with their own children by taking care of them as well. In retirement (Period 3), they receive care from their adult children.

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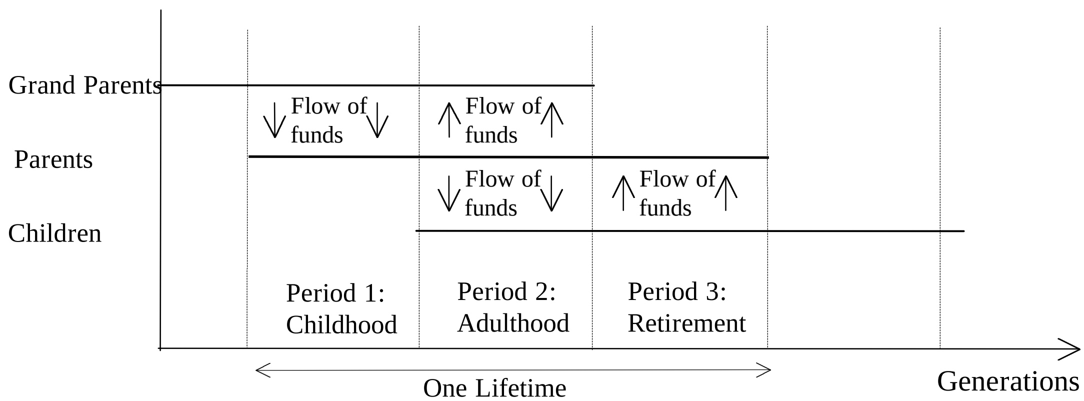
[4] Note the important channel of influence of the quantity of children affecting the quality of children first suggested by Becker and Lewis (1976).

[5] Ventura (1997) points out the strong implicit assumptions necessary to generate Galor and Zang's results, and that some statistical facts remain unexplained by their model.

All of the important decisions and production by the individual take place in Period 2. In Period 2, individuals work, receive income, and decide on how many children to have (we assume this takes place at the beginning of this period). Unlike other authors, we assume that this is a decision that does not involve altruism. The incentive for raising children is that, by implicit contract, the children will care for the parents once the parents retire. The fact that the adults simultaneously fulfil their implicit contract to take care of their own parents can perhaps be viewed as a moral example for their children (as suggested by Stark (1995)). Figure 1 illustrates the ties between generations.

Figure 1: Overlapping Generations and Familial Obligations



In modelling the fertility choice, we make several assumptions about utility and the cost of raising children.

Utility: First, we assume that the utility of the parents is subject to constant relative risk aversion (CRRA).

$$CRRA: U'(C) > 0, \frac{U''(C)}{U'(C)} = \frac{-l}{C}$$

Where U ( ) is the utility function, C is consumption, and λ is the coefficient of risk aversion. The results of the model will hold as long as the parents are risk averse, and risk aversion falls as income rises.

Costs of Raising Children: We follow the simplifying assumption of Becker and Barro (1988) and others to specify the cost of an additional child as a fixed proportion of the parent's income. This would apply especially well to the time cost of raising children, but arguments can be made for direct outlays as well. The cost of an additional child is ($k\ I$), where k is the proportional cost of an additional child and I is the parent's income.[6] The per-child costs of raising children are clearly higher for the wealthy than for the poor.

Liquidity Constraints: Parents are not allowed to borrow in order to have more children. This assumption provides us with a budget constraint on the number of possible children:

$$N_{MAX} = \frac{I}{kI} = \frac{1}{k}$$

Where N is the number of children.

The Payoff from Having Children: Children are valued according to their 'payoff" in pecuniary terms, not due to their effect on utility as in other models. However, the quality of children varies. Higher quality children offer a higher payoff to parents in retirement than lower quality children. Let γ denote a random variable representing the average 'quality' of a child. Without loss of generality, we assume that the expected value of γ is equal to 1:

$$E(g) = 1$$

If the "quality" realizations for children are independent, the variance of γ will depend inversely on the number of children.

$$Var(g) = \frac{s^2}{N}$$

We assume that each child has an average payoff of w, and that there is an additional payoff, v, associated with the first child. Thus, the expect return from having children is equal to:

$$E(Nw + v)g = (Nw + v), \quad for \quad N \geq 1$$

[6] Variable definitions are given at the beginning of Appendix I.

Expected returns from children can thus be represented as a simple linear function with a positive intercept.

