POPULATION AND ECONOMIC GROWTH : A WORLD CROSS

SECTION STUDY

NUMBER   72

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WARWICK ECONOMIC RESEARCH PAPERS

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August, 1975.

This paper is circulated for discussion purposes only and its
contents should be considered preliminary.

I. Introduction

Despite the enormous potential importance of the relationships between demographic and economic variables in the growth and development process, there is still a relatively small body of well-tested propositions about these linkages. Indeed, Perlman (1975) commented recently that economists' recommendations regarding birth control must be made "for reasons other than those simply offered by what we as economists know." The now classic work by Coale and Hoover in 1958 did not inspire the empirical work needed to shed light on the many unanswered questions in that study. What we have to date are a number of highly simplistic studies using simple correlations and single-equation models (Clark(1969))Thirlwall (1972)Chesnais and Sauvy (1972), which are at best reduced-form specifications and which do not answer the more interesting questions. We also have (Enke et.al.(1973),Barlow and Davies (1974)and Simon (1974)more sophisticated (and complicated) computer simulation macro models which assign values to the parameters a priori rather than from econometric tests. Perhaps the most extreme of these is the Meadow's Limits to Growth model. There are also some econometric models which include endogenous demographic sectors (Minami (1975), Chu et. al. (1971), McIntosh (1974)) but with the exception of Suits, et. al. (1975), these deal with particular countries. Finally there are a number of studies which have attempted to answer particular questions about relationships between economic and demographic variables, e.g. Blandy (1972) on population and employment, Leff (1971) on the age-structure and savings rates as well as the literature on the economics of fertility.

At the same time, the theoretical models which incorporate dualism and/or endogenous population growth (Nelson (1956), Niehans (1963), Enke (1963), Cochrane (1973), Sato and Niho (1971), Lloyd (1969), McIntosh (1974), Katouzian (1974))[1] have highlighted the need for empirically based models upon which policy prescriptions can be studied.

These leave still a number of outstanding issues regarding the two-way linkages between economic and demographic factors. Is the age-structure of the population, which is affected by the birth rate, (Coale (1957)) influential in determining savings rates ? This is important because a higher rate of population growth requires a higher level of investment to achieve a given level of per capita income. Is the rate of growth of population negatively related to per capita living standards ? If it is, the situation in many developing economies today may be self-correcting or merely need a "big push". On the other hand the neo-Malthusian hypothesis of Nelson and Enke holds that less developed countries may be trapped at a low level of equilibrium income with few prospects for growth. Also of interest is whether the labour force participation rate, particularly of women, is affected by family size and fertility. On the production side, it is important to know about returns to scale and the marginal contributions of the factors of production.

It is the purpose of this paper to consider these questions. We present in the next section the six estimated structural equations of a simple economic and demographic econometric model. In Section III

we incorporate the structural equations into a model of economic growth which is studied analytically and then in Section IV by computer simulations. We believe that it is important to attempt both approaches in examining the properties of a model. An analytical approach can draw on the results in the field of growth theory to generate clear predictions about the qualitative behaviour of the system. However, since our model, as it stands, is only analytically tractable if various simplifying assumptions are made, a computer simulation model based on the estimated structural equations will give a more accurate picture of its behaviour. Simulations can also tell us about the time scale in which the events predicted by the model occur. Furthermore we test in Section IV the "low level equilibrium trap" hypothesis of Nelson (1956), and in Section V show the effects of some policies on population size and per capita income.

II.   The Structural Equations

The six structural equations of our model are

$$Y = f_1(WPOP, E) \tag{1}$$

$$\frac{dE}{P} = f_2\left(\frac{Y}{P}, \%YPOP\right) \tag{2}$$

$$CBR = f_3\left(\frac{Y}{P}, \%POPAG, IMRP\right) \tag{3}$$

$$CDR2 = f_4\left(\frac{Y}{P}, \%POPAG\right) \tag{4}$$

$$IMR = f_5\left(\frac{Y}{P}, \%POPAG\right) \tag{5}$$

$$POPAG = f_6\left(\frac{Y}{P}\right) \tag{6}$$

where Y is Gross Domestic Product, $WPOP$ is the population aged 15 to 65, E is total energy consumption, dE/P is the per capita change in energy consumption, $\%YPOP$ is the percentage of the population aged 14 or less, CBR, the crude birth rate, is the number of births per thousand people, $\%POPAG$ is the percentage of people living in the rural sector, $IMRP$ is the number of infant (aged less than one) deaths per thousand people, $CDR2$ is the number of deaths at age 15 or above per thousand people in that age group, and IMR is the number of infant deaths per thousand births.

The model is estimated with data on a cross-section of 82 countries for the year 1968. The 82 countries are divided into four

regions - Africa, Latin America (LA), Asia, - known collectively as the LDC's - and 'Developed Countries' (DC's) - and the structural equations are fitted separately for each region, and for the sample as a whole - the 'World'. The 'World' does not include the Centrally Planned Economies, for which GDP data are not available, nor the Middle East which was excluded due to the combination of a small sample (six countries) and unreliable demographic data. The regressions for the 'World' are shown, for comparison, in the tables with those for the regions, but since these regions turn out to be rather different from each other, we feel that the aggregated sample is not very meaningful and do not discuss it.

The composition of the sample, and the sources of the data, are listed in the Appendix. By sometimes searching through other than U.N. sources for our data, we were able to include in our sample all those non-Centrally Planned, non-Middle Eastern countries with a population in 1968 greater than 1 million people, with the exception of Angola, Madagascar, Nepal, and Hong Kong, for which complete data could not be found.

We return now to the structural equations themselves. The production function (1) is at the core of the growth model developed in section III below, and is of considerable interest in itself because of the information it contains about the marginal productivities of factors and overall returns to scale. However, despite its importance, a production function does not appear in other cross-section macro-econometric models[2]. This is because figures on the value of the capital stock are available for only a handful of economies, and are subject,

in any case, to notorious conceptual and measurement difficulties.
We have attempted to circumvent this problem by using, as a proxy
for the quantity of capital services in production, the total
consumption of energy in each country measured in tons of coal-
equivalents.

The labour services variable, WPOP, should include
most people in the work-force.   It differs from the true input
variable - numbers in employment - according to participation and
unemployment rates, which are not known for all the countries in our
sample, but we expect that, in a cross-section study, any bias due to
this measurement error will not be significant.

Natural resources, or "land", should be included as a third
factor in the production function.   We experimented with FAO data on
the acreage of arable land but without much statistical success,
presumably because the quality of the land input is important as well
as its quantity.   Attempts to allow for this by adding temperature
and rainfall variables did not improve matters, and the third input
is not present in the results in the paper.

The production function was specified to be log-linear i.e.
Cobb-Douglas,in form, and was estimated, as were all the other equations,
by Ordinary Least Squares.   The results are shown in Table 1.   These
regressions appear to have been a success, with very high $\bar{R}^2$'sand
t-ratios.   All coefficients are positive, and their sums suggest
that each of the Less Developed regions suffers from diminishing returns
to scale with respect to the two factors.[3]   The nearly constant

returns enjoyed by the DC's may have been due, in 1968, to their
ability to draw cheaply on the primary resources of the rest of the
world, so that, in effect, output was not confined by the
geographical limits to their territory, the classical source of
decreasing returns. This situation may have changed recently with
the rapid increase in oil and other primary commodity prices.

A useful piece of information to have is the rate at which
technical progress is shifting the production function over time. We
tested for this by running a regression for each region using data on GDP
(in current $ U.S.), energy, and population for 1968 and 1963.
Total population was used as WPOP had not been calculated for the
earlier year. A dummy variable was included exponentially, such
that its logarithm took the value 1 when the data were for 1968,
and 0 for 1963. The results of estimation are shown in Table 2.
Comparison with Table 1 reveals rather stable input coefficients,
which is encouraging. The dummy variable is not particularly
significant, except for the DC's, which may be due to mis-specification
on our part, or to errors in the data caused by distortions in
exchange rate comparisons. For what they are worth, we can get an
idea of the rates of technical progress implied by the coefficients
on the dummy variable. Since the GDP figures are at current prices,
the 1968 production function must be deflated by a 1963 base price
index before it can be compared with the function for 1963. For
example, the multiplicative change in the U.S. GDP price deflator
between 1963 and 1968 was 1.24, which in fact implies that there was
technical <u>regress</u> between the two years, since 1.24 is larger than the
exponential of any of the coefficients of the dummy variable.[4] This lack of

empirical evidence for technical progress does not rule out shifts in the production function due to transfers of technology from DC's to LDC's; note the difference between intercept terms in the regional production functions.

