Population, Internal Migration, and
Economic Growth : An Empirical Analysis

by

R. Scott Moreland

No. 158

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

UNIVERSITY OF WARWICK
COVENTRY

Population, Internal Migration, and Economic Growth : An Empirical Analysis

by

R. Scott Moreland

No. 158

August 1979

I would like to thank Marcus Miller, Jeff Round, Alan Roe and Nick Stern for useful discussions. Any errors are, of course, my own.

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

I. Introduction

During the last fifteen years or so, the role of population growth in the development process has received increasing attention. This has been manifested in the literature in three broad areas. In the first, the effects of rapid population growth on the growth of income have been studied with the use of simulation models (Enke (1971) (1974), Simon (1976)) which sometimes include endogenous population growth (Suits et al (1975), Hazledine and Moreland (1977)). In general these models show that per capita income could be increased by reducing the birth rate. However, they are often either unsophisticated in terms of the demographic structure (Suits et al (1975)) or the coefficients are imposed a priori (Enke (1971)) or key demographic rates are imposed exogenously (Simon (1976)) so that no feedback exists between the economy and demographic variables.

The second strand of the literature is concerned with theoretical and empirical studies of the economic determinants of various demographic rates, most usually fertility, but also female labour force participation, infant mortality, and life expectancy. While work is still continuing in this area, it is fair to say that there is now a fairly well established set of results here. For example, we know that fertility is normally negatively associated with female education and labour force participation and with urbanisation. This research may be seen as complementing the first category to the extent that reducing the birth rate will be easier if one understands the factors which influence it. One also might expect this work to complement the development of simulation models by providing an empirical basis for including endogenous rates in these models, but unfortunately, few simulation models have their parameters estimated from a consistent set of data.[1/] As noted above, demographic rates have often been left exogenous in simulation and growth models.[2/]

The third population - development area which has received attention is that of internal migration and dualism. Here again, the focus has either been on the determinants of migration or its effects. Dualism and the effects of migration have been examined in both analytical models (Lewis (1954), Fei and Ranis (1964), Sato and Niho (1971), Niehans (1963)) as well as simulation models (Yap (1976), Kelley et al (1972), Adelman and Robinson (1978)), but no other demographic considerations are incorporated in these models.

In this paper we attempt to synthesize these three strands by estimating from a consistent set of data a two sector economic-demographic model in which the major demographic rates are endogenous. Since the interactions between economic and demographic variables are non-linear and complex, the indirect effects of changes in a particular variable may well depend upon the balance of numerical coefficients and for this reason it was felt that the model should be empirically grounded. In the following section we provide a brief overview of the model and compare it to some existing similar models. Then we discuss estimation of the model's nine behavioural equations. A "base run" simulation of a developing country "stereotype" is then described and a number of policy experiments are reported. Some sensitivity analysis of the model to

---

1/ Exceptions are Suits et al (1975) and Hazledine and Moreland (1977).

2/ In fairness, some models (Enke (1971)) predate this empirical work.

the estimated parameters is also described in Appendix B.

II. An Overview of the Model and a Brief Comparison with Other Models

Since the pioneering work of Coale and Hoover (1958), a number of increasingly complicated and sophisticated economic-demographic models have been built culminating in the ambitious BACHUE series of the I.L.O.[1/] Any model is a simplication and abstraction of the real world and is necessarily limited to focus on areas of particular interest to the investigator-model builder. Hence the BACHUE-Philippines model was built to investigate the inter-actions between employment, income distribution and population. Simon's model focuses on the long-run effects of population growth on per-worker output, a feature shared with the early Enke-TEMPO models.[2/] To the extent that models are limited in scope they will necessarily handle certain relationships more simply than if they were to focus explicitly on those relationships. In many cases this may involve not ~~including~~ a relationship or specifying it as an exogenous variable. For example, most models assume an exogenous rate of technical progress. However in Simon's "MDC" model,[3/] he explicitly sets out to explore the implications of the hypothesis that technical progress may be positively influenced by the size of the population and so in his model technical progress is endogenous. We mention this aspect of model-building here to emphasize that in the brief comparison of our model's structure with that of a selection of existing models, the presence of a variable or relation in one model should not be viewed

---

1/ See, for example, Rodgers et al (1978).

2/ Simon (1976), Enke (1963) (1966), for TEMPO, see McFarland et al (1973).

3/ Simon (1977).

as necessarily meaning it should be in another model.

The purpose of this paper is to estimate the parameters of a growth model from a consistent data set using econometric techniques with explicit focus on the demographic aspects of development. As such, four of the nine estimated behavioural equations are demographic. The model's structure is presented below in equations 1 - 9. Accounting identities are omitted here for simplicity:

(1)	FR	=	f_1(FPR, YP, Illit, LF)	(Fertility)
(2)	FPR	=	f_2(FR, Pa/P_T, CHED)	(Female Labour Force Participation)
(3)	LF	=	f_3(YP, Illit)	(Life Expectancy)
(4)	RUM	=	f_4(YA/Pa, YNA/Pna, Pa/P_T, Illit)	(Migration)
(5)	YA	=	f_5(Pa, TRACT, λ)	(Agricultural Output)
(6)	YNA	=	f_6(P^w_{na}, ENERGY, λ)	(Non-agricultural Output)
(7)	SP	=	f_7(YA/Pa, YNA/Pna, $\sum_{i=1}^{15}$ Pai/Pa, $\sum_{i=1}^{15}$ Pnai/Pna, Pa/P_T)	(Savings per head)
(8)	ΔTRACT	=	f_8(S)	(Agricultural Investment)
(9)	ΔENERGY	=	f_9(S)	(Non-Agricultural Investment)