1. The Choice of the Optimal Number of Children

When parents retire, their consumption in Period 3, C_3, is equal to:

$$C(N) = (Nw + v)g + (1 - Nk)Ir \qquad (1.1)$$

The maximization problem for parents in the second period is to choose the number of children so as to maximize consumption in Period 3:

$$\underset{\{N\}}{MAX}\ E\{U[(Nw + v)g + (1 - Nk)I]\} \qquad (1.2)$$

The trade-off involved can be thought of as follows. An additional child brings an additional return plus a reduction in the variance of third period income. However, an additional child also reduces the amount of bank savings available in the third period.

Taking the derivative of equation (1.2) with respect to N, we obtain:

$$\frac{dE(U)}{dN} = E\{U'[wg + (Nw + v)\frac{\partial g}{\partial N} - kIr]\}$$

$$= wE(U'g) + (Nw + v)E(U'\frac{\partial g}{\partial N}) - (kIr)E(U') \qquad (1.3)$$

In Appendix 1, we show that by our assumption of CRRA, this derivative is approximately equal to:

$$\frac{dE(U)}{dN} = -U''(E(C))(Nw + v)v\frac{s^2}{N^2} + E(U')(w - kIr) \qquad (1.4)$$

The first term represents the benefit of an additional child, which depends on both the variance of the average quality of the child and on the additional return from having another child. Note that having additional children reduces the variance of future income, but at some stage this gain is more than offset by the marginal cost of an additional child, which is given by the second term, *E(U')[w – kIr]*.

We can show the concavity of this function by taking the second derivative with respect to N:

$$\frac{d^2E(U)}{dN^2} = U'(E(C))vs^2\frac{(Nw+2v)}{N^3} < 0 \qquad (1.5)$$

Expected utility is maximized when $\frac{dE(U)}{dN} = 0$. In Appendix 2, we show that this is equivalent to:

$$\frac{l}{E(C)}[(Nw+v)vs^2] - (kIr - w)N^2 = 0 \qquad (1.6)$$

Equation (1.6) describes an implicit cubic function for the optimum value of N. This can be obtained by replacing for E(C) and collecting terms, where $E(C) = (Nw + v) + (1\text{-}Nk)Ir$. We then obtain the following equation, which implicitly defines the optimal number of children:

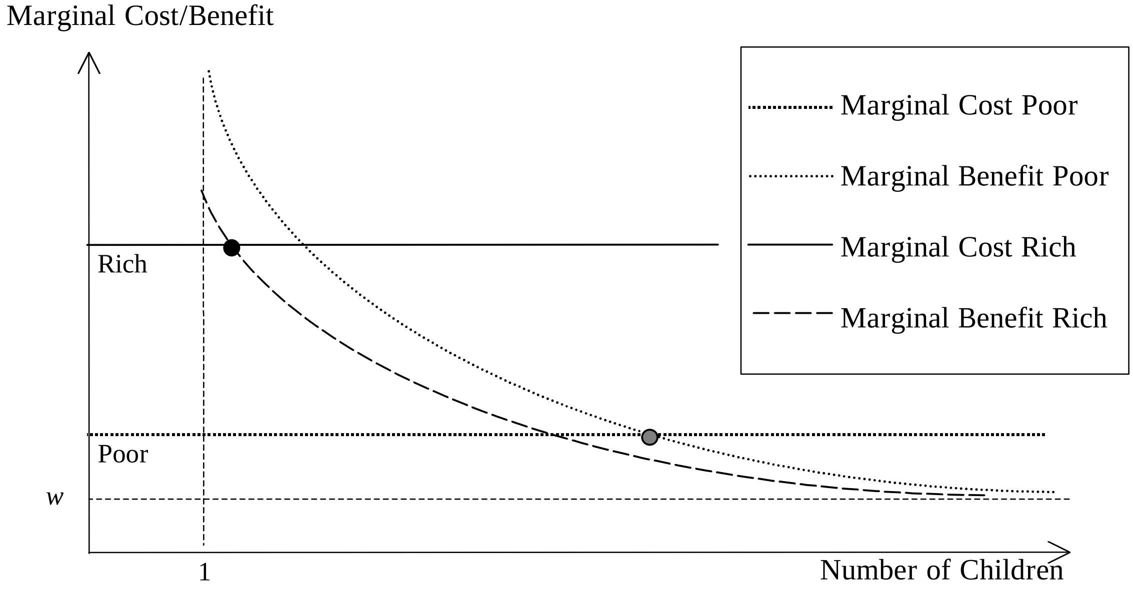
$$lv^2s^2 + lvs^2wN + (Ir - v)(kIr - w)N^2 + (kIr - w)^2N^3 = 0 \qquad (1.7)$$

