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THE ROLE OF FERTILITY AND POPULATION IN ECONOMIC GROWTH: EMPIRICAL RESULTS FROM AGGREGATE CROSS-NATIONAL DATA

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ABSTRACT

Two recently improved sets of cross-country panel data are combined in order to re-examine the effects of population growth and fertility on economic growth. Using a 107 country panel data set covering 1960-85, we find that high birth rates appear to reduce economic growth through investment effects and possibly through "capital dilution", although classic resource dilution is not evident in the data. Most significantly, however, birth rate declines have a strong medium-term positive impact on per capita income growth through labour supply or "dependency" effects.

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1. Introduction

The human species is currently going through a period of remarkable expansion. World population is thought to have been approximately 300 million in the year 1 A.D., after which it required about 1700 years to double to 600 million. (See Collins (1982).) By contrast, world population doubled from 2.5 billion to 5 billion in the 37 year period 1950-87, and, at current growth rates, would double again to 10 billion by about 2030. While the growth rate of population has actually fallen slightly since its peak in about 1970, the absolute increase in world population continues to grow every year and in 1992 was roughly 92 billion.

There is little doubt that the tremendous increase in population that has taken place since the beginning of the industrial revolution is due in large part to several mechanisms arising from technological progress, including improved food availability and, particularly in the 20th century, improved health care. It is possible, however, that in realizing the benefits of technological progress, there might be a tradeoff between the quantity of human life and its quality. This "neo-Malthusian" tradeoff might become particularly acute if, as claimed by some observers, human population has reached a level at which it is beginning to impinge significantly on the world's ecological capacity to sustain high living standards. (See, for example, the September 1989 special issue of Scientific American entitled "Managing Planet Earth".)

Such concerns suggest that policy issues related to population growth are fundamentally important, and have led to renewed interest in the relationship between fertility and growth rates of per capita real income. Early work by Coale and Hoover (1958) and others suggested that high fertility hampers per capita real income growth. Although some results, including those obtained by Hazledine and Moreland (1977) and McNicoll (1984), are consistent with this position, clear empirical support has been hard to obtain.

Several recent surveys, including Horlacher and MacKellar (1988), Kelley (1988), and Srinivasan (1988) express ambivalence about the effect of population growth on per capita income growth, and suggest that failure to obtain significant effects might be the most striking "stylized result" from the large body of research on this subject. Simon (1989) takes a stronger position, arguing that "The empirical studies of the relationship between the rate of economic development and population growth may reasonably be interpreted ... as consistently strong evidence of the absence of a negative causal effect of the latter upon the former". (See also Boserup (1981).) Some recent work, however, including Bloom and Freeman (1988), Coale (1986), and U.N. (1988) does find evidence of a "neo-Malthusian" relationship between demographic change and income growth. Blanchet (1991b) suggests that most of the work published prior to 1980 showed no relationship but that "a negative relation could be emerging".

The objective of this paper is to re-examine the cross-national empirical evidence relating fertility to per capita income growth. We use national income data made available by Summers and Heston (1991), and demographic data from United Nations World Population Prospects (U.N., 1992), allowing a large consistent data set (covering the period 1960-85) to be used. We derive a model specification that demonstrates the importance of birth rates in addition to population growth per se, and that allows us to distinguish several different possible mechanisms through which fertility might affect the growth of per capita real income.

The time series nature of our data is particularly important for at least two reasons (in addition to simply expanding the size of the data set). First, time series data allows more reliable treatment of "country-specific" effects that may be significant in explaining economic growth. We are also able to address important issues related to simultaneity discussed by Blanchet (1988), among others. Specifically, it seems likely that rising per capita incomes cause declines in fertility. If so, then fertility and population growth rates might be affected by income growth while income growth is simultaneously being influenced by fertility, leading to identification problems. We are able to test for and deal with this possible endogeneity of demographic variables.

In contrast to recent surveys, our analysis favours a "neo-Malthusian" interpretation: decreases in fertility tend to promote growth of per capita real income. Using production function based modelling, we clearly observe the "relative labour supply effect" of declining birth rates articulated by Coale and Hoover (1958): as birth rates fall, there is a period in which entry into the labour force rises more rapidly than the dependent population, yielding higher output per capita. This result is consistent with the findings of Coale (1986) and Bloom and Freeman (1988) that declining fertility produces a transitional increase in per capita income growth. In addition, we find that for high birth rate countries, birth rate declines tend to promote investment, although investment appears to be positively related to birth rates in low birth rate countries. There is also an apparent "capital dilution" effect of high fertility (but the role of possible "resource dilution" remains highly speculative). Overall, our results show more robust transitional effects than previous work and imply some effects that would also apply to comparisons across steady states.

We might also emphasize that in simple regressions, using birth rates rather than population growth as a regressor for income growth tends to give stronger results. We also confirm, as found by Bloom and Freeman (1988), U.N. (1988), and Blanchet (1991) that more recent periods (i.e. 1980-85) exhibit a stronger negative correlation between population growth and per capita output growth than earlier periods (such as 1960-65).

We do not provide a full set of references to previous work on fertility and economic development, but several of the surveys cited earlier contain fairly complete bibliographies. Widely cited studies include Easterlin

(1967), Kuznets (1967), Rodgers (1984) Chesnais (1987), McNicoll (1984) and Hazledine and Moreland (1977). Two valuable collections of papers examining the relationship between demographic change and economic development are Salvatore (1988) and Johnson and Lee (1987). The "investment effect" that we investigate is related to the "savings effect", which has itself been the subject of considerable disagreement. Leff (1969,1980) found that high youth dependency rates depress savings, as have Mason (1981), and Fry and Mason (1982), while Ram (1982) and Kelley (1986) have argued that the apparent existence of this effect is very sensitive to various aspects of specification.

Section 2 discusses the data set and briefly describes some of the "stylized facts" in the data. Section 3 contains the theoretical formulation of our econometric model, and section 4 presents, describes, and interprets our empirical results. Section 5 contains concluding remarks. A full listing of our data is available on request.

2. Data Construction and Exploration

Summers and Heston (1991) and UN World Population Prospects (1992) are our data sources. Output is measured at constant 1985 international prices. The Summers and Heston data is annual data produced in conjunction with the United Nations Income Comparison Project, and is contained in a data set called the Penn World Table - Mark 5 (or PWT5). PWT5 provides our per capita GDP and investment figures. Because PWT5 is based on purchasing power, it provides more meaningful cross country and time series comparisons than standard national income data relying on simple exchange rate multiplication to obtain comparisons.