The per capita change in energy consumption (2) is the investment function in our model.[5] The estimates are shown in Table 3. We follow Solow (1956) in assuming a Keynesian savings function, and that savings determine investment, to justify specifying income per head on the right hand side of (2).

The age distribution of the population may also influence investment. Coale and Hoover assumed that higher fertility meant lower aggregate savings. Leff (1969) found that the percentage of the population under 14 was negatively related to the gross savings rate. However, a priori predictions may not be clear-cut. Population growth, via the age distribution, may well discourage capital formation by diverting resources to current consumption of larger families. On the other hand, a rapid increase in numbers of people may stimulate extra efforts to save, especially for the provision of social overhead capital such as schools, hospitals, and rural infrastructure. Simon (1975) found that population density was positively associated with investment in irrigation.

The investment function was specified to be log-linear. Quadratic and linear forms were experimented with, but did not give such good results. In Table 3, the regression equation excluding

the age structure variable is shown for the three regions in which

this variable did not achieve a significant t-ratio.   For the

other region, Latin America, the coefficient of the age structure

variable is positive, suggesting that a high population growth rate

encourages investment.[6]

The $\bar{R}^2$s of the regressions are satisfactory, except,

perhaps, for Latin America.   Per capita GDP is always a significant

explanatory variable.   The values of its coefficient suggest that

the DC's have reached long-run equilibrium savings rate, and that

Latin America is close to doing so.   For Africa and Asia, though,

marginal propensities to save are well above average propensities.

To test the suitability of dE/P as the investment variable

GDFC/P was regressed on dE/P, for the 56 countries for which data

are available.   The dependent variable is defined as the sum from

1964 to 1968 of annual gross domestic capital formation, in $ U.S.,

divided by the average of 1963 and 1968 populations.   The results in Table 4

are reassuring,with coefficients on dE/P that are always

significant, and $\bar{R}^2$s that are reasonably high, given the likely

inadequacies of the capital formation data.

Turning to the demographic equations, we look first at

the determinants of the birth rate.   In the classical Malthusian

model as well as in those of Nelson and Enke, the birth rate is

assumed to be unaffected by living standards.   Leibenstein (1954),

on the other hand, assumes that, as development takes place,

the birth rate will drop because the costs and benefits of children

change. There has been a considerable amount of recent work on

this topic, much of it reported in supplements to the _Journal of_

Political Economy[7]. As a whole, however, these theories do

not generate an unambiguous prediction about the sign of the effect

of per capita income on fertility. Also, it is not clear how

applicable such models are to less developed, non-market oriented

countries (cif. Liebenstein (1974)).

The results of our regressions are set out in Table 5.

Linear, quadratic, and logarithmic specifications were tried - the

log specification was the most successful, and is shown here. Y/P

is significant in Africa and Latin America, with differing signs,

but not in Asia and the DC's. Given the indecisiveness of the

theory, these mixed results are not very surprising.

Two other independent variables may affect fertility and

the regressions including them are shown where the variables were

significant. %POPAG, the proportion of the people living in the

rural sector, may proxy a number of cultural and health factors.[8]

It is significant in all LDC regressions, with a negative sign in

the African equation.

The inclusion of the infant mortality rate is designed to

test the net effect of two opposing factors. On the demand side, it

is possible that parents aim for a certain _completed_ family size,

and so would respond to a fall in infant mortality by reducing the

number of births. On the supply side, however, the two variables

may move in opposite directions if they are both affected by changes in health and sanitation. We find that the coefficient on IMRP is positive and significant for Asia and the DC's, and is large enough to suggest that, given the means of the variables, a fall in infant deaths by one per thousand people would actually reduce births per thousand by <u>more than</u> one. [9] This supports the hypothesis that expected completed family size influences fertility, and is contrary to the claim that it is futile to spend resources on improving health and sanitation in poor countries since lower infant mortality will increase population growth, leading eventually to even greater misery. This we return to later in the policy section of the paper.

In the equation for Africa, the dependent variable is NBR - the "Net Birth Rate" - defined as (CBR - IMRP), which performed better than CBR. This NBR variable implies exact replacement of infant deaths by additional births. The overall explanatory power of the regression for Africa is low, however, compared to the regressions for the other regions.

We may note that these birth rate equations give little support to arguments that, given enough economic development, the population problem will look after itself. Such arguments seem to be based on the strong negative correlation between birth rates and income per head. The simple correlation coefficient (r) between CBR and Y/P is -0.81 for the pooled sample of eighty-two countries, and remains quite significant when the sample is divided into LDC's and DC's, for which the r's are -0.63 and -0.43 respectively. However, our regressions suggest that the simple correlation is spurious -

when the demographic variables %POPAG and IMR are included, the relationship between CBR and Y/P disappears, or becomes positive for three of the four regions. In simple correlations, Y/P is presumably acting as a proxy for the demographic factors.

Ideally one would like death rates for different age groups, each to be estimated as a function of our explanatory variables. Unfortunately we could only do this for infant deaths, due to data limitations. For non-infant deaths we inferred values for CDR1 (death rate of children aged 1 - 14) and CDR 2 (death rate of people aged 15 and over) using crude death rate and age structure data. Because CDR1 and CDR2 are not independently calculated, we only estimated equations for one of them, CDR2. The derivation of CDR1 and CDR2 is more fully described in the Appendix.

The CDR2 regressions (Table 6) reveal a generally negative relationship between income per head and the death rate in LDC's, as one would expect, and a positive coefficient on %POPAG, presumably due to less effective health services in rural areas. On the other hand, in the developed world, income levels are high enough to have no discernible marginal effect on deaths, and life is apparently more healthy in rural areas. In these regressions the log linear specification did not always dominate linear and quadratic forms.

Income per capita also has a negative effect on infant deaths in Asia and the DC's (Table 7), but has a positive coefficient, surprisingly, in the African regression. The %POPAG coefficient again varies in sign. Neither variable was successful in explaining any of

the variation in Latin American IMR's, so no regression equation is
shown for this region.

We turn lastly to the %POPAG regressions (Table 8) while
industrialisation is not a necessary prerequisite to development
we might nevertheless expect the proportion of the population living
in rural agricultural regions to decline as incomes increase. This
may take place, for example, through a combination of Engel's Law,
the expansion of the services sector and changes in tastes towards urban
life-styles. The results reported in Table 8 confirm the expected
inverse relationship.

III.   Models of Growth

Equations (1) to (6), though specified for a period
in time, clearly have implications for the dynamic paths of the
variables.   The current level of income per capita determines,
directly, or indirectly through IMR and POPAG, changes in population
and energy consumption which determine next period's income per capita,
and so on.   We will be particularly concerned to compare the models
generated by our equations with the well-known "low-level equilibrium
trap" theory proposed, but not tested, by Nelson (1956).

Nelson's model is illustrated in Figure 1.   Rates of
growth of GDP and population, denoted here by lower case letters y
and p respectively, are drawn as functions of Y/P.   Population
growth increases with Y/P as the death rate falls up to the point
where 'further increases in per capita income have a negligible effect
on the death rate' (pp. 897-8).   The rate of growth of output, y,
also increases with Y/P, as p increases and as 'savings as a
faction of income increase' (p. 899), though it may eventually turn
down as the savings ratio approaches a constant value, and the
capital/output ratio becomes larger.