2. The Effect of Increasing Wealth on the Optimal Number of Children

Both the wealthy and the poor are trying to maximize their expected utility from consumption (from savings and from children) when they retire. However, the wealthier the parents are initially, the higher the costs of having children will be and the less they will have to rely on children as a portion of their income. As a result, the rich have less incentive to hedge by having more children. Naturally, there is still a trade-off between greater certainty of income in the future and the expected amount of overall income.

Having more children will always decrease the uncertainty of future income. On the other hand, having more children will decrease the total amount of expected future income. In this section, we show that if the coefficient of risk aversion is not too large – that is, parents are not too biased towards certainty of income (compared with the expected level of income) – the optimal number of children will always become smaller as the wealth of the parents increases.

Figure 2: Marginal Benefit and Marginal Cost of Children for Various Levels of Income



Suppose we think of equation (1.6) as an implicit function, *F*, that defines the optimal number of children:

$$F = \frac{l}{E(C)}[(Nw+v)vs^{2}] - (kIr - w)N^{2} = 0 \qquad (2.1)$$

Differentiating *F* by the number of children, *N*, and the level of income possible without children, *I*, we can use the implicit function theorem to calculate the change in the optimal number of children for a change in potential income.

$$\frac{dN}{dI} = \frac{-l(1-Nk)(Nw+v)vs^{2}/[E(C)]^{2} - krN^{2}}{2(kIr-w)N - l(wvs^{2})/E(C) - l(Nw+v)vs^{2}(kIr-w)/[E(C)]^{2}} \qquad (2.2)$$

In Appendix 3, we show that a sufficient condition for the expression in equation (2.2) to be negative, is:

$$l < \frac{E(C)}{vs^{2}} \qquad (2.3)$$

In other words, the optimal number of children falls as wage income rises, if the coefficient of risk aversion is not too large.

3. The Effect of Income Inequality on the Optimal Number of Children

In this section, we show that the implicit function for the optimal number of children is convex. That is, for small increases in income for the very poor, the optimal number of children per family drops substantially. However, for small increases in the income of the very wealthy, the optimal number of children per family does not decrease substantially. Thus, a transfer of assets from the wealthy to the very poor will decrease the overall number of children, i.e., a transfer from rich to poor will cause a fertility decline in poor families that is larger than the fertility increase in rich families.

The second derivative of $\frac{dN}{dI}$, is given by:

$$\frac{d^2N}{dI^2} = \frac{\begin{array}{c} -2krN^2E(C)(1-Nk)\{2(kIr-w)N[E(C)]^2 - l(wvs^2)E(C) - l(Nw+v)vs^2(kIr-w)\} \\ -\{2krN[E(C)]^2 + 4N(kIr-w)E(C)(1-Nk) - l(wvs^2)(1-Nk) - l(Nw+v)vs^2kr\} \\ \{-l(1-Nk)(Nw+v)vs^2 - krN^2[E(C)]^2\} \end{array}}{\{2(kIr-w)N[E(C) - l[wvs^2]E(C) - l(Nw+v)vs^2(kIr-w)\}^2} \quad (3.1)$$