Interestingly, poor countries have relatively higher incomes in the PWT5 data set than is obtained by simple conversion of nominal GDP per capita at contemporaneous exchange rates, even though many poor countries have exchange rates that are kept higher than market-clearing levels. The basic reason is that the value of nontraded goods in poor countries tends to be underestimated by simple exchange rate conversion. Similarly, PWT5 takes into account that some countries with apparently high real incomes per capita, such as Japan, have relatively high prices for nontraded goods, (including housing and land), and thus are not as well-off as they seem at first glance. See Samuelson (1984) for a rigorous discussion of the sources of these effects.

The UN demographic data comes in five year aggregates: 1960-65, 1965-70, etc, based on mid-year estimates. Strictly speaking, therefore, each five year measure is a mid-year to mid-year measure. Thus the 1960-65 period goes from July 1, 1960 to June 30, 1965, although insisting on a particular month gives a somewhat misleading view of the precision of the data. As PWT5 contains full year data, the data for each year includes everything up to December 31st, and therefore does not match the mid-year to mid-year UN demographic data exactly. We use five year intervals 1961-65, 1966-70, ..., 1981-85 for the PWT5 data. Thus, for example, the first interval for PWT5 data goes from January 1, 1961 through December 31, 1965, and is therefore offset forward by six months from the corresponding U.N. data. We have, however, also tried interpolating the PWT5 data to create mid-year to mid-year five year estimates. Both approaches yield essentially identical results, so we have opted for the more straightforward of the two.

The annualized growth rate for 1961-65 is actually calculated as (ln(1965) - ln(1960))/5, incorporating growth from just after the end of 1960 (i.e. January 1, 1961) to the end of 1965. All ratios and rates of growth are expressed in per cent. The use of five year (rather than annual) periods allows us to concentrate on medium-term performance as fluctuations due to business cycle effects are substantially smoothed by the aggregation.

Our starting data set was the list of 138 countries covered by Summers and Heston (1991). We omitted countries from this list on three grounds. First, we omitted 19 countries where data was missing for more than two years. (When there was only one or two years of missing data, as for Indonesia 1960-61, we extrapolated the time series forward or backward as necessary.) Second, we omitted four additional countries because of their heavy dependence on natural resource extraction. Our rationale is that national accounting techniques do not deal adequately with resource extraction, since no correction is made for the associated depreciation of natural capital. Nor is our supply side analysis able to deal with the substantial variations in output of resources which are controlled by cartels such as OPEC. While these effects are minor for most countries, they create a very serious problem in interpreting the data for a few. (The exact criterion we used was to omit countries for whom over 50% of GDP was accounted for by primary nonrenewable resource extraction in any five year period.)

Third, we omitted eight additional countries for which the UN estimate of annual population growth rates and the PWT5 population growth rates (derived from World Bank data) differed by more than one percentage point (e.g. 2.5% as opposed to 3.5%). For most countries agreement was very close, but a few (e.g. Afghanistan in 1981-85) produced very different estimates, suggesting that the data for these countries is unreliable and that the match between PWT5 and UN data may not be very good. In the case of Taiwan, there is no recent UN data.[1] Appendix 1 lists the 107 countries left in our sample in ascending order of their 1961-65 real GDP per capita. Appendix 2 lists the countries omitted according to the three criteria just described. Our overall data set is a balanced panel of 107 x 5 = 535 observations.

Before making use of this panel data set, however, we undertake some preliminary analysis comparable to that of many previous studies.

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[1] Taiwan has been omitted from U.N. data since the early 1970s as a political concession to China.

Specifically, we begin by using full period aggregates (1961-85) for each country (i.e. 107 observations) and run simple cross-sectional regressions of economic growth on population growth and crude birth rates. Comparing the results obtained here with previous work allows us to see how much of the difference between our findings and previous work is due to the new data we are using, rather than to the innovations of exploiting the panel structure of the data and using the production-function based estimation procedure developed in Sections 3 and 4 of the paper. The simple correlation coefficients between per capita output growth and population growth and birth rates are -0.21 and -0.44 respectively. We emphasize that such correlations simply establish association, not causality.

In Table 1 we report the results of simple OLS regressions of per capita GDP growth versus population growth and versus birth rates. A recent study by Kelley (1992) suggests, however, that statistical measures of correlations such as these may be sensitive to the treatment of heteroscedasticity and to systematic differences between sub-samples. We therefore report four additional estimates making different adjustments for possible heteroscedasticity. Each adjustment applies a different set of weights to the observations. Specifically, we report the White (1980) adjustment for heteroscedasticity of general unknown form (implemented by SHAZAM 6.2), and we report estimates obtained by weighting the observations by population, by real GDP per capita, and by real GDP.

These weightings could be viewed as attempts to control for statistical problems of heteroscedasticity, where it is assumed that the variance of measured rates of economic growth is a linear function of these variables. In fact, however, regression of the squared residuals from the population regression on the three weighting variables reveals a very weak overall relationship ($R^2 = 0.05$) and a significant relationship ($t=-2.2$) only with real per capita GDP. The same test on the residuals from the birth rate regression reveals an even weaker relationship. It may, therefore, be more appropriate to view the regression results obtained by weighting observations by population or by GDP primarily as descriptions of what has actually happened to the world (in the sense that observations are weighted by some measure of their importance). The regressions incorporating GDP per capita weights could be viewed as making some sort of adjustment for data quality, as higher income countries tend to produce higher quality data. We would view the White-adjusted results as the better formal statistical correction for heteroscedasticity.

We have also divided the sample into two parts, as the least developed economies may well exhibit different relationships from the others. We ranked the sample in order of average real per capita GDP over the period 1961-85. Using the regressions of economic growth on population growth and birth rates, we performed the Chow test for parameter stability at each point in the series. The results suggested a significant break between the poorest 40 countries and the rest. (The ordering of countries on 1961-85 averages is slightly different from that shown in Appendix 1, where the ranking is by 1961-65 GDP levels, but the poorest 40 are nearly identical, except that Nigeria, Gabon and the Sudan replace Egypt, Sri Lanka and the Congo.) In Tables 1 and 2 we report the regression coefficients within each sub-sample as well as across the whole sample and we repeat the exercise for the beginning and ending five-year periods. SHAZAM 6.2 (see White et. al. (1990)) was used for these regressions.