If the economy is to the left of T_1,(y-p) is positive -
per capita income is growing.   If the economy is to the right, (y-p)
is negative, so that Y/P will fall. T_1 is a stable equilibrium
at which Y/P is constant, and a "low-level equilibrium trap", if it
occurs at the subsistence level of income where, à la Malthus, p = 0.
The zero population growth assumption is not empirically relevant and

in any case makes little difference to Nelson's model T_2, on the other hand, is an unstable equilibrium - a slight disturbance of Y/P to the left of T_2 will result in a decline to T_1, whereas a movement to the right will lead to growth in Y/P up to T_3, which might be called a 'high-level equilibrium' trap, (though Nelson has doubts about its existence - p. 905n.). If an economy finds itself to the left of T_2, then the aim of its policies must be to shift the y and the p curves in order to move T_2 to the other side. Of course, the possibility cannot be ruled out <u>a priori</u> of the y curve being in the position, say, of the curve y' in Figure 1, so that there are no traps at all.

We may note that, although in Nelson's trap model a lowering of the population growth curve, by, say, a birth control programme, will increase the chances of per capita income growth by moving T_2 to the left, there is no reason to expect a significant simple correlation between (y-p) and p. Given a sample of economies spread out along the Y/P axis, some would have positive, some negative rates of per capita income growth.

It may be noted that Nelson's equilibrium trap is essentially similar to the 'balanced growth' paths of neo-classical growth theory. (Solow, Swan (1956)). In the basic neo-classical model (Figure 2) population growth is assumed constant, and the y curve is always falling as the marginal product of capital diminishes, but, as in Nelson's model, the income growth curve cuts the population growth curve from above, so that the intersection point is a stable equilibrium where Y/P is constant.

We can use the estimated version of equations (1) through (6) to test the predictions of balanced growth generated by these theoretical models. For analytical tractability it will be assumed that the age distribution is fixed, i.e.

$$WPOP = \rho POP,$$

where ρ is a constant. Then the production function (1) is written

$$Y = A\rho^{\alpha} P^{\alpha} E^{\beta} \tag{1}'$$

Differentiating with respect to time (t) yields

$$\frac{dY}{dt} = \frac{dA}{dt} P^{\alpha} E^{\beta} + \alpha \frac{d\rho}{dt} \rho^{\alpha-1} AP^{\alpha} E^{\beta} + \frac{dP}{dt} A\rho^{\alpha} P^{\alpha-1} E^{\beta}$$

$$+ \beta \frac{dE}{dt} A \rho^{\alpha} P^{\alpha} E^{\beta-1}$$

so that, as $d\rho/dt = 0$,

$$y = a + \alpha p + \beta e \tag{7}$$

where lower case letters are rates of growth (e.g. $y \equiv \frac{dY}{dt}/Y$). Looking first at the energy growth term, we write the estimated specification of equation (2)

$$\frac{dE}{dt}/P = B\left(\frac{Y}{P}\right)^{\delta} \tag{2}'$$

incorporating the (assumed constant) age structure term into the intercept B. (1)' can be written

$$Y = A \rho^{\alpha} P^{1-\beta} E^{\beta} P^{\theta}, \qquad \theta \equiv \alpha + \beta - 1 \tag{1}''$$

so that
$$\frac{Y}{P} = A\rho^{\alpha} \left(\frac{E}{P}\right)^{\beta} p^{\Theta}$$

and
$$\frac{P}{E} = A^{1/\beta} \rho^{\alpha/\beta} \left(\frac{Y}{p}\right)^{-1/\beta} p^{\Theta/\beta} \tag{8}$$

Therefore

$$e \equiv \frac{dE}{dt}/E = \frac{\frac{dE}{dt}}{P} \cdot \frac{P}{E} = C \left(\frac{Y}{P}\right)^{\delta - 1/\beta} p^{\Theta/\beta} \tag{9}$$

where

$$C = A^{1/\beta} \rho^{\alpha/\beta} B$$

Consider first the developed countries. These come very close to meeting the conditions of the basic Solow-Swan model. With returns to scale ($\alpha + \beta$) and savings coefficient δ not significantly different from one, (9) becomes

$$e = C \left(\frac{Y}{P}\right)^{1 - 1/\beta}$$

$$= 1.334 \left(\frac{Y}{P}\right)^{-0.39} \tag{9'}$$

substituting in C the mean value of ρ for the DC's.
To obtain an expression for population growth, p , is more difficult, since although p = CBR-CDR, our estimated demographic functions do not sum and subtract into simple expressions. To obtain a sort of synthetic expression for population growth, for the DC's, we took the difference between the values of CBR and CDR predicted by our

regression equations, and regressed this difference on Y/P:

$$p = 0.092 \left(\frac{Y}{P}\right)^{-0.31} \qquad R^2 = 0.61 \tag{10}$$

Balanced growth occurs, if

$$y - p = a + (\alpha - 1) p + \beta e = 0 \tag{11}$$

If we assume that there is no technical progress, so that a = 0, and substitute in (9)' and (10), (11) becomes

$$0.957 \left(\frac{Y}{P}\right)^{-0.39} - 0.068 \left(\frac{Y}{P}\right)^{-0.31} = 0,$$

or, re-arranging,

$$\frac{Y}{P} = (14.074)^{12.5} \tag{12}$$

- a very large number indeed !   It seems that the average DC is a long way from being 'trapped' into balanced growth.

For the LDC regions, our attempts to estimate a logarithmic population growth equation were not successful - the relationships are apparently more complicated. Therefore we will simply assume that population growth is constant at some rate n.

Unlike the DC's, none of the LDC regions appear to have constant returns to scale or constant average savings propensities. Swan (1956) showed how balanced growth could be redefined to allow for non-constant returns to scale, when the production function is Cobb-Douglas, and Solow (1956) demonstrates that a variable savings rate by itself does not cause problems. Here we show how to deal with non-constant returns and variable savings rates when they occur together in the model.

Define a variable

$$M \equiv P^{(1/\beta - \delta + \Theta/\beta) / (1/\beta - \delta)} \tag{13}$$

so

$$P \equiv M^{(1/\beta - \delta) / (1/\beta - \delta + \Theta/\beta)} \tag{14}$$

Now (9) becomes

$$e = C(\frac{Y}{M})^{\delta - 1/\beta} \tag{9}''$$

If P is growing at the constant rate n, then M grows at the rate

$$m = n(1/\beta - \delta + \Theta/\beta) / (1/\beta - \delta) \tag{15}$$

From (7) (putting $a = 0$)

$$y = \beta C(\frac{Y}{M})^{\delta - 1/\beta} + \alpha n \tag{16}$$

We can look for a balanced growth path where

$$y = m$$

since y and m are both functions (in the case of m, a constant, trivially so)of Y/M.   Put

$$y - m = \beta C \left(\frac{Y}{M}\right)^{\delta - 1/\beta} + \dot{n}(\alpha - (1/\beta - \delta + \Theta/\beta)/(1/\beta - \delta))$$

$$= \beta C \left(\frac{Y}{M}\right)^{\delta - 1/\beta} + n(\alpha - \mu) = 0 \qquad (17),$$

writing $(\alpha - \mu)$ for the second term in brackets, which must be negative if there is to be a balanced-growth level of Y/M.

These parameters can be calculated from the estimated equations for each LDC region.

For Africa, $\alpha - \mu =$ 0.258, so that there is no positive value of Y/M that will satisfy (17) – Y will always grow faster than M.   However, since $\mu =$ 0.177 for Africa, M is growing at a rate that is only about 1/6 of the population growth rate, n, so that y may well be less than n and per capita income, Y/P, be falling.

In Latin America $(\alpha - \mu) = -0.405$, so there is a positive solution to (17) giving the constant value of Y/M that will eventually be reached.   In this balanced growth state Y and M are growing at the rate $n\mu$, so that the equilibrium growth rate of income per capita,

$$y - p = n(\mu - 1) = -0.595 n \qquad (18),$$

is actually negative.

The main cause of this decline is decreasing returns to scale. If $\alpha + \beta$ were equal to one, θ would be zero and μ would equal one, so that the balanced growth path would be an orthodox trap with Y/P constant.

In Asia we find that $(\alpha - \mu)$ is a very large negative number, $- 29.507$. This occurs because $1/\beta - \delta$ is very small (and is negative), due to the very strongly increasing propensity to save out of income. There is a positive solution to (17), by as y is now an increasing function of Y/P (cf.(16)), and m is constant, the y-curve cuts m from below, so that the equilibrium is unstable - if the economy were not exactly on the balanced growth path, it would be moving further away from it.