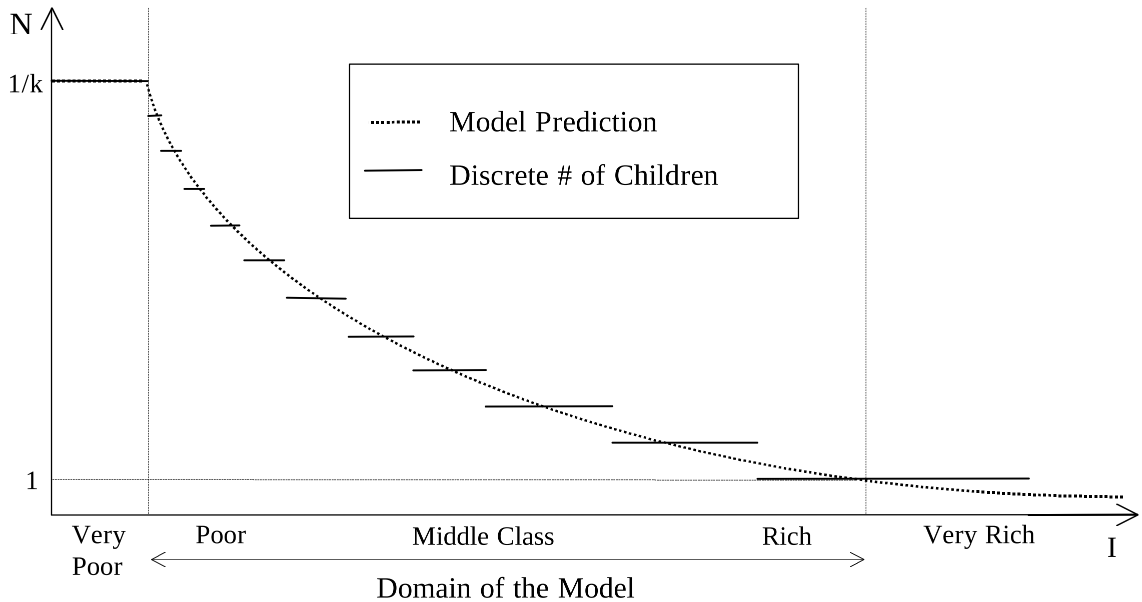
In Appendix 4, we show that this second derivative is positive as long as:

$$\frac{l s^2}{N} < \frac{[E(C)]^2}{(Nw+v)v} \quad (3.2)$$

This condition is satisfied if, $\frac{dN}{dI} < 0$. In other words, as long as the optimal number of children falls as income rises, the implicit function for the optimal number of children is convex. Increasing the variance of the distribution of a convex function (while holding its shape constant) increases the average value of the function. Therefore, an increase in the inequality of income distribution will increase the average fertility rate, and vice versa.

The optimal number of children for different levels of income is graphed in Figure 3.[7] From the graph, it is apparent that a transfer of income from the rich to the poor will always decrease the average fertility of the society. That is, if the average level of income is held constant, a more equal income distribution will lower the fertility rate for society. Lower fertility reduces capital dilution and dependency effects, and in this way increases the rate of economic growth.

Figure 2: Optimum Number of Children for Different Levels of Income



3. Empirical Evidence

Like Perrotti (1996), our empirical analysis shows strong evidence for a negative link between inequality and economic growth, working through fertility choice. We find little evidence to support the preposition that inequality reduces growth through a reduction in investment. Previous studies that have been used to support the investment channel have mostly ignored fertility in their regression models.

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[7] Note that there are restrictions on the number of children of the very poor and the very rich. The very poor always have 1/k number of children. The very rich have zero children.

Our empirical analysis uses inequality data recently collated by Deninger and Squire (1996) of the World Bank. Other variables are from the Penn World Tables version 5.6, the World Bank's World Tables and from the UNESCO Statistical Yearbooks. As in Barro (1991), Benhabib and Spiegel (1994), Galor and Zang (1997) and Partridge (1997), we use the White (1980) correction for heteroskedasticity when calculating the standard errors.

Table 2a shows the results of various cross country growth (1965 to 1985) regressions similar to regressions found in Alesina and Rodrik (1994), and in Persson and Tabellini (1996). Regression number (1) shows the standard human capital augmented Solow-type growth regression (used for example in Mankiw, Romer and Weil (1992), with growth regressed on the initial level of income, primary school enrollment ratio, the investment share of GDP and fertility rates. All coefficients are significant and have the expected sign.

Regressions number (2) and number (3) show that inequality measures are very significantly negative in a basic growth regression that includes the initial level of GDP and primary education, but excludes investment and fertility. These regressions are similar to regressions in Alesina and Rodrik (1994), and in Persson and Tabellini (1996). The significant negative sign of the inequality measure in these regressions were used to claim support for a causal link between inequality, investment and growth.

However, if inequality affects growth through investment, inequality measures should loose significance once the investment share of income is introduced into the basic regression. Regression number (4) and number (5) show that this is not the case. The inequality measures remain significant and the sizes of their estimated coefficients remain largely unchanged.

Instead, the inequality measures lose their significance once the fertility rate is introduced into the regression, in regressions (6) and (7). The estimated coefficient on the inequality measures changes significantly when fertility is introduced into the basic regression. This is strong evidence that much of the negative effect of inequality on growth works through increasing fertility.