TABLE 1: Per Capita Output Growth vs. Population Growth

Regression coefficients (t-statistics) [White-adjusted]

Period / Method	Whole Sample n=107	Less Developed n=40	More Developed n=67
1961-85 OLS	-0.44 (-2.4) [-3.3]	0.61 (1.0) [1.2]	-0.19 (-1.2) [-1.4]
weight=population	-0.72 (-3.4)	-2.57 (-3.9)	-0.14 (-0.8)
weight=RGDP p.c.	-0.25 (-1.9)	0.69 (1.1)	-0.10 (-0.7)
weight=GDP	-0.25 (-1.6)	-2.70 (-4.1)	-0.09 (-0.5)
1961-65 OLS	-0.62 (-2.0) [-2.2]	-1.15 (-1.5) [-1.7]	-0.29 (-1.0) [-1.1]
weight=population	-1.18 (-2.7)	3.38 (3.3)	-0.66 (-2.0)
weight=RGDP p.c.	-0.30 (-1.4)	-1.08 (-1.6)	-0.13 (-0.5)
weight=GDP	-0.93 (-3.0)	3.55 (3.6)	-0.39 (-1.2)
1981-85 OLS	-0.64 (-2.2) [-2.4]	-1.29 (-1.2) [-1.3]	1.02 (-3.5) [-2.8]
weight=population	-1.39 (-3.3)	-4.43 (-6.8)	-1.24 (-4.3)
weight=RGDP p.c.	-0.68 (-3.1)	-0.96 (-1.1)	-0.94 (-3.4)
weight=GDP	-0.43 (-1.4)	-4.25 (-7.1)	-1.02 (-4.1)

TABLE 2: Per Capita Output Growth vs. Crude Birth Rates

Regression coefficients (t-statistics) [White-adjusted]

Period / Method	Whole Sample n=107	Less Developed n=40	More Developed n=67
1961-85			
OLS	-0.61 (-5.1) [-5.5]	-0.96 (-1.8) [-1.9]	-0.3 (-2.0) [-2.3]
weight=population	-0.77 (-5.7)	-1.83 (-7.0)	-0.12 (-0.8)
weight=RGDP p.c.	-0.38 (-3.6)	-1.11 (-1.9)	-0.20 (-1.4)
weight=GDP	-0.29 (-2.4)	-1.84 (-7.6)	-0.07 (-0.4)
1961-65			
OLS	-0.77 (-3.5) [-3.7]	-1.23 (-1.1) [-1.2]	-0.35 (-1.5) [-1.5]
weight=population	-1.25 (-5.0)	2.95 (4.4)	-0.63 (-2.8)
weight=RGDP p.c.	-0.39 (-2.4)	-1.24 (-1.3)	-0.17 (-0.8)
weight=GDP	-0.88 (-4.6)	3.36 (4.9)	-0.35 (-1.4)
1981-85			
OLS	-0.63 (-2.7) [-2.9]	-1.90 (-2.4) [-3.3]	-1.29 (-4.8) [-4.3]
weight=population	-1.49 (-4.6)	-3.06 (-9.1)	-1.47 (-6.1)
weight=RGDP p.c.	-0.84 (-4.1)	-1.94 (-2.8)	-1.26 (-4.8)
weight=GDP	-0.65 (-2.3)	-3.04 (-9.4)	-1.31 (-5.7)

The overall inference arising from inspection of Tables 1 and 2 is that the correlation between fertility and economic growth is negative. Comparing Tables 1 and 2 shows that birth rates have a more significant and more uniform negative relationship with per capita output growth than do population growth rates, regardless of period or sample stratification. In addition, negative relationships are stronger in the latest period than in the earliest period. The most striking finding from this analysis, therefore, is the consistently strong negative relationship between birth rates and per capita economic growth in the most recent period. It remains to be seen, however, whether we can find persuasive evidence of a causal connection running from fertility to economic growth. Drawing reasonable inferences would seem to require more detailed structural modelling, which we seek to do in the following sections.

In addition, one cost of doing simple cross-sectional regressions of the type reported here is that information contained in the time-varying behaviour of any one country is ignored: only cross-sectional variation is used to derive inferences. Exploiting the fairly long time series by constructing panel data based on five year intervals allows more complete use of the information contained in the data.

3. Theoretical Specification

A useful starting point for considering the sources of economic growth is to write down an aggregate production function. (Two examples of production function based approaches are Browning (1982) and Hazledine and Moreland (1977).)

$$Y = Y(K,H,R;\theta,\phi) \tag{1}$$

where Y stands for real domestic output, K represents capital, H represents effective labour input, R represents fixed factors of production, such as land and natural resources, θ represents the state of technology, and ϕ represents other influences. Using lower case letters to represent per capita values (obtained by dividing by population, P), differentiating (1) with respect to time, letting "hats" denote proportional changes, and rescaling θ and ϕ appropriately, we can derive the following expression for the rate of growth of output per capita,

$$\hat{y} = a_K\hat{k} + a_H\hat{h} + (a_S - a_R)\hat{P} + \theta + \phi \tag{2}$$

where the subscripted coefficients represent elasticities of output with respect to the particular input so, for example, $a_K = Y_K K/Y$; and a_S is a parameter representing returns to scale ($a_S = a_K + a_H + a_R - 1$). From the first three terms on the right hand side of (2) we observe that changes in population growth or fertility can have an impact through the rate of per capita investment, $\hat{k}$, through changing the effective labour input per capita, $\hat{h}$, or through the net effect of resource dilution and economies of scale as represented by the coefficient (a_S - a_R).

If we had data on all these variables, we could readily estimate a_K, a_H, and (a_S-a_R). The estimated sign of the third parameter would test (one statement of) the classical Malthusian hypothesis: that diminishing returns to fixed resources tend to outweigh increasing returns to scale. Related "neo-Malthusian" hypotheses suggesting that fertility might reduce per capita income growth through investment and labour participation effects could also be tested. It should also be noted that population "optimists" such as Simon (1986) emphasize a positive effect of population growth on technical progress suggesting, in effect, that θ is positively related to population growth.

Actual data falls short of what would be desired, but our data sources do provide consistent estimates of real gross investment as a share of real GDP and the share of the population that is of "working age" (i.e. between 15 and 64), denoted IS (for "investment share") and w (for "working age" population share) respectively. We need to link this data to the variables appearing in (2). Looking first at capital and investment, we assume that depreciation occurs at constant rate δ, and note that the change in capital stock equals gross investment minus depreciation, leading to the following relationship.

$$a_K\hat{k} = Y_K(dK/Y) - a_K\hat{P} = Y_K(IS) - a_K\delta - a_K\hat{P} \tag{3}$$

The link between the working age population share, w, and effective labour input per capita, h, should also be considered. As the ratio of working age population to total population rises, the effective labour input per capita would be expected to rise more than proportionately because falling dependency rates release parents, especially mothers, to devote more time to producing market output. Letting the relation between effective labour per capita and w be denoted h = h(w), we can write:

$$\hat{h} = \hat{w}(1+\lambda) \tag{4}$$

where $\lambda = h'(w)w/h$, the elasticity of effective labour per capita with respect to the working age share.