With their simplifying assumptions about population growth, the calculations of this section are not a complete representation of our model. Nor do they provide any information on the time scale of economic events - the speed at which balanced growth paths are approached.

These matters are dealt with in the next section, which reports the results of using the computer to fully solve the growth model generated by all six structural equations.

However, the analytical calculations do show that a variety of growth paths may be expected. They suggest that continued growth in per capita incomes is likely in the Developed Countries, but possibly not in the LDC regions, where standards of living may, at least eventually, decline.

IV.   Simulations with the Estimated Model

In the previous section, the full estimated model (equations 1-6) was simplified so that it could be made analytically tractable. However, the **full** model can be dealt with non-analytically using the computer to calculate actual values taken by the functions. We performed two types of exercises. First we calculated y, p and e for a range of Y/P values. Secondly, we ran simulations of the time paths of the model's variables.

Results of the first series of calculations are plotted in Figure 3. The curves were drawn by hand through a large number of calculated points. These are for a "regional stereotype", which is a hypothetical country in each region with the average population and age-structure and the estimated structural equation parameters for that region.[10] They show the rates of e, p and y which the steroetype would be experiencing at various levels of Y/P. These curves will be shifting over time with, for example, the scale effects of population increase unlike the Nelson diagrams and so will not generate fixed equilibrium, or "trap" levels of Y/P. However, they give an indication of whether a stereotype is likely to experience a low level equilibrium trap and also the relevance of the shapes and positions of the curves in the Nelson model.

In examining Figure 3, it will be noted that in all the less-developed regions intersections exist where y = p. In Africa this occurs at \$225-\$250 with p = y ≃ 2.8% and, in Latin America at a higher level of income, around \$400 and p = y ≃ 3%. However, a

country which found itself at or near these points would not
necessarily remain there. Indeed, since both cases involve rates
of growth of population and energy which are unequal and above zero,
the country is sure to eventually experience a _decline_ in Y/P.
This is because, although E/P increases due to e > p population
is also increasing and the effects of diminishing returns to scale
shift the e and y curves. In the Nelson paper, it is suggested
that traps occur at a subsistence level of income such that p = o.
However, our evidence suggests that while such traps exist, they
are perhaps all the more depressing since they do not constitute
long run equilibriums but merely point to upper limits on the
attainable level of Y/P.[11]

In Asia, and Latin America there are unstable traps where
the p curve intersects the y curve from above. These occur at
Y/P =$725 and p = y $\simeq$ 1.5% for Asia and Y/P=$850 and p = y $\simeq$ 1.7%
in Latin America. Thus,in addition to the role played by the positive
rates of growth of population and energy at these levels, there are
additional factors operating to make these points upper bounds on Y/P.
However, a region which found itself just to the right of these points
would secularly expand since y > p. In Asia the situation is
helped by the fact that e increased with Y/P. This is because
δ - 1/β, the exponent on Y/P in the e function (c.f. equation (9)),
is positive (.0216) here whereas in Africa, Latin America and even
the Developed Countries it is negative (-.2930, -.7761, and -.3939
respectively).

In the Developed Countries, no trap exists and while e and consequently y decline with Y/P, p remains relatively constant and well below y. This means, for example, that the rate of growth of income per head, y - p, is approximately 2.2% at $4,500.

Our model's structural equations are different from those implied by Nelson and Enke, so the model behaves differently. For example, at no level of Y/P is either our "capital" (energy) growth relation or population growth negative. Normally y and e decline with income which also effects both birth and death rates in our model. Nevertheless, despite these differences, the interesting hypothesis that there might exist in less developed regions ceiling levels of income per head which will not be exceeded cannot be rejected.

The model can also be used to generate dynamic simulations of the time paths of all the variables. Starting with the observed (1968) values the model can be solved to predict the changes in variables for the next period which are then plugged in to generate further changes, and so on. With our three death rate variables (CDR1, CDR2, and IMR), the birth rate, and the given age distribution of the population we can predict the age distribution in the following time period. This will also generate p and with the equation for e and the production function predict GDP in the next time period. We postulate that the parameters of the model which have been estimated with cross section data are applicable over time. No particular significance is attached to the actual values of the numbers generated; we are interested, rather, in the orders of magnitude.

We just report here the results for a regional sterotype in
the year 2,000 for the variables population and GDP/POP.|12| These are
given in row 2 of Table 11. Starting (1968) values for all the simula-
tions are shown in row 1 of the same table.

In Africa, which starts at a very low per capita income
of $129, we see that over the simulation period income grows to $162.
With income per head growing at less than 1% per year the stereotype
country does not reach the upper bound of Y/P suggested in Figure 3
before A.D. 2,000. However,a larger simulation revealed a maximum
Y/P of $177.2 with a population of 51.3 million in the year 2,039.
In simulations performed with particular countries in Africa the
picture is different. In all cases, the time path of GDP/POP depended
crucially on the initial conditions facing the country, particularly
the difference between the rate of growth of the working population (w)
and of energy (e). Since $y = \alpha w + \beta e$ and $\alpha < \beta$, in countries
where $e >> w$ it is not surprising that Y/P grows for some time.
Yet all of these countries will eventually reach a maximum level of
income, since with higher incomes e falls and p rises. Indeed,
in four African countries the simulations indicate secularly falling
GDP/POP and in three a maximum level of income is reached in about
30 years. For example, Ghana which starts in 1968 with a per
capita income of $241 and 8.38 million people, reaches a maximum
in 2,002 at $270 and 21 million people.

In Latin America, the regional stereotype reaches a trap
about 1990 at $498[13]. This compares with the static curves of
Figure 3 which put the maximum level of income between $400-$425.

Again simulations with individual countries differed from the regional stereotype although the pattern was similar. Nine countries' income reached a maximum during the simulation period and two had secularly declining incomes. In the rest, the rate of growth of income per head was falling.

In Asia, where the static calculations indicated that a regional stereotype with GDP/POP < $725 would experience falling income per head, income indeed falls from $108 in 1968 to $74 in 2,000. In six of the individual country simulations income per head fell and in one (West Malaysia) it grew but reached a maximum. In the rest, incomes rise, but again the rate of growth of income per head falls.

The Developed Country stereotype, as expected from Figure 3, appears to experience no problems in the near future as income per head continues to increase in the simulations. However, because e falls with income per head, y also falls so that the rate of growth of income per head, as in the less developed countries, also falls.

These simulations may be compared with the analytic results of Section III. As predicted, the DC's do not reach balanced growth in a reasonable time period.[14] The comparison is less valid for the LDC's, for which the analytical model was simplified, but the suggestion from section III that in the less developed regions income per head might, at least eventually, decline does receive support from the simulations.

V.   Policy

        In this section we examine the impact of ten demographic
policy experiments on per capita income.   These assumed costless
and immediate reductions in the birth rate, child death rates
(CDR1), and the infant mortality rate (IMR) and increases in the
rate of energy growth.   The impacts of these policies in the year
2,000 are reported in Table 11, rows 3-12.

        We did four birth rate experiments which consisted of
reductions in CBR by various amounts as well as holding the birth
rate at its starting level.   Beginning with the   CBR- constant
policy, we see that in Africa, Latin America and the Developed
Countries, incomes are marginally lower in the year 2,000 while
in Asia income is marginally higher.   This is because in the former
regions, a marginal reduction in the birth rate would otherwise
have taken place, while in Asia a slight increase would have been
experienced.

        This experiment contrasts with the more dramatic changes
induced by the three other experiments when the crude birth rate
was lowered by 10 and 15 births per 1,000 population and finally
in the zero population growth (ZPG) experiment by enough to keep
$p = 0$.   The key to the effectiveness of these policies lies in
their effect on the age structure of the population.   By reducing
the number of children without immediately affecting the working
population, they cause an immediate increase in per capita income.

Also, from the energy growth equation (9)

we can see that a <u>ceteris paribus</u> rise in ρ , the ratio of the

working population (15-65) to the total population, increases e.