The model has two economic sections - agricultural and non-agricultural. These are taken to correspond roughly with the two demographic sectors in rural and urban areas. Fertility and female labour force participation rates are simultaneously determined. Rural fertility is a constant times urban fertility. Life expectancy at birth is endogenous and survival rates are determined from Coale-Demeny model life tables. Inter-sector migration is also endogenous. Output in the two economic sectors is seen as Cobb-Douglas funtions of labour and capital terms and exogenous technical progress. As discussed later, constant returns to scale are assumed. Savings per head is endogenous and is the weighted average of sectoral savings. Investment in each sector is a function of over-all savings. Education growth is also endogenous. Hence the model is a supply-based model with no labour market, no foreign trade or investment, no sectoral demand, and no government. Implicitly it reaches an equilibrium in each period, except that the existence of a migration function implies less than perfect adjustment of sectoral labour supplies to inter-sectoral differences in living standards.

Of all the existing models, perhaps those of Yap (1976), Kelley-Williamson-Cheetham (1972), Simon (1976) and Suits et al (1975) are closest to the present model in scope and structure and so we shall briefly compare these to it. We should also mention here, Casetti's[1/] study in which he similarly simulates the behaviour of a stereotype less developed country with a model in which population growth is endogenous. The present model, however, is much more sophisticated in terms of structure (two sectors versus one , endogenous labour force participation) and is more empirically based than Casetti, which has some coefficients set by 'guestimates'.

The main difference between the present model and the four other ones is that the demographic side is more highly developed. The Suits et al model has endogenous birth and death rates as well as labour force participation, but as it is only a one-sector model it contains no migration. Furthermore, the Suits model does not disaggregate the

---

1/ See Casetti (1977).

population by age and so fails to capture one of the main facits of economic-demographic interaction. The Simon model has endogenous life expectancy, but fertility rates are set exogenously and while the model has two sectors, no migration exists in the sense that it is a dis-equilibrium phenomenom. In the two other models, those of Yap and Kelley et al, migration functions are present but the demographic side is otherwise undeveloped.

On the economic side, the Kelley et al and Yap models are strongly neo-classical in flavour with, for example, labour receiving its marginal product[1/] and capital flows responsive to differential intersectoral rates of return. The Kelley et al model is the only one to contain prices and a demand side.

All the others, as well as the present model, are supply driven. Kelley et al and Yap have CES production functions while Simon's, like the present one, has Cobb-Douglas functions. Suits et al generates output via a labour productivity function so that there is only one factor of production and no capital or investment in that model.

The supply of investment funds in the present model and Yap, Kelley et al, and Simon is provided by private savings. In Yap, government investment is also present. In both Yap and Kelley et al, savings functions exist for workers and entrepreneurs, although in Kelley et al no saving out of labour income exists. In Simon, investment behaviour differs between sectors and does not depend on the functional distribution

---

1/ In Yap, a minimum wage is assumed.

of income. In this sense, Simon's model is similar to the present model, He also includes an age-structure effect in the industrial investment equation but imposes *a priori* a negative effect. However none of the four other models contains a Keynesian savings function modified to have an age structure term and defined at the sectoral level as does the present model.

Simon's model is the only one to contain social overhead capital and endogenous technical progress in the industrial sector. The other models, the present one included, assume exogenous rates of technical progress.

The Yap model contains skilled urban workers and unskilled rural and urban workers. Apart from this none of the other models except the present one, contain education.[1/] In Yap, the supply of skilled workers feeds through the labour market and affects output. In the present model no such effects exist and education's main effects are felt in the demographic sphere.

Finally in terms of the parameter estimates, the Suits *et al* model is similar to the present model in that the behavioural equations were estimated from an international cross-section. However, that model is very simple and is unable to pick up any age structure effects. It also, as noted, contains no investment and has only one sector. It is furthermore unclear if the model is based on developed or less developed countries. The Yap model is based on Brazilian data and *a priori*

1/ It could be argued that Simon's social overhead capital implicitly contains the stock of human capital.

estimates. Simon's parameters are based on "educated guesses" as to what they should be as are these in Kelley *et al*.

In summary, it is clear that the present model does not contain features which one might have included in the light of existing models. Notably, there is no explicit labour market and no distinction between workers and capitalists. However, like Kelley *et al* and Simon we also assume constant returns to scale, a subject which we come back to later. While we have chosen the Cobb-Douglas over the CES production function, this is not too serious given that no labour market exists in the model and all available labour is employed. This is consistent with the long run focus of the model. Where the present model has strength, however, is on the demographic side and the fact that it is estimated from a consistent data base. Since we are primarily concerned here with the interactions of demographic and economic phenomena the demographic behavioural relations and accounting system, it was felt, should be properly modelled. Moreover since the behaviour of the system depends upon the parameters it is important that these be based on actual data rather than one's "feel" for it.

III. Data and Model Estimation

Many of the existing simulation models were specified with parameter estimates which were not based directly on empirical data. This was, for example the case with the models of Simon (1976), (1977) and the early Enke-TEMPO models. Although authors usually claim that they take 'reasonable' estimates of parameter values, in many cases the *a priori* theory is often not sufficiently strong to unambiguously predict the *sign* of a coefficient not to mention the magnitude. Furthermore, assumptions such as constant returns to scale often bias the results of the model from the very start in terms of the efficacy of certain policies in say, raising per capita income. Also, the whole pattern of coefficients may influence the growth path of a model. On the other hand it is easy to exagerate the sensitivity of a model to certain parameters and it is thus essential that any model be tested for its sensitivity to all of its parameters and we do this in a separate section below.