We must also impose some structure on the nature of technical progress. Recent work (including Abramovitz (1986), Romer (1986), Dowrick and Nguyen (1989), and Dowrick and Gemmell (1991)) suggests that there may be systematic variations in rates of technical progress over time and according to level of development. In particular, the benefits of technical progress may be difficult to realize if infrastructure in human and physical capital is below some threshold level. Thus the link between level of development and technical progress may be nonlinear. Accordingly, we specify technical progress as a quadratic function of some index of development, z, and include a vector of dummy variables, one for each period of observation (after the first), yielding the following technical progress function.

$$\theta = \theta_{01} + \theta_{0t}D_t + \theta_1 z + \theta_2 z^2 \tag{5}$$

The final term in (2), ϕ, is a residual representing "random error" and any other source of unmodelled variation. Some of these factors might be specific to particular countries, such as institutional or political factors. Accordingly, we specify two components to the error term: a country specific component and a general white noise component. Indexing countries by i and periods of observation by t, this yields:

$$\phi_{it} = \mu_i + \epsilon_{it} \tag{6}$$

Substituting (3), (4), (5), and (6) into (2), we obtain an equation suitable for estimation.

where $\alpha_0 = \theta_{01} - a_K\delta$, $\alpha_1 = Y_K$, $\alpha_2 = a_H(1+\lambda)$, $\alpha_3 = (a_s - a_R - a_K)$, $\alpha_4 = \theta_1$,

$$\hat{y} = \alpha_0 + \alpha_1 IS_{it} + \alpha_2 \hat{w}_{it} + \alpha_3 \hat{P} + \alpha_4 z_{it} + \alpha_5 z_{it}^2 + \alpha_6 D_t + \mu_i + \epsilon_{it} \tag{7}$$

$\alpha_5 = \theta_2$, and $\alpha_6 = \theta_\alpha$.

Estimation of equation (7) does not allow separation of the independent effects of returns to scale, resource depletion, and capital shallowing. Nor does it allow us to distinguish between the output-employment elasticity (a_H) and the effective labour elasticity (λ). Nevertheless, it does allow estimates of the net direct effect of population growth on per capita income growth. In addition, we can write the following equation for investment and for the rate of change, $\hat{w}$, in the working age share of population.

$$IS_{it} = I(br_{it}, PI_{it}, Y_{it}) + \mu_i + \epsilon_{it} \tag{8}$$

$$\hat{w} = \hat{w}(br_{-3}, br_0) \tag{9}$$

where br stands for the crude birth rate, and PI stands for the price of investment. Thus we hypothesize that investment rates may be affected by the price of investment, level of per capita income, and by birth rates. It is possible that investment could be either a complement or substitute for fertility. We expect $\hat{w}$ to be very close to the simple difference between the current birth rate and birth rate three periods (i.e. 15 years) earlier since these rates are the primary flows into the general population and working age population. This is not an identity, however, as unobserved age-specific mortality rates and second order population dynamics are also relevant. One could complete a dynamic system by estimating the dependence of birth rates and population growth (or mortality rates) on income:

$$br = br(y) \qquad ; \qquad \hat{P} = \hat{P}(y) \tag{10}$$

4. Estimation and Results

The data are defined and described in Tables 3 and 4. We have again divided the sample into two groupings using the rankings of real per capita GDP in 1961-65, as listed in Appendix 1. This time, however, we have applied the sequential Chow test to the estimates of production equation (7). The structural break is most pronounced between the poorest 31 countries and the rest. This defines the groupings that we use throughout the rest of the paper.

TABLE 3: DATA SOURCES AND DEFINITIONS

y = per capita real output calculated from the Summers and Heston PWT5 (1991) RGDP series (five year average) in 1985 U.S. dollars.

P = population (five year average) from U.N. World Population Prospects (WPP, 1992).

$\hat{y}$ = annualized five-year growth rate of per capita real income in percent. (PWT5)

$\hat{P}$ = annualized five year population growth rate (in percent). (WPP)

br = crude birth rate per 100 of the population per year. (WPP). (We use rates per 100 instead of the conventional rate per thousand to match other percentage variables.)

w = share of the population of working age (ages 15-64) (percent). (WPP)

$\hat{w}$ = annualized five year growth rate in the share of population of working age (in percent), calculated from WPP series.

IS = investment as a % share of GDP (5 year average) calculated from PWT5.

PI = relative price of investment, calculated from PWT5 investment price series divided by GDP price series, and adjusted for changes in the relative price of investment in the base country (U.S.) using the implied U.S. investment price time series from OECD National Accounts: 1960-87. We use the log of PI, denoted LPI.

RP = relative productivity as measured by the ratio of domestic labour productivity (y/h) to maximum labour productivity for that period across all countries. We use LRP, the log of RP. This variable represents z, the "index of development" that enters the technical progress function.

TABLE 4: Data Summary

	Least Developed n=155	More Developed n=380	107 countries	Whole Sample x 5 periods =	535 obs.
Variable	Mean	Mean	Mean	St. Dev.	Corr'ln with $\hat{y}$
$\hat{y}$	1.76	2.25	2.11	3.41	1.00
$\hat{P}$	2.59	1.90	2.10	1.01	-0.10
br	4.51	3.17	3.56	1.31	-0.18
w	53.2	56.8	55.7	5.4	0.12
$\hat{w}$	-0.10	0.20	0.11	0.53	0.09
y(1985 $US)	912	4486	3451	3292	0.11
P (millions)	59.1	18.3	30.1	99.1	0.04
IS	12.8	20.6	18.3	9.23	0.29
PI	2.43	1.86	2.02	1.42	-0.08
LRP	-2.87	-1.19	-1.68	1.00	0.19

An observation is a five year period for a given country. Table 4 shows that there is remarkably wide variation across the observations in income growth rates, population growth rates, and birth rates (among other things). It is perhaps also of interest that the strongest crude correlation involving income growth is with investment.