Since p is simultaneously lower, the rate of growth of per

capita income must increase as $y - p = \rho (\alpha - 1) p + \beta e$ and

$\alpha < 1.$

In these experiments we see that in all regions GDP/POP is

increased by a policy of lowering the birth rate.   The impact is

all the more impressive in Asia where, recall, income was seen to fall

throughout the simulation period.   However, only in the ZPG experiment

was the reduction sufficient to avoid a trap in Asia.   In the other

two experiments, GDP/POP eventually declines within the period.

The idea of calculating cost-benefit ratios and rates of

return on birth reduction policies has been discussed by various authors,

particularly Enke.[15]   To give an idea of the order of magnitude of

the benefits involved, we calculated the undiscounted benefits of

births avoided due to a policy of reducing the birth rate by 10

births per 1,000 population.   The benefits were calculated over a

five and ten year period following Enke and Suits' <u>et. al</u>. formula:

$$V = \frac{\sum_{t=1}^{n} \{P_t \ (\tilde{Y}/\tilde{P}_t - Y/P_t)\}}{\sum_{t=1}^{n} \{P_t \ (CBR_t) - \tilde{P}_t \ (\tilde{CBR}_t)\}}$$

where   V   =   average value per birth avoided

CBR_t =   birth rate at time t without the policy

$\tilde{CBR}_t$ =   "   "   "   "   " with the policy

$\tilde{P}_t$ =   population at t with the policy

P_t =   population at t without the policy

Y/P_t =   per capita income at t without the policy

$\tilde{Y}/\tilde{P}_t$ =   per capita income at t with the policy

n   =   5 or 10 years

The numerator of this expression calculates the difference between GDP resulting from a birth control policy and the level of GDP that would be required to provide the smaller (post policy) population with the per capita GDP which would have occurred in the absence of the policy.   The denominator is simply the number of averted births.

The results are set out in Table 10 .   These are reported only for illustrative purposes and cannot be directly compared to other more rigorous calculations.   However, the size of the benefits is sufficient to suggest high returns available from this sort of policy given that the cost of preventing a birth may be around $100.[16]

We turn now to policy experiments 5 and 6, where the child mortality levels are reduced; these were conducted to illustrate the fallacy pointed out by Coale and Hoover in the "burden of dependency" argument. [17] The argument offered is that with high child mortality the economy must support a large number of relatively unproductive children who never reach their full economically active age. Therefore it is argued that a reduction in mortality will avoid this "waste" so that the "burden of dependency" is reduced. However, as Coale and Hoover point out, the avoidance of these "wasted" childrens' deaths not only allows them to mature and become fully active in the labour force, but also to become parents. The larger number of parents, if fertility remains unchanged, will produce more children and the dependency burden will actually increase slightly. Thus considering the effects of reducing CDR1 by 8 deaths per 1,000, the dependency rate increases in all regions as indicated in Table 9 .   The effects on GDP/POP here are symmetric with those experienced under a birth reduction policy, except that the change in the dependency rate, which will affect e $_\lambda$ is not as marked.

An alternative policy which works through mortality changes is to reduce the infant mortality rate. This has been proposed because of its obvious humanitarian benefits as well as its alleged indirect benefits towards development. Hence if the birth rate varies directly with infant mortality, then a reduction in the infant mortality rate not only reduces the trauma and suffering of infant deaths but also reduces the birth rate. Of course the important thing with respect to the economy is the number of surviving children.

If families undercompensate for child deaths then a reduction in child

mortality will not bring about a corresponding lowering of the birth

rate so that the number of surviving children actually increases. In

our experiements it will be noted that policies 7 and 8 have no

effect in Africa where, infant deaths are exactly compensated for

in the estimated birth rate equation.   In Latin America, where IMR

has no effect on births, the policy is similar to that of reducing

CDR1 and while Table 11 actually shows a slight increase in GDP/POP

in year 2,000 under policies 7 and 8, this is due to the influence

of the percentage of the population under 15 years on dE/P which was

found to be very strong in Latin America.   Hence, while p is

increased by the mortality reduction e is increased by even more

so that income per head increased.   The overall effect is to raise

and flatten the time path of GDP/POP which reaches a maximum e.g. in 8

in 2001 rather than 1996.   In Asia we see that the policy has been

effective in raising incomes, but the gains are not very large and

the tendency for incomes to fall over time is not reversed.   While

population is lower, the effect on the age distribution is not

great;   for example, the dependency rate in 2003 is .708 in contrast

with .762 with no policy.   The picture in the Developed Country

stereotype is similar.

We turn now to the last experiments where we increased

e by one percentage point in experiment 9 and tried a two-pronged

policy in experiment 10 of increasing e by one percentage point

and decreasing CBR by 15.   The results of the former policy are

relatively straightforward. Raising e increases y and hence

Y/P in all regions.   In Latin America the policy raises e sufficiently

to avoid the maximum level of Y/P which it usually hits in the simulation period (see Table 11). However the policy was not sufficiently strong to pull Asia out of its trap of declining income per head.

An interesting experiment was 10 where we simultaneously raised e and lowered CBR. Of all the experiments conducted, this one had the greatest effect on Y/P. Recall in our earlier discussion of reductions in CBR (experiments 2-4) that its effects in the age structure tended to increase e and hence Y/P. Here we are able to observe this complimentarity. The increases in Y/P in the year 2000 due to policy 10 were $102.3, $101.4, $47.0 and $3765.5 in Africa, Latin America, Asia and the DC's respectively. The sums of the effects of policy 3(CBR-15) and of policy 9 (e + 0.01) on Y/P in year 2,000 are $93.5, $83.3, $12.3 and $3279.8 respectively. All of these are less than the effects of the joint policy 10.

VI.   Conclusions

In this paper we have attempted to answer a number of questions about the links between economic and demographic variables as well as to address some of the larger policy issues. The model's size was sometimes deliberately constrained so that its parameters could be estimated from a wider data base than most previous studies. Another advantage of a simple model is that it is easier to deal with analytically and in simulations. One consequence of our approach is that our implicit welfare variable is income per head so that we have neglected other important variables such as consumption, employment and the distribution of income. A feature of our model is that we have taken account of the age structures of the population by using actual rather than inferred age structure data.

Our structural equations show that many of the supposed relationships between demographic and economic variables which are often assumed a priori or based on pooled cross section regressions or simple correlations are not supported when the sample is split up into groups of homogeneous countries. For example, unlike Leff, we find that the age structure is only important in explaining   savings /investment behaviour in Latin America.   Even for the pooled (World) sample, as in Latin America, we find a positive effect of a young population rather than the negative one found by Leff.   Also, in considering the effects of income on birth and death rates we find that there is no clear sign pattern and that the often supposed negative relationship may be due to not considering the degree of urbanization of the economy, as well as the lumping together of developed and less developed regions.   We also

confirm that infant mortality has a significant positive relation-
ship with the birth rate which suggests another policy tool for
lowering the rate of population increase.   Finally, our confirmation
of decreasing returns to scale in the less developed regions implies
that the absolute size of the population is important.

The estimated model was also studied as a system.   A growth
model incorporating empirically estimated parameters was solved for
the different regions.   Stable balanced growth paths were found for
the developed countries and Latin America, but not for Africa and Asia.
We were also able to find empirical support for the low-level equilibrium
trap hypotheses of Nelson, although not for the full Malthusian assumption
that such traps occur where the rate of growth of population is zero.
Consequently our "traps" do not represent equilibrium but ceiling levels
of income, as confirmed in our dynamic simulations.

Finally we considered the effects of various demographic
policies on per capita income.   We confirm that birth control does
have a positive effect and that implied cost/benefit ratios of averted
births are high.   Furthermore, complimentarity is observed between
policies designed to raise investment and those designed to lower
births.

Footnotes:

[1]   For an excellent review of this literature see Pitchford (1974).

[2]   For example, Suits et. al. (1975) have the growth in GDP as a function solely of the share of capital formation in GDP. This formulation clearly limits the extent to which they may allow for the contribution of population to output and growth.

[3]   The omission of the land variable may mean that the true returns to population and energy are even lower than those found here. 'Land' is likely to be correlated with both the included variables, which will bias upwards the estimated coefficients of these variables (cf. Johnston, Econometric Methods, second edition, pp. 168-9).