We feel in light of the points made above that it is important that the coefficients of the behavioural equations be based on empirical evidence rather than an investigator's "feel" for the data. Hence all the parameters in the present growth model were empirically estimated. Ideally, of course, one would like to have as many observations as possible in estimating parameters. We adopted the philosophy that all parameters should be estimated from observations corresponding to the same countries on country at roughly the same dates. Alternative approaches include use of (a) time series data from a particular country, (b) international-cross-section data or (c) some combination of the two. The first alternative was not considered because we wanted a more general analysis than could be drawn from estimating a model of a particular country. Modelling a specific country inevitably involves taking account of individual characteristics of that country with a subsequent loss of generality. Pooling of time-series and cross-section data, such as the data base for the Chenery and Syrquin (1975) study would have been ideal but unfortunately for many of the demographic data we needed, the series do not exist or are of highly dubious quality. Thus we chose to use international cross-section data most of which are for the year 1968 and are drawn from UN sources. A list of countries, all of which were less developed countries, appears in the appendix as well as the data sources. Our sample contains only thirty-nine countries despite the fact that demographic data exist for over sixty less developed countries. The reason the sample is not larger is that, unlike other empirically based medals, notably Suits et al (1975), our model explicitly takes account of the age distribution of the population in urban and rural areas and not merely the total size of the population. Thus the common denominator for all the countries in our sample was that they had reliable age distribution data for rural and urban populations. As will be evident in discussion of the empirical estimates, this data was essential in some of the equations.

A brief discussion of the philosophy of cross-section estimation is called for here. It is often alleged that cross-section estimation is a "snap-shot" at a point in time or a "point estimate" and as such the dynamic implications are limited so that the use of cross-section estimates of the parameters of a dynamic computer simulation model would be inappropriate. It is my contention that the philosophy of cross-section estimates implies a dynamic interpretation and that if one does not accept that interpretation it is difficult to accept a cross-section as a valid data base for anything. The theory of cross-section estimation is that there is an underlying structure, defined by the relation to be estimated, to which the countries (or whatever observations one is using) belong. If one has correctly specified the relation and included all of the relevant variables then as the independent variables change, the estimated equation will predict a change in the dependent variable. Since changes take place over time, the cross-section equations have dynamic implications. In terms of the present model, we are assuming that each country in the sample is at a particular stage in the development process vis à vis the variables concerned. As a country develops, so the variables are seen to change.

Of course it is possible that the structure changes over time and that this change can more easily be captured by time series analysis. One way around this problem would be to take the cross-section at various points in time and then test for a structural change. However, this would have required enlarging the data base and as indicated this proved inpracticable. Secondly, even if one does discover a structural change one still has the problem of explaining that change. For these reasons where structural changes are known to exist, for example, shifts in the production function due to technical progress, these were included as exogenous variables in the model. In any case, we can test the sensitivity of the model to changes in the structural parameters by running simulations with alternate parameter estimates as we indeed do later on in the paper.

It should also be emphasised that a simulation exercise of this sort is more interested in orders of magnitudes and the signs of the rates of change of variables than in pin-point accuracy of predictions; hence the exercise is largely qualitative in nature.

IV. The Estimated Equations

1. Fertility and Female Labour Force Participation

In the classical Malthusian model, as well as in those of Nelson (1956) and Enke (1963) the death rate is assumed to vary directly with living standards while the birth rate is assumed constant. However recently there has been considerable theoretical and empirical work linking economic and fertility variables and even as early as 1954 Leibenstein assumed that as development took place the birth rate would drop. It is well known that a simple cross-section of countries with fertility on one axis and per capita income on the other will yield a negative relationship. Yet, when other relevant variables are included the relationship is not so clear.[1/] There have been several papers recently where population growth was assumed to be endogenous through fertility changes[2/] within the context of a growth model. Hence, a long term economic-demographic model would be incomplete without an endogenous fertility equation.

The dependent variable used to measure fertility in this study is a fertility rate defined as total births divided by the total population aged 15-45 years old, the so-called fertile age group. Other measures sometimes used include the net or gross reproduction rates, various age-specific fertility rates, children-ever-born or just the crude birth rate.

1/ See Hazledine and Moreland (1977), Weintraub (1962), as well as Simon (1974) and Leibenstein (1974) for good reviews.

2/ See for example, Sato and Niho (1971), Kelley *et al* (1972), Hazledine and Moreland (1977), Suits *et al* (1975).