As already noted, the longitudinal panel structure of our data allows investigation of possible unmodelled country-specific factors. Following Greene (1990), and using the associated procedures in the LIMDEP 5.1 econometrics package (as described in Greene (1989)), we were able to test for country specific effects and carry out appropriate estimation in their presence. For each equation the "error" term is of the form $\epsilon_{it} + \mu_i$, where i refers to the country and t refers to the period. μ is the country specific term. Running a simple pooled OLS regression assumes that $\mu_i = 0$. A fixed effects model assumes that μ_i is a fixed constant (across time periods) for each country, in which case an appropriate estimation technique is least squares with country specific dummies. The third possibility is that μ_i is itself a random variable, yielding an error components model, referred to as a "random effects" model, that can be estimated using generalized least squares. We report all three possibilities.

Greene describes tests to determine whether the OLS model is rejected in favour of the fixed effects model. We calculate both the F-test (for the joint significance of the country dummy variables) and the likelihood ratio test, which is distributed Chi-squared. We also calculate the Lagrange multiplier test (Chi-squared) of the random effects model against OLS and the Hausman test (Chi-squared) of the fixed effects model against the random effects model. For all these tests we report the associated "P-values" showing the significance level at which the null hypothesis can be rejected.

In addition to using statistical tests to choose between fixed effects, random effects, and OLS, there are important conceptual issues that bear on this choice. Fixed effects models may attribute "too much" of the cross sectional variation to country-specific effects, especially in the presence of minor specification errors in functional form. Random effects models have the advantage of allowing some country-specific effects, but without imposing the excessively rigid structure of fixed effects.

We report the OLS results and the results of the fixed effects (FE) and random effects (RE) models if either is preferred to OLS. In all cases we include dummy variables for each period to capture period fixed effects, but we do not report the coefficients here.

Full sample results are reported in Table 5. We find that the country-specific fixed effects are not significant on the F-test, but are significant at the 0.05 level on the likelihood ratio test. The random effects model is preferred to the fixed effects model, so we report both.

The IV regression (for instrumental variables) is an attempt to correct for possible endogeneity of birth rates. As noted in the introduction, Blanchet

(1988, 1991b), among others, has emphasized that birth rate and population variables might be endogenously influenced by changes in income. If demographic variables are simultaneously affected by changes in per capita income, then simply regressing income growth on demographic variables using ordinary least squares or related techniques will not produce meaningful results. The first line of defence, noted by Blanchet, is that demographic variables seem to be closely related to the level of income rather than to income growth. If it is the level of income that is important, then regressing income growth on demographic variables is not necessarily a problem.

This would be a complete defence if the data were based on very short time periods. If one uses 5 year or 10 year periods, however, then variation in growth rates across countries over the period can lead to significant variations in the level of income and hence birth rates within the period. This problem is obviously much less severe with 5 year periods (as we have) than with 10 year periods, but it certainly requires some attention, and can be addressed by the time series aspect of the data. We test for endogeneity using Hausman's test for exogeneity (as described in Beggs (1988)). As indicated in note 4 in Table 5, there is only modest evidence of endogeneity. We do, however, report the results from an associated instrumental variables regression in column 4 (IV) of Table 5 that uses strictly predetermined birth rates as instruments.

TABLE 5: Per Capita GDP Growth - whole sample: n=535

(t-statistic) [White-adjusted t-stat]

Variable	OLS	Fixed Effects	Random Effects	IV: n=428
$\hat{w}$	0.85 (2.9) [2.7)	0.31 (0.9)	0.79 (2.7)	1.33 (3.1)
$\hat{P}$	0.02 (0.1) [0.1]	-0.33 (-1.0)	0.02 (0.1)	-0.27 (-1.1)
IS	0.10 (5.5) [3.9]	0.09 (2.3)	0.10 (5.2)	0.11 (5.2)
LRP	-0.45(-0.8)[-0.7]	-1.61 (-0.8)	-0.50 (-0.8)	-0.74 (-1.0)
LRP^2	-0.14(-1.0)[-0.8]	-0.86 (-1.8)	-0.16 (-1.0)	-0.12 (-0.7)
summary stats				
adj. R^2	0.104	0.152		
s.e.	3.61	3.51		

diagnostics: Hetero: ***; Reset (2) -; Endogeneity: P=0.02 **
model selection: FE vs OLS: F: P=0.13, X^2: P=0.02**; RE vs OLS: P=0.50; FE vs RE:P=1.0
*** indicates significance at P=0.01 level, ** at P=0.05, * at P=0.1.
"Endogeneity" reports the significance of the Hausman test for endogeneity of the two demographic variables.

The notes following the table require some explanation. The three asterisks following "Hetero" means that the null hypothesis of homoscedasticity can be rejected at the .01 level of significance using Shazam 6.2 diagnostics. The dash beside the term "Reset" means that the Ramsey Reset (2) test of specification showed no evidence of misspecification at the .10 level of significance. The "P=.02" beside the term endogeneity means that the null hypothesis that the demographic variables are exogenous to the dependent variable could be rejected at the .02 level of significance. Similarly, in the model selection line, the "P-values" show the significance level at which the null hypothesis that the second listed model is correct could be rejected in favour of the first. Thus, for example, FE vs. RE: P=1 means that the null hypothesis that the random effects model is correct in favour of the fixed effects model cannot be rejected at any level of significance. The overall outcome of the model selection tests reported in Table 5 is that likelihood ratio tests do not give much basis for rejecting OLS in favour of either fixed or random effects models, but there is evidence of endogeneity.

The correction for endogeneity of $\hat{w}$ is to replace $\hat{w}$ with "instrumental variables" that are correlated with $\hat{w}$ but that are known to be exogenous. In general, instrumental variables are problematic because the results are highly dependent on the instruments chosen. In effect, for IV estimation to be useful it is important that good instruments be available. In this case we have excellent instruments: beginning of period birth rates and the beginning of period birth rate 3 periods (i.e. 15 years) earlier. These birth rates are strictly exogenous to current period growth, as they are predetermined, and as an arithmetic matter, are the overwhelmingly major determinant of $\hat{w}$. However, our data reports complete birth rate data only back to 1950, so we lose the first period when using this approach. Using these predetermined instruments has the effect of strengthening the apparent labour participation effect. The basic point here is that declines in fertility increase labour force participation (i.e. they reduce dependency), which in turn tends to raise per capita economic growth.

All parameter estimates are, of course, contingent on the model being correctly specified, in which case parameters should be stable over subsamples of the data. In fact, however, we can reject the hypothesis that the parameters are stable across levels of development. The sequential Chow test indicates that the break is most significant between the poorest 31 countries and the rest. The test statistic is F(10,515) = 4.97. Accordingly we emphasize the results estimated separately for the least developed group of countries and the others.