Reverse causality can be a problem in this analysis. If high fertility leads to high inequality, inequality can be associated with low rates of economic growth without there being any causal link between the two. One way to overcome this ambiguity is to use instrumental variables, with the list of instruments chosen to minimize the effect of any reverse causality between inequality and fertility.

Table 2b presents the results of using instrumental variables on the regressions shown in Table 2a. The instruments used are listed at the bottom of Table 2b. The coefficient estimates in Table 2b are similar to the estimates in Table 2a. As before, inequality measures are significant in the basic regression, and remain largely significant and unchanged with the introduction of investment. However, they become insignificant when fertility is introduced into the basic regression.

Table 3 shows the results of regressing fertility (using OLS and IV) on the primary determinants of fertility and on measures of inequality. (Instruments used are the same as those used in table 1b.) The regression results show that high inequality has a significant and positive impact on the fertility rate. This is true whether we consider the OLS estimates or the IV estimates. Table 3 also shows the results of running the same regressions with the investment share of GDP as the dependent variable. The regression results shows that the effect of inequality on investment in ambiguous, and not statistically significant.

Taken together, these results provide strong evidence that higher fertility is an important, if not the main channel by which inequality adversely affects growth. And, it also appears to be the case that investment is a more ambiguous and uncertain channel of transmission than previous studies have indicated.

Table 2a: Growth Regressions (OLS) with Measures of Inequality

Regression No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	2.849 (4.347)	1.459 (3.430)	-0.281 (-0.563)	1.055 (2.406)	-0.629 (-1.231)	3.678 (6.552)	4.171 (6.234)
GDP60	-0.386 (-5.545)	-0.233 (-4.174)	-0.207 (-3.397)	-0.289 (-4.721)	-0.263 (-3.771)	-0.382 (-5.474)	-0.411 (-5.221)
PRIM	0.924 (3.198)	2.362 (5.349)	2.372 (4.747)	1.654 (4.219)	1.676 (3.822)	1.338 (4.167)	1.126 (3.258)
I/Y	3.794 (1.947)			5.388 (2.811)	5.381 (2.441)		
FERTNET	-0.389 (-4.255)					-0.445 (-4.746)	-0.537 (-5.450)
GINIAV		-0.0264 (-2.891)		-0.0240 (-2.868)		-0.00572 (-0.709)	
QUINT2AV			3.847 (1.878)		4.028 (2.083)		-0.358 (-0.224)
R^2	0.460	0.255	0.253	0.388	0.353	0.413	0.435
S.E.E.	0.744	0.854	0.908	0.792	0.851	0.776	0.795
No. of Obs.	91	91	79	91	79	91	79

T-statistics based on White's heteroskedasticity-consistent covariance matrix appear in parentheses ( ).

Table 2b: Growth Regressions (IV) with Measures of Inequality

Regression No.	(2)	(3)	(4)	(5)	(6)	(7)
Constant	2.327 (2.767)	-0.742 (-1.276)	1.307 (1.561)	-0.689 (-1.340)	3.756 (6.864)	4.339 (3.410)
GDP60	-0.287 (-3.980)	-0.231 (-3.583)	-0.304 (-4.530)	-0.267 (-3.949)	-0.386 (-5.583)	-0.411 (-5.262)
PRIM	2.502 (5.438)	2.435 (4.879)	1.701 (4.125)	1.683 (3.871)	1.430 (3.118)	1.091 (2.859)
I/Y			5.335 (2.727)	5.387 (2.463)		
FERTNET					-0.419 (-2.780)	-0.548 (-4.109)
GINIAV	-0.0476 (-2.620)		-0.0300 (-1.763)		-0.0119 (-0.507)	
QUINT2AV		6.715 (2.062)		4.399 (1.418)		-0.951 (-0.279)
R^2	0.247	0.240	0.385	0.352	0.411	0.435
S.E.E.	0.874	0.916	0.794	0.851	0.777	0.795
No. of Obs.	91	79	91	79	91	79

T-statistics based on White's heteroskedasticity-consistent covariance matrix appear in parentheses ( ).
Instruments used: Index of Civil Liberties, Latin America Dummy, Number of Riots per Year, Socialist Economy Dummy and Number of Strikes per Year.