Table I : Estimated Equations

(39 observations, t-values in parenthesis)

1. Fertility	(a) (2SLQ)	$\ln(FR) = \underset{(4.67)}{4.873} - \underset{(-1.22)}{0.1238}\ln(FPR) + \underset{(1.57)}{0.1013}\ln(Illit) - \underset{(-1.66)}{0.1339}\ln(YP) + \underset{(0.6)}{0.056}\ln(q_0)$	
	(b) (OLS)	$\ln(FR) = \underset{(6.38)}{4.357} - \underset{(-1.62)}{0.061}\ln(FPR) + \underset{(2.5)}{0.1265}\ln(Illit) - \underset{(-1.7)}{0.096}\ln(YP) + \underset{(0.97)}{0.058}\ln(q_0)$	$R^2 = 0.66$
2. Female Labour Force Participation	(a) (2SLQ)	$\ln(FPR) = \underset{(3.92)}{15.061} - \underset{(-2.75)}{1.997}\ln(FR) - \underset{(-1.84)}{0.417}\ln(YP) - \underset{(-1.57)}{0.297}\ln(CHED)$	
	(b) (OLS)	$\ln(FPR) = \underset{(4.56)}{14.164} - \underset{(-3.15)}{1.824}\ln(FR) - \underset{(-1.80)}{0.398}\ln(YP) - \underset{(-1.55)}{0.284}\ln(CHED)$	$R^2 = 0.35$
3. Life Expectancy		$LF = \underset{(43.0)}{68.145} - \underset{(-3.3)}{669.23}(1/YP) - \underset{(-6.5)}{0.225}\,Illit$	$R^2 = 0.80$
4. Migration Propensity	(a) (2SLQ)	$RUM = \underset{(3.6)}{37.57} + \underset{(1.6)}{5.779}(YNA/Pna - YA/Pa)/(YA/Pa) - \underset{(-0.3)}{0.062}\,Illit - \underset{(-2.65)}{70.67}(Pa/P_T)$	
	(b) (OLS)	$RUM = \underset{(9.6)}{38.39} + \underset{(1.84)}{0.865}(YNA/Pnn - YA/Pa)/(YA/Pa) + \underset{(0.8)}{0.056}\,Illit - \underset{(-4.8)}{48.91}(Pa/P_T)$	$R^2 = 0.50$
5. Agricultural Production		$\ln(YA) = \underset{(14.35)}{3.199} + \underset{(24.23)}{0.773}\ln(Pa) + \underset{(7.12)}{0.227}\ln(TRACT)$	$R^2 = 0.578$
6. Non-Agricultural Production		$\ln(YNA) = \underset{(93.8)}{6.857} + \underset{(6.43)}{0.413}\ln(P^W_{na}) + \underset{(9.14)}{0.587}\ln(ENERGY)$	$R^2 = 0.693$
7. Savings Per Head		$SP = \underset{(-4.39)}{-139.216} + \underset{(1.7)}{0.138}(YA/Pa)\cdot(Pa/P_T) + \underset{(23.6)}{0.268}(YNA/Pna)\cdot(Pna/P_T) - \underset{(-2.3)}{197.7}(\sum_{i=0}^{15} Pa_i/Pa)\cdot(Pa/P_T) + \underset{(2.4)}{181.2}(\sum_{i=0}^{15} Pna_i/Pna)\cdot(Pna/P_T) + \underset{(3.9)}{229.5}(Pa/P_T)$	$R^2 = 0.97$
8. Agricultural Investment		$\Delta TRACT = \underset{(-0.33)}{-64.78} + \underset{(10.00)}{1.167}\,S$	$R^2 = 0.73$
9. Non-Agricultural Investment		$\Delta ENERGY = \underset{(-0.25)}{-0.0001} + \underset{(20.0)}{0.0006}\,S$	$R^2 = 0.92$

List of Variables

FR : Fertility Rate (Births /Population between 15 and 45 years old)

FR_r, FR_u : rural and urban fertility rates

FPR : Female labour force participation rate for ages 15-45

Pa : total agricultural population

Pna : total non-agricultural population

P^w_{na} : non-agricultural labour force

P_T : total population

Pa_i, Pna_i agricultural or non-agricultural population at age i

LF : male life expectancy at birth

q_o : probability of dying before age 1 (value corresponding to LF calculated from Coale-Demeny model life Tables)

Illit : adult illiteracy rates

CHED : secondary school enrolment rate

RUM : net rural-urban (agricultural-non-agricultural) migration rate

YA : agricultural output

YNA : non-agricultural output

TRACT : tractors in use

ENERGY : energy consumption

S : total savings

SP : savings per capita

YP : per capita GDP

ΔTRACT : average yearly change in tractors in use (during a 5 year period)

ΔENERGY : average yearly change (during a 5 year period)

Any measure which avoids pitfalls caused by differences in age structure between countries is preferable to the crude birth rate. Our measure, calculated using age distribution data and the crude birth rate, was :

$$FR = CBR \div \left\{ \frac{\left(\sum_{i=15}^{45} Pna_i + Pa_i \right)}{P_T} \right\}$$

In the simulation model, all age groups were assumed to have the same fertility rate, although as indicated below rural and urban rates differ. Hence while the CBR will be affected by the whole of the fertile age group, smaller cohorts within that group will have less effect.

The economic theory of fertility, as expounded in the literature,[1/] has produced five main explanatory variables. These are: education, percentage of the population rural or agricultural, infant mortality rate, female labour force participation rate and income levels. As the theoretical and empirical significance of these variables are adequately covered elsewhere, we do not propose to discuss them in any detail here.

Education, measured here by adult illiteracy (Illit) is, both empirically and theoretically, one of the strongest variables in explaining fertility differentials. Educational level is almost always significantly negatively related to fertility.[2/] It is also of interest to include it in a model of this sort because education is alleged to be an important

---

1/ cf. Leibenstein (1974) for a review and critique of this literature.

2/ cf. T.P. Shultz (1974) for a good review of empirical results of explaining fertility.

policy tool in achieving a more equitable society. Hence, the expected sign on Illit is positive.