Results for the least developed group are reported in Table 6. There is only weak evidence that country effects are significant, but we report both the fixed effects and random effects results. There is no evidence that the demographic variables are endogenous with respect to income growth rates. The coefficients on population growth are negative, but of little statistical significance. Overall, the regression has little explanatory power. We conclude that for these countries we have not been able to estimate a reliable systematic relationship between factor inputs and output growth. We suspect that this finding may reflect the relatively poor level of data quality for these countries. Even so, the favoured (OLS-White adjusted) regression for this set of 31 very poor countries does show an economically large and statistically significant positive effect of increases in the working age population share on per capita income growth, suggesting that declines in fertility would boost per capita growth for this set of countries.

TABLE 6: Per Capita Production Function less developed countries: n=155

(t-statistic) [White-adjusted t-stat]

Variable	OLS	Fixed Effects	Random Effects
$\hat{w}$	1.57 (1.9) [2.1]	1.00 (1.0)	1.46 (1.7)
$\hat{p}$	-0.12 (-0.3) [-0.2]	-0.74 (-1.1)	-0.22 (-0.5)
IS	0.06 (1.4) [1.1]	0.07 (0.7)	0.06 (1.4)
LRP	5.48 (1.1) [1.0]	-10.8 (-1.4)	3.05 (0.6)
LRP^2	0.75 (0.9) [0.7]	-2.43 (-1.6)	0.32 (0.3)
summary stats			
adj. R^2	0.104	0.152	
s.e.	3.61	3.51	

diagnostics: Hetero: **; Reset(2) -; Endogeneity: P=0.76
model selection: Fixed eff. vs OLS: F: P=0.18, X^2: P=0.04**; Random effects vs OLS, P=0.91; Fixed vs Random, P=1.0
The IV estimates are not reported as endogeneity is not significant.

The results for the more developed countries are much clearer. The regression explains one-third of the variance in growth rates and the coefficients are estimated with reasonable precision. Neither specification of country effects - fixed or random - is statistically significant, but there is clear evidence of endogeneity so we report the Instrumental Variable estimates as our preferred model.

The coefficient on population growth represents the combined effect of returns to scale, resource dilution, and capital dilution. A natural null hypothesis is that the net effect of resource dilution and economies of scale would be zero, leaving only the capital dilution effect, which should be roughly equal to the (negative of the) output elasticity with respect to capital, normally taken to be about -0.25. Our preferred (IV) point estimate of this combined effect is an elasticity of -0.26, which is very close to this null hypothesis.

The investment share has a strong and robust positive effect on per capita income growth (as expected). The nonlinearity captured by the significant quadratic term suggests declining marginal returns to investment. The effect of investment on per capita growth is, however, positive throughout our range of observations. The variable LRP (the log of relative labour productivity) represents the index of development, z, in equation (5). Its negative (but non-linear) effect indicates a "catch-up" phenomenon that we attribute to technology transfer. The two coefficients (on LRP and LRP^2) are jointly significant at the 1% significance level in both the OLS and IV regressions. Finally, the most relevant result for our analysis is the significant effect of the change in the working age population ($\hat{w}$) on income growth. The coefficient is statistically significant and quite large in economic importance, especially in the (preferred) IV regression.

TABLE 7: **Per Capita Production Function**
- more developed countries: n=380

(t-statistic) [White-adjusted t-stat]

Variable	OLS	IV: n=304
$\hat{w}$	0.67 (2.3) [2.0]	1.41 (3.40)
$\hat{p}$	-0.09 (-0.6) [-0.5]	-0.26 (-1.2)
IS	0.08 (4.4) [3.2]	0.09 (4.0)
LRP	-1.99 (-2.4) [-2.9]	-1.80 (-1.8)
LRP^2	-0.95 (-3.2) [-3.6]	-0.84 (-2.4)
summary stats		
adj. R^2	0.328	0.322
s.e.	2.64	2.74

diagnostics: Hetero: ***; Reset(2) -; Endogeneity: P=0.004 ***
Fixed Effects vs OLS: F: P=0.60, X^2: P=0.27; Random Effects vs OLS, P=0.33; Fixed vs Random, P=1.0
Neither the fixed effects nor the random effects estimates are reported as neither is significantly preferred to OLS.

The instrumenting regression to correct for endogeneity is reported in Table 8. The relationship between changes in birth rates and the growth in the working age proportion of the population is stronger within the group of more developed economies. Our expectation that a one percentage point reduction in the birth rate induces, fifteen years later, one percentage point growth in the working age share is confirmed.

TABLE 8: Growth in working age share of population versus birth rates

Reporting the coefficients & (White) t-stats from the OLS regression of $\hat{w}$

Variable n=	Whole Sample 428	Less Developed 124	More Developed 304
birth rate	-0.91 (-2.4)	-0.67 (-7.3)	-0.99 (-22)
birth rate_{15}	0.89 (20)	0.54 (4.8)	0.95 (21)
R^2	0.654	0.507	0.670

Note: the constant term from the regression has not been reported here.

The previous tables suggest that investment is an important determinant of per capita income growth, as the investment variable, IS, has a consistently large and significant coefficient in the entire sample and in the sub-sample of 76 more developed countries. Fertility might in turn have an effect on investment and therefore an indirect effect on economic growth in addition to the direct effect already estimated. Tables 9 and 10 report regression results for investment using birth rates, the price of investment and income as explanatory variables.

Table 9: Investment: less developed economies

(31 countries x 5 = 155 obs)

Reporting the coefficients & (t-statistic) [White t-stat] from regressions of IS

	OLS	Fixed Effects	Random Effects
birth rate	-15.1 (-3.2) [-3.0]	-8.9 (-1.5)	-9.3 (-1.9)
(birth rate)^2	1.8 (3.2) [3.1]	1.2 (1.6)	1.2 (1.9)
PI	-12.7 (-12) [-13]	-8.2 (-4.3)	-10.7 (-7.6)
y	0.66 (4.0) [4.1]	0.93 (3.5)	0.81 (3.9)
y^2	-0.07 (-0.2) [-0.2]	-0.63 (-1.3)	-0.35 (-0.8)
adj. R^2	0.710	0.845	
s.e.	4.59	3.36	

diagnostics: Hetero: **; Reset: OLS: ***; Fixed effects ***; Random effects ***
model selection: Fixed effects vs OLS: P=0.000 ***; Random effects vs OLS: P=0.000 ***; Fixed vs Random: P=1.0
The coefficients on y and y^2 have been multiplied by 100 and 10^6 respectively. Period dummies are included but not reported here.