[4]   The exponentials are 1.107 for Africa, 1,139 for Latin America, 1,127 for Asia, and 1.192 for the DC's.

[5]   To reduce the influence of purely cyclical factors, the change in energy consumption is taken over a five year period. dE/P is defined as the difference between total energy consumption in 1968 and in 1963, divided by the average of 1968 and 1963 population, all divided by 5, to get back to a one-year time period. Correspondingly, the Y/P variable in the equation is the average of 1968 and 1963 GDP, divided by the average population, with 1963 GDP converted into 1968 prices by being multiplied by the GDP price deflator, 1.24.

[6]   It should be noted that higher investment rates are not necessarily a good thing. The proper welfare variable is consumption per head, not income per head, and more investment means less current consumption, which may not be judged compensated for by higher future levels of consumption resulting from the extra investment.

[7]   Journal of Political Economy, March/April 1973, 1974.

[8]   For example, fertility may be higher in the countryside as children may be a source of cheap labour on the farms and mothers may be able to combine (non-market) farm work with child-rearingwhereas in the urban sector this is more difficult. However, if health conditions are poorer in rural areas, then natural fecundity may be adversely affected.

[9] The mean value of IMRP in Asia is about 3. One infant death averted per thousand people would therefore represent a fall in IMRP of 25%, which in turn, according to Table 5, would induce a fall in CBR of 25 x 0.172 = 4.31%. With the mean of CBR equal to 39, this implies a reduction in the number of births of about 1.7 per thousand people.

[10] In both these and the dynamic simulations, bounds were put on some of the variables. These were:

$$10 \leq \%POPAG \leq 100 \quad \text{in the LDC's}$$
$$5 \leq \%POPAG \leq 100 \quad \text{in the DC's}$$
$$20 \leq CBR \leq 80 \quad \text{in the LDC's}$$
$$CBR \leq 80 \quad \text{in the DC's}$$
$$CDR \geq 10 \quad \text{in all regions}$$
$$\Delta CDR/\Delta(Y/P) \leq 0 \quad \text{in Asia}$$

[11] Enke (1963) also analyses this possibility which occurs at the level of Y/P which a country attains when it runs into his "zero-improvement curve".

[12] In fact we performed simulations also for individual countries which are not fully reported here. The age-structure was determined in each period using the calculated death and birth rates and by employing standard demographic techniques.

[13] It will be noted that Latin America, which starts in 1968 with Y/P of $ 60 should, according to Figure 3 experience falling income since it is to the right of the trap. However, the calculations for Figure 3 and these simulations are not strictly comparable as the constant terms in the structural equations differ.

[14] For example after 500 years, Y/P is over $50,000 and still growing at 0.1%.

[15] See Enke (1971), Simon (1969) Zaidon (1971) and Suits et. al. (1975).

[16] See Simon (1970) or Enke (1966).

[17] Coale and Hoover (1958) p. 23.

Table 1: Estimated Structural Equations : Production Functions (t-values in parentheses)

	Dependent Variable	Constant	Ln(WPOP)	Ln(E)	$\bar{R}^2$
Africa	LN(Y)	6.529 (54.36)	0.435 (5.98)	0.455 (10.23)	0.925
Latin America	LN(Y)	6.774 (10.87)	0.393 (4.94)	0.524 (9.16)	0.980
Asia	LN(Y)	6.8201 (38.72)	0.357 (3.89)	0.393 (3.76)	0.932
DC's	LN(Y)	6.841 (53.88)	0.263 (3.33)	0.717 (10.85)	0.980
World	LN(Y)	6.905 (11.62)	0.250 (6.38)	0.65 (30.42)	0.696

Table 2: Estimated Production Function with Pooled 1963 and 1968 observations

	Dependent Variable	Constant	Dummy	Ln(POP)	Ln(E)	$\bar{R}^2$
Africa	Ln(GDP)	6.050 (42.38)	0.102 (1.22)	0.473 (7.97)	0.441 (12.17)	.907
Latin America	Ln(GDP)	6.397 (65.9)	0.130 (1.74)	0.402 (6.05)	0.502 (10.9)	.970
Asia	Ln(GDP)	6.394 (37.24)	0.119 (0.97)	0.387 (5.53)	0.383 (4.70)	.925
Developed Countries	Ln(GDP)	6.592 (78.6)	0.176 (2.68)	0.267 (4.32)	0.700 (14.15)	.977

Table 3:   Estimated Structural Equations : Investment

	Dependent Variable	Constant	Ln(Y/P)	Ln(%YPOP)	$\bar{R}^2$
Africa	Ln (dE/P)	−14.654 (−12.39)	1.903 (7.98)		0.723
Latin America	Ln (dE/P)	− 7.793 (− 3.29)	1.1301 (2.58)	3.183 (2.35)	0.267
Asia	Ln(dE/P)	−17.61₁ (− 5.43)	2.5655 (4.03)		0.629
Developed Countries	Ln(dE/P)	− 9.249 (− 6.63)	1·000 (5.35)		0.568
World	Ln(dE/P)	−11.857 (− 2.61)	1.507 (14.42)	0.905 (2.03)	0.815

Table 4:   Testing the Relationship Between dE/P and capital Formation

	Dependent Variable	Constant	ln(dE/P)	dE/P	$\bar{R}^2$
Africa (7)*	ln(GDFC/P)	8.009 (4.77)	0.659 (2.02)		0.340
Latin America (16)	GDFC/P	192.841 (3.60)		4497.46	0.547
Asia (8)	ln(GDFC/P)	6.503 (19.56)	0.404 (5.71)		0.818
Developed Countries (21)	ln(GDFC/P)	8.719 (36.82)	0.614 (5.0)		0.545
World (52)	ln(GDFC/P)	8.739 (45.90)	0.791 (14.75)		0.810

* number of observations.

Table 5:   Estimated Structural Equations : Birth Rate

	Dependent Variable	Constant	Ln(Y/P)	Ln(%POPAG)	Ln(IMRP)	$\bar{R}^2$
Africa	Ln(NBR)	4.838 (9.07)	- .05₂ (-1.91)	- 0.200 (- 1.97)		0.087
Latin America	Ln(CBR)	- 0.213 (- 0.33)	0.188 (2.81)	0.732 (9.66)		0.897
Asia	Ln(CBR)	1.817 (2.02)	0.131 (1.12)	0.253 (2.97)	0.172 (2.74)	0.805
Developed Countries	Ln(CBR)	2.958 (6.17)	0.024 (.34)		0.235 (2.96)	0.375
World	Ln(CBR)	3.113 (9.33)	-0.040 (-1.14)	0.138 (3.03)	0.199 (6.36)	0.870

Table 6:   Estimated Structural Equations :   Death Rate

	Dependent Variable	Constant	Y/P	$(Y/P)^2$	%POPAG	Ln(Y/P)	Ln(%POPAG)	$\bar{R}^2$
Africa	Ln(CDR2)	2.206 (-1.25)				-0.231 (-2.57)	0.394 (1.17)	.366
Latin America	CDR2	2.738 (1.07)			0.15332 (2.90)			.291
Asia	CDR2	4.229 (0.92)	-.0306 (-2.76)	0.000041 (3.22)	0.1509 (2.52)			.755
Developed Countries	Ln(CDR2)	2.785 (19.37)					- 0.113 (-2.09)	.133
World	CDR2	- 1.993 (-0.63)	0.00569 (2.08)	-.0000007 (-1.04)	0.2652 (6.78)			.548

Table 7:   Estimated Structural Equations :   Infant Mortality

	Dependent Variable	Constant	Ln(Y/P)	Ln(%POPAG)	Y/P	%POPAG	$\bar{R}^2$
Africa	IMR	-91.233 (- 0.51)			0.2024 (1.78)	1.9044 (2.18)	0.100
Latin America							
Asia	Ln (IMR)	12.613 (3.84)	- 1.286 (- 3.47)	-0.471 (-1.19)			0.623
Developed Countries	Ln (IMR)	6.875 (8.02)	- 0.507 (- 4.45)				0.461
World	Ln (IMR)	5.567 (5.60)	- 0.409 (-4.43)	0.255 (1.95)			0.697