The infant mortality rate is often included as an explanatory variable with an expected positive coefficient as parents seek to replace infants lost through deaths. On the other hand, one may argue that the pyschological shock of an infant death implicitly raises the costs of pregnancy and thus works in the other direction. Furthermore the health of parents on the population as a whole may biologically influence fecundity, although empirical confirmation of this link is less clear.[1/] In an effort to capture the general link between health and fertility - particularly infant health - we took as an independent health variable the life table value of the probability of dying in the first year of life (q_o) corresponding to the life expectancy in the country.[2/] It should be noted, however, that this is not strictly speaking equivalent to using infant mortality rates, since life table values assume a stable population. The expected sign here is ambiguous.

The third variable which we included was the level of overall per capita income. It is widely acknowledged that a long run negative relationship exists between income and fertility although the strength of the relation is not so strong as that indicated by zero-order correlation coefficients might suggest,[3/] Also, according to the strict household decision making models of fertility, when both female labour force

---

1/ See Anker (1978) who found a significant quadratic relationship between life expectancy and the GRR.

2/ We used male life expectancies and then computed the Coale-Demeny model (West) life table to get q_o. In the simulation model, we thus compute the contemporaness q_o corresponding to the current LF value.

3/ See Simon (1974) and Hazledine and Moreland (1977). The zero order correlation between FR and YP was -0.69.

participation and an opportunity cost of time (here, Illit) variable are included, income is not needed in the equation. However, this theoretical point is only valid if we do not allow for the effects of the husband's income, unearned income and wealth. To the extent that these influence fertility and are proxied by YP, an income term is justified in the equation. We expect a negative sign here.

The fourth variable we included was the female labour force participation rate for women in the fertile age group (15-44).[1/] The rationale for inclusion of this variable need not detain us long here. Numerous theoretical and empirical studies have pointed to its relevance and the obvious simultanaeity between these two variables.[2/] The expected sign is negative given the time-intensive demands of child bearing and rearing by women who almost universally are given this role in all societies. Indeed for certain age groups we might expect one variable to be the one minus the other. As discussed below we ran both ordinary and two stage least squares regressions because of the simultanaeity problem between these two variables.

A potentially important influence on the overall level of fertility is the extent of urbanisation. For various reasons to do with the opportunity costs of a mother's time and the economic value of children to parents one expects rural areas to have higher fertility patterns than urban areas. However, rarely are these differentials more

---

1/ It is important not to use the <u>overall</u> participation rate which is based on the total population and which in high fertility countries would just be a bad measure of the age distribution of the country. This would then be negatively related to fertility tautologically since high fertility implies a young population or a smaller percentage in the 15-44 age group.

2/ See Anker (1978) for a recent simultaneous model and Standing (1978) for a good review of the arguments in both directions.

than 15 or 25 per cent.[1] We originally attempted to include the percentage of the population in agriculture as an explanatory variable by considering the fertility rate to be the sum of rural and urban rates weighted by the proportion of the total population in each area in much the same way as in the savings functions discussed below. This would have allowed us to disaggregate the function into separate rural and urban fertility functions for use in the simulation model. However the results were unsatisfactory and the estimated coefficients gave unrealistic predictions of the rural-urban fertility differential. This technique was then abandoned in favour of the assumption that the rural rates is a constant, ρ, times the urban rate:

$$\rho = FR_r / FR_u \qquad r = \text{rural} \quad u = \text{urban}$$

Then it follows that,[1]

$$FR_r = FR \div \left(\sum_{i=15}^{45} P_{ai} / \sum_{i=15}^{45} P_i + (1/\rho) \sum_{i=15}^{45} P_{nai} / \sum_{i=15}^{45} P_i \right)$$

where FR is calculated from the estimated behavioural equation.

ρ is calculated by taking as a proxy for the fertility rate in each sector the ratio of the population under one year to that in the fertile age group. This assume that infant mortality patterns are the same in each sector. The mean value of ρ for the sample and the value used in the simulations was 1.25.

1/ See Kuznets (1974).

2/ P_{ai} and Pna_i are the agricultural and non-agricultural populations at age i. As explained, "rural" and "urban" are in this paper taken to mean agricultural and non-agricultural.

Hence, while we do not include the percentage of the population in agriculture directly in the regression equation, the sectoral split of the population is not omitted from the model.

In summary then our fertility equation has as independent variables, illiteracy, female labour force participation, income per capita and the probability of dying at age less than one. The expected signs are respectively positive, negative, negative and ambiguous.

We turn now to the labour force participation variable. This will play a role as a simultaneous variable in the fertility equation as well as feeding into the labour force determination in the economic sphere. This aspect will be discussed in more detail below. As indicated this variable (FPR) is the participation rate for females aged 15-45 years old.

FPR is hypothesized to be a function of (a) fertility, (b) YP/P_T and (c) the secondary school enrolment rate.[1/] Fertility should, through the child care burden, act as a depressant on FPR, as alluded to above. Hence, a negative sign is expected. The expected relationship between YP and FPR is negative since as development takes place, *ceteris paribus*, the need for women to work and supplement family income declines. However, if female wages increase with YP, more women may be tempted into the labour force.

1/ In the simulation model in determining rural and urban labour forces, FPR is assumed to be the urban rate with rural rates for both sexes over 15 assumed to be 100. Hence we implicitly assume that Pa/P_T will positively affect the countrywide FPR.