Table 3: Fertility Regressed on Measures of Inequality						
Dep. Var. **Reg. No.**	**FERTNET** **(8) OLS**	**FERTNET** **(9) OLS**	**FERTNET** **(8) IV**	**FERTNET** **(9) IV**	**I/Y** **(10)**	**I/Y** **(11)**
Constant	5.034 (10.286)	8.370 (12.251)	3.618 (4.153)	9.266 (12.066)	0.0717 (2.017)	0.0587 (1.468)
GDP60	-0.729 (-3.306)	-0.959 (-4.418)	-0.607 (-2.532)	-0.946 (-4.036)	0.0389 (2.761)	0.0500 (3.478)
$(GDP60)^2$	0.059 (2.026)	0.0883 (2.851)	0.0536 (1.755)	0.0935 (2.754)	-0.00427 (-2.138)	-0.00603 (-3.011)
PRIM	-1.910 (-3.605)	-1.799 (-3.376)	-2.172 (-3.747)	-1.889 (-3.229)	0.103 (3.140)	0.0940 (2.623)
GINIAV	0.0455 (3.915)		0.0803 (4.261)		-0.000383 (-0.567)	
QUINT2AV		-8.116 (-3.074)		-13.684 (-3.519)		-0.0136 (-0.101)
R^2	0.712	0.719	0.673	0.695	0.4042	0.403
S.E.E.	0.816	0.810	0.870	0.844	0.0606	0.0602
No. of Obs.	91	79	91	79	91	79

T-statistics based on White's heteroskedasticity-consistent covariance matrix appear in parentheses ( ).
Instruments used: Index of Civil Liberties, Latin America Dummy, Number of Riots per Year, Socialist Economy Dummy and Number of Strikes per Year.

The following variable definitions are used in the regression tables:

GR6085 is the growth of real GDP between 1960 and 1985. GDP60 is real GDP in 1960. PRIM is the primary school enrollment ratio averaged between 1960 and 1985. I/Y is the average investment share of GDP averaged between 1960 and 1985, FERTNET is the fertility rate net of infant mortality averaged between 1960 and 1985. GINIAV is the average of the GINI coefficients available. QUINT2AV is the share of income received by the bottom 40% of the economy, average of the data available.

4. Conclusion

This paper argues that the primary channel through which inequality affects growth is through the effect of income distribution on fertility. The link between fertility and growth has already been well established. Solow-type growth models have long been shown to imply that an increase in fertility lowers the rate of output growth. This can happen either through classic capital dilution or by an increase in the dependency ratio. If income inequality increases fertility, high inequality will lower the rate of economic growth. Our model robustly generates the result that higher inequality leads to higher fertility and we present evidence that higher fertility is likely to be the main channel by which inequality adversely affects growth.

Unlike other popular approaches to fertility choice, we rely on a non-altruistic reason for poor parents' tendency to have more children: parents receive support from their children when they retire. This payoff is risky, either because some children die or because some children renege on their promise of support. So increasing the number of children therefore reduces the riskiness of this payoff. Because the payoff from children is more important for poor parents, the poor tend to have more children then the wealthy. While it is clear that increasing the income of parents will reduce their fertility in this model, there is an important asymmetry in that lowering income inequality will reduce the fertility of the poor more than it would increases the fertility of the rich. This asymmetry relies on parental risk aversion and the effect that increasing the number of children has on the variance of the return from children.

Once the effect of fertility is taken into consideration, there is little empirical evidence to support the theory that inequality reduces economic growth through an adverse effect on investment. Using recently collated inequality data, our econometric analysis shows that much of the observed negative relationship between inequality and economic growth can be explained by the effect of inequality on fertility. Empirically, inequality appears to have a large positive effect on fertility, and fertility in turn has a large negative impact on economic growth. This stands in contrast to the weak empirical evidence for a link between inequality and investment once fertility is introduced. Previous studies concentrating solely on the investment channel have in general ignored fertility in their empirical work.

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Appendix 1

Variable Definitions

I	–	Income of parents in Period 2
U	–	Utility
C	–	Retirement (Period 3) consumption
r	–	Bank (or world) interest rates
N	–	Number of children
w	–	Marginal return of additional 'average' child
v	–	Additional payoff from first child
g	–	Random variable representing the actual average 'quality' of children

$$E(g) = 1 \quad , \quad \mathrm{var}(g) = \frac{s^2}{N}$$

$k\,I$	–	Cost of having an additional child
l	–	Coefficient of risk aversion

(By construction, all of the above variables are larger than zero)

Differentiation of expected utility with respect to the optimal number of children, N, yields:

$$\frac{dE(U)}{dN} = wE(U'g) + (Nw+v)E(U'\frac{\partial g}{\partial N}) - (kIr)E(U') \tag{1.3}$$

We make use of the approximation that $\mathrm{cov}(a,b) \approx \frac{\partial a}{\partial x}\frac{\partial b}{\partial x}\mathrm{var}(x)$.