Table 8:   Estimated Structural Equations : %POPAG

	Dependent Variable	Constant	Y/P	$\bar{R}^2$
Africa	%POPAG	90.2388 (25.79)	−0.07521 (−3.69)	0.310
Latin America	%POPAG	71.7193 (16.09)	−0.05681 (−6.37)	0.687
Asia	%POPAG	77.18 (19.31)	−0.0914 (−6.50)	0.805
Developed Countries	%POPAG	35.7375 (7.87)	−0.00952 (−4.6)	0.478
World	%POPAG	69.6024 (29.71)	−0.02482 (−12.67)	0.663

Table 9 :   Child Dependency Rates in 2003

	No Policy	CBR-10	CDR1-8
Africa	.890	.683	.921
Latin America	.787	.569	.817
Asia	.762	.555	.783
Developed Countries	.448	.219	.458

Table 10:   Undiscounted Average Value of an Avoided Birth
(CBR Reduced by 10)

	After 5 Years	After 10 Years
Africa	$ 263	$ 596
Latin America	$ 803	$1078
Asia	$ 197	$ 446

	AFRICA		LATIN AMERICA		ASIA		DEVELOPED COUNTRIES	
	POP	GDP/POP	POP	GDP/POP	POP	GDP/POP	POP	GDP/POP
Starting value (1968)	8.30	129.2	12.98	460.8	82.8	108.8	28.81	2609.5
Value in 2000 with: No Policy	18.69	163.1	31.50	496.1**	187.2	74.2	37.47	4917.9
(1) CBR Constant	18.73	162.6	32.04	495.3	182.5	76.0	38.07	4857.3
(2) CBR-10	14.47	207.9	23.28	497.2	141.9	94.3	26.57***	6323.1
(3) CBR-15	12.69	234.9	19.94	507.3	122.9	107.0	22.31***	7161.5
(4) ZPG	8.30	372.8	12.98	589.3	82.8	153.1	28.81	5969.2
(5) CDR1-5	19.92	155.9	33.56	490.1	198.3	72.2	38.93	4804.2
(6) CDR1-8	20.71	151.7	34.88	486.5	205.4	69.4	39.86	4735.1
(7) IMR-25	18.69	163.1†	32.51	496.9	180.6	76.4	37.27	4931.0*
(8) IMR-50	18.69	163.1†	35.56	497.8	168.1	81.2	37.27	4931.0*
(9) e + 0.01	18.82	184.8	30.99	568.2	188.35	83.7	37.47	5953.2
(10) e + 0.01 } CBR-15	12.79	265.4	19.49	597.5	123.07	121.2††	22.3***	8683.4

* IMR = 20 ;   ** Reaches maximum in 1970 at 498.1 ;   *** Policy induces negative population growth;
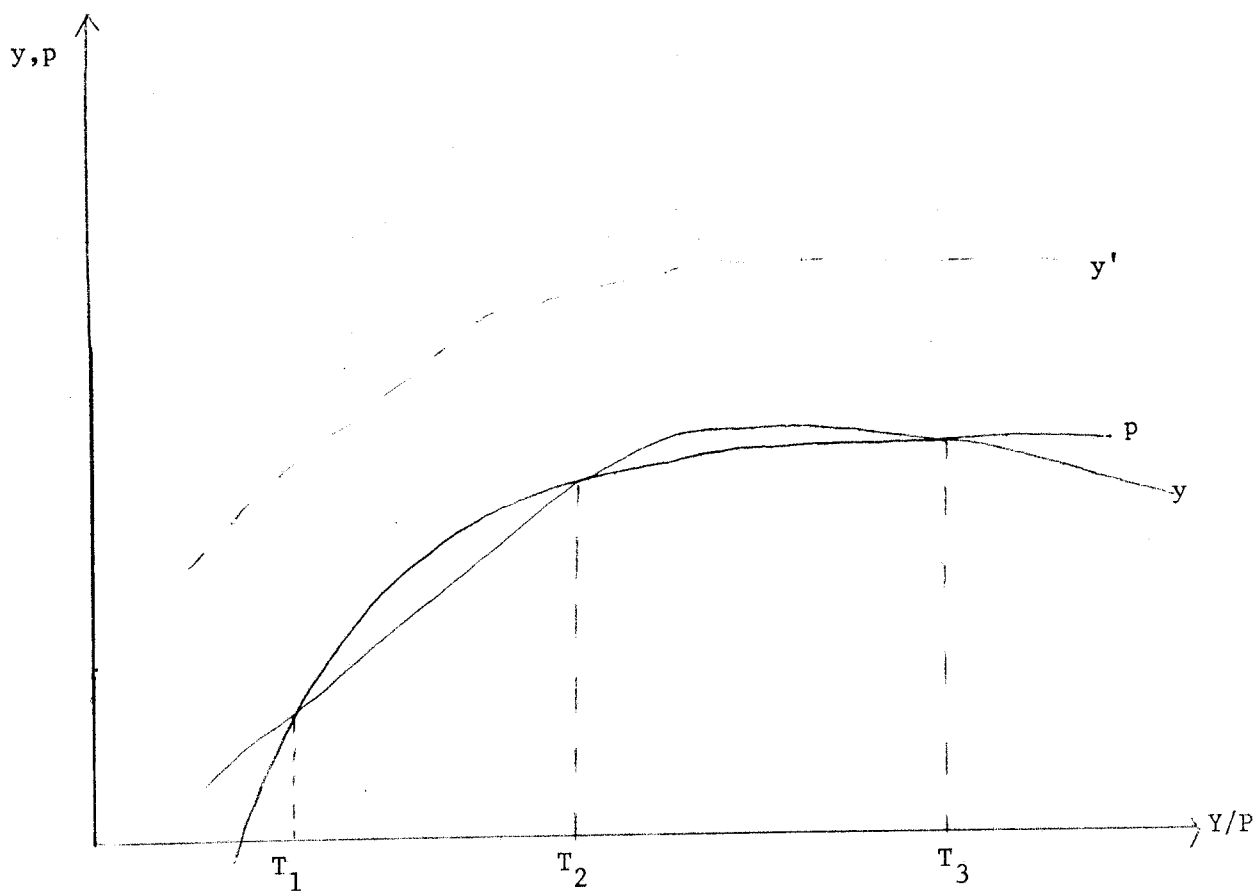† NBR used ;   †† Reaches maximum in 1993 at 121.5 ;