The effect of education on FPR is less clear from the empirical and theoretical literature.[1/] On the one hand, education - particularly female - may raise a women's propensity to enter the labour force as her skills allow her to compete more successfully with men. She may also seek a return on her (or the state's) investment in her 'human capital'. There may also be an accompanying change in tastes away from domestic work in favour of market work. On the other hand more education will delay entry into the labour force thereby depressing, ceteris paribus, the FPR. Also, in low income countries the 'human-capital' approach may be less applicable as the choice facing a woman about entering the labour force may be equivalent to the choice of how much food will be on her plate. In fact there may be a negative relationship, particularly if increases in education are unequally distributed in favour of the better-off and if not-working becomes a status symbol. On balance, although no strong a priori expectations exist given that our independent variable here is the secondary school enrolment rate, increases in which may delay entry into the labour force, we will predict a negative sign on this variable.

Turning now to the empirical results of the FR and FPR equations, we present in Table I both ordinary and two stage least squares results for log-linear specifications of these equations. All coefficients with unambiguous a priori sign expectations have the correct signs and are significant in both sets of equations with the exception of FPR in the 2SLQ FR equation. However it is quite common, particularly with small

---

1/ See Standing (1978) Chapter 6 for a good review of this variable's relation to FPR.

samples, for the standard errors of the coefficients in simultaneous estimations to increase over the OLS estimates. The education term in the FPR equation is negative and significant and q_0 in the FR equation is positive but not significant. The main difference in coefficients between OLS and 2SLQ appears on the endogenous variables which is expected. The overall level of significance as measured by the R^2 in the OLS equations is 0.66 for the fertility and 0.35 for the FPR equations. The latter is not particularly low for such a relation.

2. Life Expectancy

Mortality is handled in the model by endogenously predicting female life expectancy at birth and then with the use of Coale-Demeny Regional Model Life Tables,[1/] age specific survivor rates can be obtained. These survivor rates can then be used with the fertility rates and migration rates to project the population by age, and location one period forward.

We do not assume here any difference in rural and urban mortality patterns. This is because firstly, it is not clear *a priori* whether health conditions are better or worse in urban areas. Certainly access to hospitals and doctors is likely to be better in urban than in rural areas. On the other hand, communicable diseases will spread faster and the lack of sanitation facilities such as flush toilets and running water are likely to be more serious health hazards in urban than in rural areas.

1/ Coale and Demeny (1966); Model West was used. This equation is a variant of one used in Rodgers *et al* (1978).

Empirically, too, there is no clear cut pattern of rural versus urban mortality.[1/] Since it is well known[2/] that the age distribution of a population is affected more by fertility than by mortality, we assume that mortality patterns in rural and urban areas are identical.

A truly satisfactory explanation of life expectancy or mortality patterns would involve a model of health with "inputs" such as access to public and private health and medical facilities, nutrition, etc. Such a model is beyond the scope of the present study. However it is clear that as a country develops, not only will individuals have increasing access to commonly available health services, but the rise in their own standards of living will allow them to purchase more and better quality food, shelter etc. Hence, as a proxy for all of these variables we included per capita income as an explanatory variable.[3/] This was entered as the reciprocal of YP in order to give a function which has an asymptote or upper bound on the dependent variable. One would expect, looking at world-wide life expectancies, that this asymptote would be around 75 on perhaps 70 given our restricted sample of only developing countries.

Education may also affect life expectancy at birth, particularly since it is likely that as the educational level increases infant mortality will decrease. Also education may affect people's knowledge and use of public health and medical facilities as well as the choice of their diet and hence nutrition. We would then expect a negative sign on the coefficient of the illiteracy variable.

1/ A look at the available UN data on rural and urban crude death rates revealed that about half the time rural rates were higher and half the time urban rates were higher. In an earlier study (Hazledine and Moreland (1977)) no significant link for developing countries could be found between the percentage of the population in agriculture and the adult crude death rate.

2/ See Coale (1957).

3/ The formulation here follows Rodgers (1977).

Turning to the empirical results we first see that the constant, which is the asymptotic (ignoring the Illit term), is 68.15 or in the neighbourhood of 70 years as expected. The coefficient on the reciprocal of per capita income is negative as expected and significant. Illit is also negative and significant. The overall explanatory power of the equation, as expressed in the R^2, is good at 0.80.

3. Inter-sector Migration

One of the most striking demographic features of developing countries is their high rate of urbanisation. Urban population growth rates in virtually every country are higher than rural rates and sometimes approach 6% per year. Such differential growth rates can only be explained by high rates of migration. While such migration is a normal consequence of the transformation of an agrarian to an industrial economy, the implied migration rates in developing countries are unprecidented by the experience of present day developed countries during their period of industrialisation. Hence an essential feature of any economic-demographic model of a developing country, perhaps more important even than endogenous fertility, is migration.

Strictly speaking, rural to urban migration is not the same as agricultural to non-agricultural migration. In measuring rural-urban migration, there is a question of what constitutes an "urban" and what constitutes a "rural" area. With enough migration, any small rural town will eventually become a city and hence become urban.[1/] In the meantime

---

1/ This of course is just a consequence of defining 'urban' as some arbitrary number of inhabitants.

workers who transfer out of agriculture to work in 'rural' towns would be classified as "rural-rural" migrants rather than "rural-urban" migrants. Hence, one cannot always make strict associations between economic and geographic locations. In fact, in our model, only intersector migration is used although as already indicated, natural increase components are taken as rural and urban so that there is really no distinction. The only way around this problem would be to have some kind of sectoral location mechanism in the model which would allow a sectoral-geographical mapping. It was decided that this was an unnecessary complication which would also involve serious data problems.