This allows us to solve for the first and second components of (1.3) as follows:

$$E(U'g) = E(U')E(g) + \mathrm{cov}(U',g) \approx E(U')E(g) + U''(E(C))I\left(\frac{\partial C}{\partial g}\right)\mathrm{var}(g)$$

$$E\left(U'\frac{\partial g}{\partial N}\right) = E(U')E\left(\frac{\partial g}{\partial N}\right) + \mathrm{cov}\left(U',\frac{\partial g}{\partial N}\right)$$

$$\approx E(U')E\left(\frac{\partial g}{\partial N}\right) + U''(E(C))\left(\frac{\partial C}{\partial g}\right)\frac{\partial(\partial g/\partial N)}{\partial g}\mathrm{var}(g)$$

We can then impose the following assumptions, E(γ)=1 and E(∂γ / ∂N) = 0, to get:

$$\frac{dE(U)}{dN} = (Nw+v)U''(E(C))\left(\frac{\partial C}{\partial g}\right)\frac{\partial(\partial g/\partial N)}{\partial g}\mathrm{var}(g) + wE(U')$$

Thus,

$$\frac{dE(U)}{dN} = U''(E(C))(\frac{\partial C}{\partial g})\,\text{var}(g)[(Nw+v)\frac{\partial(\partial g/\partial N)}{\partial g} + w] + E(U')[w - kIr]$$
$$+\, wU''(E(C))\left(\frac{\partial C}{\partial g}\right)\text{var}(g) - (kIr)E(U')$$

However, the variance of the average quality of a child is defined as var(γ) = σ^2 / N. Furthermore, it is also true that ∂C / ∂γ = Nw + v. We can take the probability limit of the derivative of child quality with respect to the number of children to find:

$$\frac{\partial g}{\partial N} = \frac{(p-g)}{N} \Rightarrow \partial\frac{(\partial g/\partial N)}{\partial g} = \frac{-1}{N}$$

Substituting:

$$\frac{dE(C)}{dN} = U''(E(C))(Nw+v)\frac{s^2}{N}[(Nw+v)\left(\frac{-1}{N}\right) + w] + E(U')(w - kIr)$$

$$\Rightarrow \frac{dE(U)}{dN} = -U''(E(C))(Nw+v)v\frac{s^2}{N^2} + E(U')(w - kIr) \qquad (1.4)$$

Appendix 2

Taking the second derivative of expected utility with respect to the number of children, N, yields:

$$\frac{d^2E(U)}{dN^2} = U'(E(C))vs^2\frac{(Nw+2v)}{N^3} < 0 \qquad (1.5)$$

Therefore, expected utility is maximized by setting $\frac{dE(U)}{dN} = 0 \quad \Rightarrow$

$$-U''(E(C))(Nw+v)v\frac{s^2}{N^2} + E(U')(w - kIr) = 0$$

Using the definition of CRRA, $\frac{U''(E(C))}{E(U'')} \approx \frac{-l}{E(C)}$

$$\Leftrightarrow \quad \frac{U''(E(C))}{E(U'')}(Nw+v)vs^2 + (kIr - w)N^2 = 0$$

So expected utility is maximized and N is optimal when:

$$\frac{l}{E(C)}[(Nw+v)vs^{2}]-(kIr-w)N^{2}=0 \qquad (1.6)$$

Appendix 3

We need to show the conditions under which the following derivative is negative:

$$\frac{dN}{dI}=\frac{-l(1-Nk)(Nw+v)vs^{2}/[E(C)]^{2}-krN^{2}}{2(kIr-w)N-l(wvs^{2})/E(C)-l(Nw+v)vs^{2}(kIr-w)/[E(C)]^{2}} \qquad (2.2)$$

Some algebraic manipulation will demonstrate that the optimal number of children falls as income rises *if and only if* the following condition is met:

$$2(kIr-w)N>\frac{l(wvs^{2})}{E(C)}+\frac{l(Nw+v)vs^{2}(kIr-w)}{[E(C)]^{2}} \qquad (A3.1)$$