Figure 1:   Nelson's Model

Figure 2:   Neoclassical Model
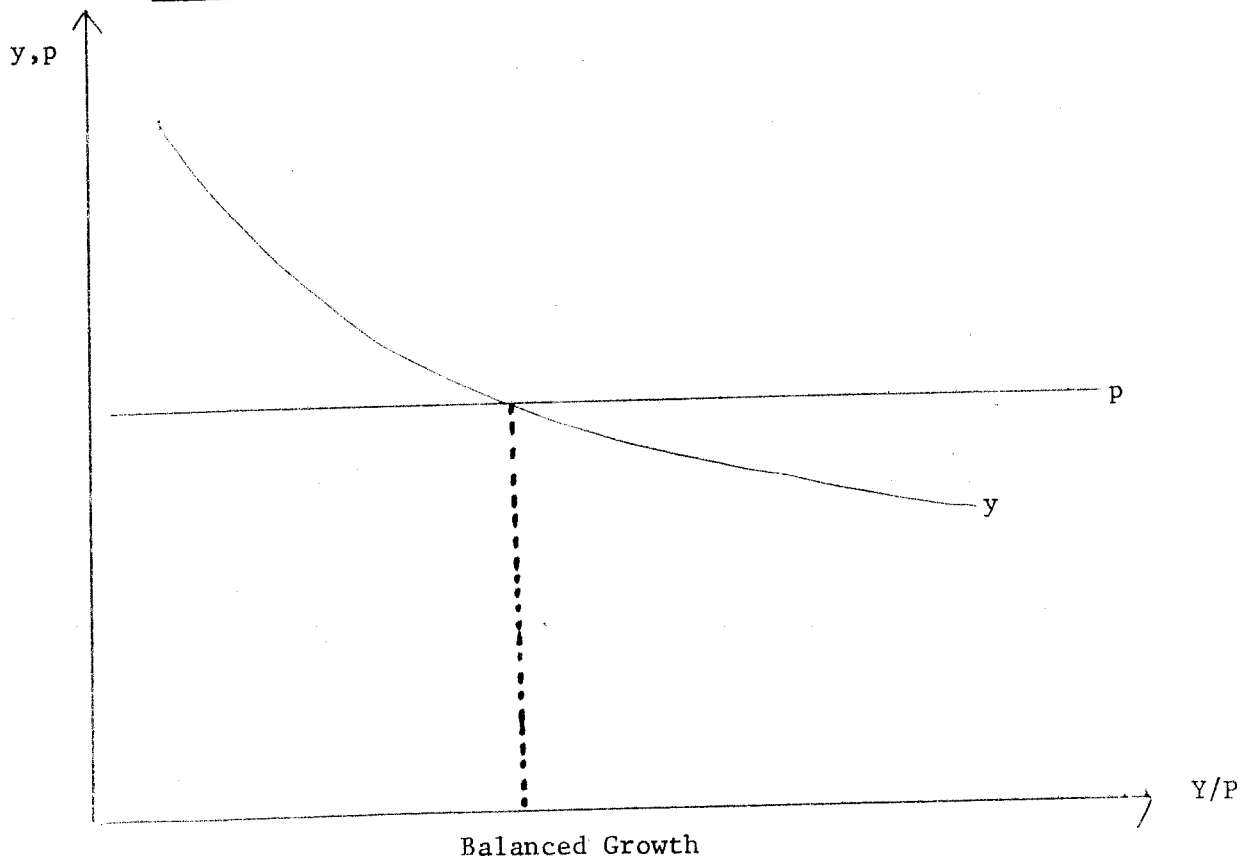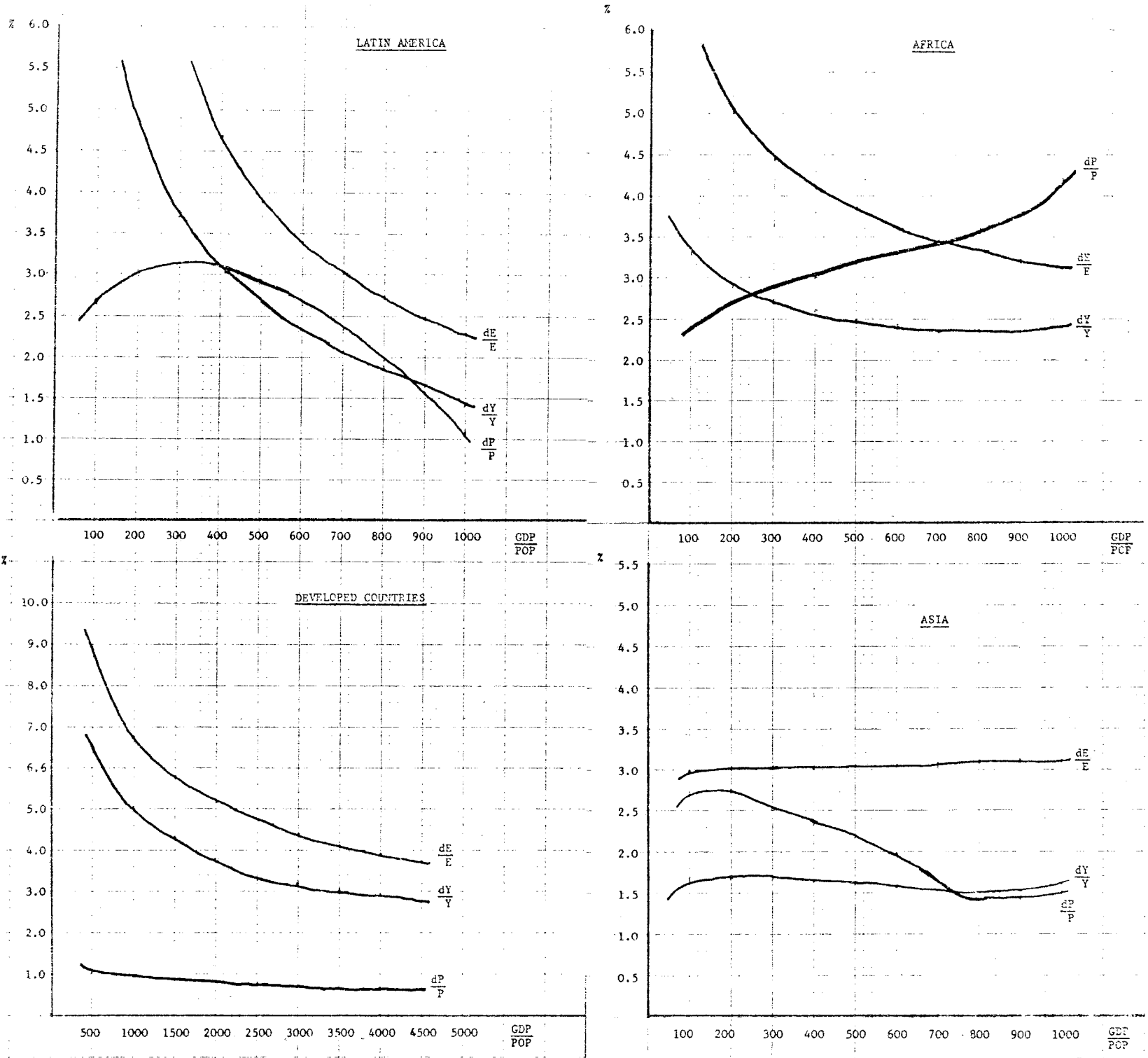

Balanced Growth

Figure 3:   Growth Rates as Functions of Y/P

45.

Appendix:

Data Sources

GDP : U.N. Statistical Yearbooks, World Bank Atlas, 1970.
Total Population : U.N. Demographic Yearbooks.
Energy : U.N. World Energy Supplies, 1961-70.
CBR, CDR, IMR : U.N. Demographic Yearbooks.
%POPAG : F.A.O. Yearbooks, 1970, 71.
Age Distribution Data : U.N. Demographic Yearbooks, Allemeine Statistik
    Des Auslands Länderkurz, Keyfitz : Population Facts and Methods of
    Demography, Enquête Demographic (Mali and Upper Volta).
Age Specific Death Rates : U.N. Demographic Yearbooks.
GDFC : U.N. Yearbook of National Accounts Statistics.

Composition of the Regions

Africa (29 countries)
    Burundi, Central African Republic, Chad, Dahomey, Ethiopia,
    Ghana, Guinea, Ivory Coast, Kenya, Liberia, Malawi, Mali,
    Mauritania, Niger, Nigeria, Rwanda, Senegal, Sierra Leone,
    S. Rhodesia, Sudan, Togo, Uganda, Tanzania, Upper Volta,
    Zaire, Zambia, Algeria, Morocco, Tunisia.

Latin America (19 countries)
    Argentina, Bolivia, Brazil, Chile, Columbia, Costa Rica,
    Dominican Republic, Ecuador, El Salvador, Guatemala,
    Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay,
    Peru, Uruguay, Venezuela.

Asia   (11 countries)
    Burma, India, Indonesia, Korean Republic, West Malaysia,
    Pakistan, Philippines, Singapore, Sri Lanka, Thailand,
    Taiwan.

Developed Countries (23 countries)
    Belgium, France, West Germany, Italy, Netherlands, Austria,
    Denmark, Finland, Norway, Portugal, Sweden, Switzerland,
    United Kingdom, Greece, Ireland, Spain, Australia, New
    Zealand, Canada, U.S.A., Japan, Israel, Puerto Rico.

The calculation of CDR2

Let Z = CDR1/CDR2 the mean of which was 0.8457 in LDC's and 0.421 DC's,
A_1 = (population aged 1-15)/(population aged 1 and over)
A_2 = (total population)/(population aged 1 and over), then

$$CDR = [CDR2.(A_1 Z + 1 - A_1)/A_2] + IMR.CBR.$$

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