In addition, the more important distinction may not be so much the rural-urban vs. agricultural-non-agriculture as the traditional employment-modern employment distinction.[1/] Many migrants to the non-agricultural sector have few marketable skills and wind up in the organised informal subsistence service sector as street vendors, porters and day labourers; from the point of view of a realistic dual-economy model, such workers may have only migrated from one low productivity sector to another. Indeed, this is often the aspect of migration which is so politically sensitive in developing countries. Inclusion of this aspect into the model would essentially involve disaggregation of the non-agricultural sector into modern and traditional industries. Again this would involve formidable data and modelling efforts which were judged beyond the scope of the present study. However, recognition of this simplification should be borne in mind in interpreting the results of some of the simulations described later.

1/ See McNicoll in Tabah, Population Growth and Economic Development in the Third World.

While there have been many studies at the micro-level on factors influencing the probability of an individual migrating from one area to another,[1/] comparatively few studies at the macro-level exist. Of those at the macro-level which do exist, even fewer use international cross-section data.[2/] Undoubtedly, the main reason for this lack of macro-level analysis is the dearth of comparable data on migration rates across countries. While data on practically all other demographic concepts exist in varying quantities and qualities in UN and UN-agency publications, none are published on migration. Hence, we were forced, given the potential importance of migration in the model, to construct a measure of inter-sector, or rural-urban migration rates.

We are able to observe the agricultural and non-agricultural population in different years so we know the overall growth rates. We also know something about the natural growth rates from the fertility and death rates and from the rural and urban age distributions. With this information, we were able to construct our measure of the propensity to migrate as follows.

The rural-urban fertility ratio is approximated by the ratio of the proportion of the rural population under 1 year old to the proportion of the urban population under 1 year old.[3/]

1/ See Yap (1977) and Todaro (1976) for recent reviews.

2/ See Annable (1972) and Preston (1978).

3/ The observed number of infants (P_{or} and P_{ou}) actually should be adjusted for infant mortality to arrive at births, but since we are assuming the same mortality pattern in rural and urban locations we can ignore this.

$$\rho = \frac{P_{or} / \sum_{i=1}^{65+} P_{ir}}{P_{ou} / \sum_{i=1}^{65+} P_{iu}}$$

With this and given the crude birth rate, total population and proportion in agriculture we get rural births:

$$\text{RBIRTHS} = (\text{CBR}/1000) \div \left\{ (Pa/P_T) + (1 - Pa/P_T)\, \frac{1}{\rho} \right\} P_T \cdot \frac{Pa}{P_T}$$

Rural deaths are derived directly from the death rate under our assumption of the same mortality pattern in rural and urban areas:

$$\text{RDEATHS} = (\text{CDR}/1000) \cdot (\frac{Pa}{P_T}) \cdot P_T$$

The change in the rural population in the mid 1960's $\overline{\Delta P}_a$ is calculated from the average overall growth rate of the rural population between 1960 and 1970,

$$G = \{\ln(Pa^{70}) - \ln(Pa^{60})\}\, \frac{1}{10}$$

$$\overline{\Delta P}_a = G.P_a$$

This together with the births and deaths allows calculation of the migration propensity,

$$\text{RUM} = \frac{\overline{\Delta P}_a - \text{RBIRTHS} + \text{RDEATHS}}{P_a} \cdot (-1000)$$

This measure differs from the one used by Annable in that we assume rural-urban differences in fertility where as he did not. Preston (1978) has recently calculated rural-urban migration rates using inter-censal data. His rates are somewhat lower than ours, although the ranking and correlation between our two series are close. The mean and standard deviations for our estimates was 18.76 and 11.61 whereas for Preston's calculations they were 14.05 and 9.65 for the same sample of 18 countries. The somewhat lower estimates by Preston are expected since he is measuring rural-urban migration whereas I have primarily measured agricultural-non-agricultural migration. Given our observation above that some movement out of agriculture may not involve movement out of rurally defined areas, we would expect higher rates on our definition. For the full sample of 39 countries, the mean value of RUM was lower, however, at 16.45 with a standard deviation of 10.93. The country with the highest rate was Puerto Rico with a rate of 59.82 and Columbia was the lowest with 4.48.

We turn now to the determinants of the migration rate and the specification of the migration function in the present model. The migration literature, particularly the micro-level studies, suggest a number of variables as determinants of migration trends. Since the prime reason for anyone moving is to presumably be better-off, an important potential variable is the non-agricultural-agricultural income differential. This might have been written alternatively as the difference in marginal products between the two sectors where these are taken as the wage rates. This formulation was rejected on two grounds. First, it assumes profit maximising behaviour which is a strong assumption in the context of the present model. Secondly, the relative living standard may be better reflected in the average level of income in the two sectors than in the marginal product-cum-wage rate; given that urban areas offer many common facility amenities such as schools, hospitals and transport facilities not available in rural areas, these will be taken into account in the measure of non-agricultural per-capita product. Hence, our relative income term is given by the proportional gain in average income between non-agriculture and agriculture:

$$\left(\frac{YNA}{Pna} - \frac{YA}{Pa}\right) \div \left(\frac{YA}{Pa}\right)$$

A variant on this theme as suggested by Todaro and Harris and Todaro[1/] and incorporated in Annable's study is that the *expected* wage differential (which reflects the proability of getting a job) is the relevant variable. However incorporating unemployment or tightness of the labour market into this equation would have necessitated adding a labour market to the model. Given the poor quality of unemployment data by sector and the complications for model structure, it was decided not to incorporate the Todaro hypothesis here. In any case, the inter-sectoral income differential for the sample was so high, - on average about 400% - that even at very high rates of urban unemployment the differential would still remain high.[2/]

While the expected sign on the relative income term in this equation is positive, causality will run in both directions. The transfer of labour from low productivity agriculture to higher productivity non-agriculture will increase the marginal and hence average income level in rural areas while lowering the marginal, and hence

---

1/ See Harris and Todaro (1970).