But we know from equation (1.6) that:

$$\frac{l}{E(C)}[(Nw+v)vs^{2}]-(kIr-w)N^{2}=0 \Leftrightarrow (kIr-w)N=\frac{l(wvs^{2})}{E(C)}+\frac{l(v^{2}s^{2})}{E(C)N}$$

Clearly, this implies:

$$(kIr-w)N>\frac{l(wvs^{2})}{E(C)} \qquad (A3.2)$$

Also note that:

$$(kIr-w)N>\frac{l(Nw+v)vs^{2}(kIr-w)}{[E(C)]^{2}} \quad \text{iff} \quad N[E(C)^{2}]>l\,s^{2}(Nw+v)v \qquad (A3.3)$$

A sufficient condition for the above statement to hold is that:

$$l<\frac{E(C)}{vs^{2}}$$

Inspection of equations (A3.1), (A3.2) and (A3.3) above will show that the necessary conditions are met for $\frac{dN}{dI}<0$.

Appendix 4

Consider the second derivative of $\frac{dN}{dI}$,

$$\frac{d^2N}{dI^2} = \frac{\begin{array}{l} -\ 2krN^2E(C)(1-Nk)\{2(kIr-w)N[E(C)]^2 - l\,(wvs^{\,2})E(C) - l\,(Nw+v)vs^{\,2}(kIr-w)\} \\ -\ \{2krN[E(C)]^2 + 4N(kIr-w)E(C)(1-Nk) - l\,(wvs^{\,2})(1-Nk) - l\,(Nw+v)vs^{\,2}kr\} \\ \quad \{-l\,(1-Nk)(Nw+v)vs^{\,2} - krN^2[E(C)]^2\} \end{array}}{\{2(kIr-w)N[E(C)]^2 - l\,[wvs^{\,2}]E(C) - l\,(Nw+v)vs^{\,2}(kIr-w)\}^2} \tag{3.1}$$

$\frac{d^2N}{dI^2} > 0$ iff the numerator for the above function is larger than zero.

The numerator is equal to:

$$\begin{array}{l} -2krN^2E(C)(1-Nk)\{2(kIr-w)N[E(C)]^2 - l\,(wvs^{\,2})E(C) - l\,(Nw+v)vs^{\,2}(kIr-w)\} \\ +\{2krN[E(C)]^2 + 4N(kIr-w)E(C)(1-Nk) - l\,(wvs^{\,2})(1-Nk) - l\,(Nw+v)vs^{\,2}kr\}\{krN^2[E(C)]^2\} \\ +\{2krN[E(C)]^2 + 4N(kIr-w)E(C)(1-Nk) - l\,(wvs^{\,2})(1-Nk) - l\,(Nw+v)vs^{\,2}kr\} \\ \quad [\,l\,)(1-Nk)(Nw+v)vs^{\,2}] \end{array} \tag{3.2}$$

$$\begin{array}{l} =\ 2krN^2(1-Nk)\,l\,(Nw+v)vs^{\,2}(kIr-w)E(C) + l\,(wvs^{\,2})krN^2(1-Nk)[E(C)]^2 \\ +2N[E(C)]^2(kr)^2N^2[E(C)]^2 - l\,s^{\,2}(Nw+v)v(kr)^2N^2[E(C)]^2 \\ +\{2N[E(C)]^2kr - l\,s^{\,2}(Nw+v)vkr + 4(kIr-w)N\ E(C)(1-Nk) - l\,(wvs^{\,2})(1-Nk)\} \\ \quad [\,l\,(1-Nk)(Nw+v)vs^{\,2}] \end{array} \tag{3.3}$$

But, equation (2.6) implies that when N is optimal, $(kIr-w)N\ E(C) > l\,(wvs^{\,2})$.

And, when $\frac{dN}{dI} < 0$, from equation (2.7) we know it is true that $N[E(C)]^2 > l\,s^{\,2}(Nw+v)v$.

Therefore, by inspection, if $N[E(C)]^2 > l\,s^{\,2}(Nw+v)v$, the numerator expressed in (3.4) is larger than zero.

But, we know from Appendix 3 that if $\frac{dN}{dI} < 0$ then $N[E(C)^2] > l\,s^{\,2}(Nw+v)v$.

Therefore, if $\frac{dN}{dI} < 0$ then $\frac{d^2N}{dI^2} > 0$.

In other words, if the optimal number of children decreases as the income of the parents increases, the reduction in the number of children for a given increase in income, becomes smaller as the income of the parents becomes larger.