For the less developed countries, we find a quadratic birth rate effect that is negative over the region covered by the data (i.e. higher birth rates reduce investment). This effect is, however, only of marginal significance in the models with country-specific effects. The price effect is large, significant, and negative, as expected, and there is a significant positive and essentially linear income effect. The preferred estimates are provided by the random effects model.

In the more developed countries we find, as expected, that price effects are important, and that the income effect is non-monotonic. Country effects are very important and the random effects model provides our preferred estimates. Most interestingly, we find a significant non-monotonic relationship between fertility and investment, with a turning point at a birth rate of about three percent. When birth rates are below three percent, investment shares increase with birth rates. Increases in birth rates above three percent tend to decrease investment.

Table 10: Investment: more developed countries
(76 countries x 5 = 380 obs)
Reporting coefficients & (t-statistics) [White t-stat] from regressions of IS

	OLS	Fixed Effects	Random Effects
birth rate	-0.91 (-0.5) [-0.5]	12.9 (4.3)	7.05 (3.0)
(birth rate)^2	-0.05 (-0.2) [-0.2]	-2.1 (-5.0)	-1.17 (-3.5)
PI	-10.7 (-13) [-13]	-9.7 (-6.1)	-9.8 (-9.0)
y	0.18 (3.7) [3.7]	0.34 (5.1)	0.25 (4.6)
y^2	-0.12 (-4.1) [-4.4]	-0.14 (-3.7)	-0.13 (-4.1)
adj. R^2 s.e.	0.541 5.81	0.800 3.84	

diagnostics: Hetero: -; Reset: OLS ***; Fixed effects -; Random effects -.
model selection: Fixed effects vs OLS: P=0.000 ***; Random effects vs OLS: P=0.000 ***; Fixed vs. Random: P=1.

So far we have identified three mechanisms through which fertility, as measured by crude birth rates, might affect per capita economic growth. The first effect is through changes in the share of the population of working age. The second effect is through changes in the population growth rate leading to changes in the availability of capital and natural resources per person and to changes in the realization of economies of scale, and the third effect is through the per capita investment rate. It is possible to calculate an implied net effect of birth rate changes on per capita output (or income) growth. The net impact effect of a birth rate reduction today, taking past birth rates as given, can be obtained using the chain rule as illustrated in equation 11.

$$d\hat{y}/dbr = \frac{\partial\hat{y}}{\partial IS}\frac{dIS}{dbr} + \frac{\partial\hat{y}}{\partial\hat{w}}\frac{d\hat{w}}{dbr} + \frac{\partial\hat{y}}{\partial\hat{p}}\frac{d\hat{P}}{dbr} \qquad (11)$$

Consider the application of equation 11 to our preferred estimates for the more developed countries. Note that population growth is just the difference between birth and death rates plus net (in) migration, so that the derivative of population growth with respect to the birth rate is simply one. If we use the (preferred) IV results for the production function and the random effects results for the investment equation, we would infer that a decline in the birth rate from, for example, 4 to 3 percent, will raise the growth rate of the working age share by about 1 percentage point, raising the annual per capita growth rate of GDP by approximately 1.4 percentage points. If birth rates did not decline further, after 15 years per capita GDP would be some 23 percent higher, even in the absence of other contributing factors. In addition, the lowered fertility would be estimated to increase investment by about .10 percentage points. The effect of this depends on the initial investment level (due to non-linearities) but starting from an investment share of about 15%, would raise per capita GDP growth by about .12% per year. The capital dilution effect contributes another .26%. While these two effects appear relatively "small" they will raise per capita GDP by 6% over 15 years, yielding an overall increase from all three effects of 29% over 15 years. This is, of course, a purely illustrative calculation and the precise numbers should not be taken too seriously. It does, however, give an idea of the relative magnitude of the effects we have estimated.

It is important to emphasize that the labour participation effect is a medium term benefit only, and that it could begin to reverse itself after about 40 to 50 years when increases in old age dependency relative to new labour force entrants begin to become significant. This potential negative "rebound" effect depends very much, of course, on retirement practice, public policy toward old age, and the precise dynamics of the model structure, and is not a necessary implication of falling fertility.

These calculations do not presume any dynamic feedback effects in which higher incomes induce a further decline in fertility. Such effects would tend to increase the apparent gain from a fertility decline. A "complete" structural dynamic system can be obtained by specifying birth rates and population growth rates as a function of income. Estimated random effects equations for birth rates and population growth follow (t-statistics are in parentheses).

$$BR = 11.6 - 1.05(25.7)\log(y) \quad R^2 = 0.70 \quad \text{(Random effects)}$$

$$\text{Pop. growth} = 5.7 - 0.46\ (8.04)\log(y) \quad R^2 = 0.31 \quad \text{(Random effects)}$$

Birth rates show a remarkably close relationship to (the log of) income. The corresponding relationship of population growth to income is mitigated both by mortality and by migration (as is consistent with Tables 1 and 2), but is also strongly significant. It would be possible to take the estimates of equations (7), (8), (9), (10) and (11) and run a dynamic simulation for a country (assuming particular starting values). The behaviour and properties of this dynamic system are highly sensitive to particular estimates and specifications. While we feel that the basic pattern in the data is fairly clear, there is substantial uncertainty over precise specification and actual estimation, and the effects we capture explain only a modest amount of total variation. Therefore, we would not regard the dynamic properties of the system as appropriate for presentation as "empirical" results at this stage. It is, however, important to emphasize that one type of behaviour that can emerge is a dynamic demographic transition in which income growth plays a role. More elaborate analysis of this dynamic system is, however, beyond the scope of this paper. See Blanchet (1988) for some interesting dynamic simulations of this type.

5. Concluding Remarks

We have recently observed a striking and unprecedented variation across countries in per capita income growth. Variation in investment rates is highly significant but explains only a modest share of total variation. We offer evidence that variation in fertility, especially variation in the extent to which birth rates have fallen, might also be an important contributing explanation.

Our analysis is not undermined by the concern that birth rate changes might be an endogenous response to income growth. Even when birth rate changes are strictly predetermined in income growth regressions, the effect of birth rates on income growth remains at least equally significant. In other words, birth rate declines precede income growth increases. Nevertheless, as already discussed, the effects we estimate might well be part of a self-reinforcing demographic transition with feedback effects.

While the most striking effect of birth rate changes arises through the labour supply (or "negative dependency") effect, there are also effects in high birth rate countries arising from the impact of birth rates on investment. In addition, there may be a "factor crowding" effect of increased population which we attribute to capital dilution. We have pointed out that the labour effect is transitory (though important over the medium term). It is also possible that the effect of birth rates on investment that we measure could reflect adjustments along a transition path that would disappear in a comparison of steady states. Our interpretation, however, is that these effects do apply across steady states.

We do not report any conclusions in favour of classical Malthusian resource dilution. However, it is worth mentioning one related speculative point. Our regression equations explaining per capita output growth contain dummy variables for each period. In the interest of saving space we did not report estimated coefficients for these dummy variables in the paper. However, they do show a consistent trend slowdown in per capita growth over the 1961-85 period. For example, in the basic full sample OLS regression (Table 5), the coefficients for the 2nd, 3rd, 4th, and 5th periods in the are .18, -1.03, -1.31, and -3.28, respectively, with the latter 3 all being significant at the .01 level or better. Thus, for example, annualized per capita growth was approximately 3.28 percentage points lower in 1981-85 than in 1961-65, correcting for other factors.

Our modelling exercises implicitly attribute this to an unexplained slowdown in technological progress but, keeping in mind that population in the less developed world approximately doubled between 1960 and 1985, it might be an unmodelled consequence of resource dilution at a world level. We emphasize, however, that this is very speculative and is tempered by the observation that the slower growth of the 1980s might simply be a return to trend growth after a period of remarkably high growth in the 1960s.

This paper uses a slightly more detailed theoretical structure as a foundation for estimation than is the case with much of the cross-national empirical analysis relating fertility to growth. The theoretical structure does, nevertheless, leave much in the background. In particular, technological change is taken as an exogenous explanatory variable. A natural next step would be to model the endogenous emergence of technological progress as the outcome of maximization by firms in an imperfectly competitive environment. More detailed modelling of the endogenous determination of fertility in a model of economic growth would also be an important line of research. More generally, modelling and estimating a combined economic-demographic dynamic system must be regarded as an important research direction.

We focus on per capita output (or income) as the variable to be explained. To the extent that one uses income to approximate welfare, there are many adjustments that one might make. For example, children do not seem to require as much consumption as adults to achieve a given welfare level. Thus instead dividing output by population to get a measure of "welfare", effectively weighting children and adults equally, one might weight adults and children differently. Other adjustments might include trying to correct output for environmental damage, for "protective" expenditures such as police, jails, etc., and for leisure. Because of these adjustments, we would not claim that our results are anything more than suggestive from a welfare point of view.

We have also not attempted to address corresponding normative questions of whether there is a case for intervention in fertility decisions, or what an optimal population policy might be. Our analysis would be a useful input to such deliberations but, as described in Dasgupta (1988), even if there is a trade-off between quantity of life and quality of life, there are fundamental philosophical difficulties in making social choices on such issues.

APPENDIX 1: Countries in sample order

No.	Country	RGDP 1961-65	No.	Country	RGDP 1961-65
1	U.R. Tanzania	531	55	Jamaica	4867
2	Ethiopia	547	56	Dominican R.	4937
3	Uganda	741	57	Portugal	5078
4	Rwanda	770	58	Algeria	5337
5	Lesotho	772	59	Panama	5469
6	Gambia	826	60	Tunisia	5564
7	Zaire	868	61	Guatemala	5588
8	Malawi	879	62	Malaysia	5804
9	Myanmar	907	63	Greece	5921
10	Guinea	995	64	Cyprus	6156
11	China	1055	65	Brazil	6234
12	Botswana	1220	66	Jordan	6346
13	Mali	1238	67	Colombia	6661
14	Nepal	1269	68	Iran	6835
15	Central Africa	1331	69	Nicaragua	7332
16	Kenya	1332	70	Japan	7377
17	India	1403	71	Hong Kong	7491
18	Indonesia	1426	72	Costa Rica	7675
19	Cameroon	1597	73	Mauritius	7751
20	Haiti	1679	74	Singapore	7895
21	Gabon	1783	75	Peru	7938
22	Benin	1865	76	Syria	8180
23	Madagascar	1943	77	Suriname	8782
24	Bangladesh	1979	78	Fiji	8783
25	Chad	2026	79	Barbados	9104
26	Zimbabwe	2063	80	South Africa	9139
27	Thailand	2146	81	Argentina	9154
28	Cote d'Ivoire	2204	82	Ireland	9366
29	Egypt	2225	83	Spain	9757
30	Congo	2326	84	Chile	10559
31	Cape Verde	2330	85	Uruguay	10564
32	Sierra Leone	2372	86	Iraq	10827
33	Ghana	2515	87	Mexico	10910
34	Pap. N. Guinea	2574	88	Austria	10954
35	Mauritania	2701	89	Finland	11601
36	Mozambique	2772	90	Italy	12647
37	Liberia	2868	91	Israel	13399

APPENDIX 1: Countries in sample order (CONTINUED)

No.	Country	RGDP 1961-65	No.	Country	RGDP 1961-65
38	Pakistan	2872	92	Venezuela	13863
39	Angola	2903	93	France	14405
40	Senegal	2920	94	Germany Fed.Rep.	14521
41	Rep. of Korea	2994	95	Denmark	14547
42	Honduras	3003	96	United Kingdom	14799
43	Sudan	3027	97	Iceland	14993
44	Swaziland	3078	98	Norway	15443
45	Nigeria	3134	99	Belgium	15546
46	Philippines	3387	100	Sweden	16595
47	Bolivia	3641	101	Netherlands	17384
48	Turkey	3698	102	Luxembourg	18405
49	Sri Lanka	3838	103	Australia	18689
50	Paraguay	3990	104	New Zealand	20265
51	Yugoslavia	4423	105	Canada	22223
52	El Salvador	4468	106	Switzerland	22504
53	Morocco	4473	107	United States	26449
54	Ecuador	4767			

APPENDIX 2: Countries omitted from the sample

Missing data

Burkina Faso
Comoros
Guinea Bissau
Seychelles
Bahamas
Dominica
Grenada
St. Lucia
St. Vincent & Grenada
Bahrain
Oman
United Arab Emirates
Yemen
Hungary
Poland
Solomon Islands
Tonga
Vanuata
Western Samoa

Resource dependent

Zambia
Trinidad & Tobago
Kuwait
Saudi Arabia

Population discrepancy

Burundi
Niger
Somalia
Togo
Guyana
Afghanistan
Taiwan
Malta

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