2/ Of course at the margin such differences may matter.

average, product in urban areas thus tending to lower this term. While this is undoubtedly a recursive process subject to lags, it would be inappropriate to ignore this problem given the bias which could be produced. Accordingly, as reported below, we ran both ordinary and two-stage least squares where the income term is "purged" of its relationship with the RUM error term by specifying it to be a function of RUM and the variables discussed below.

A second variable which may influence migration is education. The usual human capital theory approach would hypothesize a positive association between education and migration as those with more skills move to areas where their skills are more marketable. Secondly, the better educated may have better information on job prospects and be better searchers. On the other hand, less educated migrants may have potentially higher gains - at least in their minds - so that a negative association of education and migration may result. Standing (1975) has furthermore suggested that the aspirations of migrants in terms of the jobs and wages they would accept may be lower than is commonly assumed. This would suggest that the uneducated would migrate fairly easily and that the human capital argument is weakened. Hence, *a priori* expectation on the sign of our measure of education - adult illiteracy - is ambiguous.[1/]

1/ There is a unresolved data problem here as well as a potential simultaneity problem. The data problem arises because education data are not given by sector so we are forced to assume an equal distribution of educational attainment by sector. The simultaneity problem is that even if we could observe the intersector distribution, if the country were not in steady - state equilibrium, the observation of a relatively low level of education in rural areas may simply reflect the fact that the educated have migrated - this could be overcome somewhat by taking lagged values.

The proportion of the population in the destination (or conversely the originating) sector may also be important. Micro-level studies suggest that the existence of friends and relatives in destination areas are important attractions to potential migrants as well as sources of information. Urban biases also exist in the provision of government health and educational services so that the relative size of this attraction may increase with city size given certain economies of scale in provision.[1/] Moreover, Collier and Green (1978) confirm the phenomenon of "allometric growth" whereby city size and city growth rates are positively correlated in many parts of the Third World.

We also expect a significant correlation between the percentage of the total population in urban (or rural) areas and net migration rates for the reason that high rates of urbanisation are caused by high migration rates. Hence, there is a potential simultaneity problem. Accordingly we also ran the instrumental variable equation[2/] with Pa/P_T as endogenous with an expected negative sign. However, in the growth model, since the relationship between RUM and Pa/P_T is essentially a recursive one working through the population projection accounting, the equation relating RUM to Pa/P_T is not used in the model. We also experimented with entering a lagged value of Pa/P_T, the value for 1960 (approximately a 6 year lag). The results were not dissimilar to those reported here.

1/ See Lipton (1977) for an exposition of urban bias.

2/ The instruments were YP and SP. YP is justified on the grounds that as an economy develops rural-urban inequality may be reduced for reasons additional to those already mentioned - e.g. income in food prices. SP, savings may to the extent that they influence the finance of investment, influence non-agricultural job prospects if investment has an urban bias.

Another variable which may potentially influence migration is age. Micro-level studies suggest that migrants are often young adults - particularly single males - who have few family ties and thus have low costs of moving. Experimentation with incorporating various age variables were not encouraging and therefore in this equation age does not enter. However, in the simulation model an age pattern of migration is assumed.

The empirical results on migration are encouraging. Both the relative income variable and the proportion in agriculture had coefficients with the expected signs and which are significant at the 5% level or better in the two stage estimation. Illiteracy had a small negative coefficient which, however, was not significant. The R^2 of 0.50 in the OLS equation, while low, is not too disappointing given the relative crudeness of the data here. It is to be noted that the bias present in the OLS estimates particularly on the relative income term is substantially reduced in the two stage estimate.

Finally, as a further check on the results we ran the migration equation using the 18 observations calculated by Preston for the dependent variable. The results were largely similar to those of our own with all variables having the same signs and levels of significance.[1/]

1/ The OLS equation was:

$$\begin{aligned} RUM = \; & \underset{(2.81)}{18.164} + \underset{(3.17)}{3.40}(Yna/Pna - YA/Pa)/(YA/Pa) \\ & - \underset{(-0.6)}{0.05}\ Illit - \underset{(-1.67)}{23.16}(Pa/P_T) \qquad R^2 = 0.62 \end{aligned}$$

4. Production

As indicated previously, the model has two sectors - agricultural production and non-agricultural production - which, notwithstanding the caveats made in the migration discussion, correspond roughly to rural and urban sectors. No urban dual structure with traditional and modern sectors is assumed; this is a simplifying assumption caused primarily by data constraints.

Agricultural output (YA) was estimated as a Cobb-Douglas function of the agricultural population and stock of tractors. Agricultural population (Pa) was taken as the labour force here because there are serious problems in defining the working population in agricultural economies where the extended family and family farm are prevalent.[1/] Obviously, this is not the case with all developing countries where agriculture is often organised in large capitalist estates for some products. The capital term in this equation was proxied by the stock of tractors (TRACT) measured in physical units. Agricultural land was not explicitly included since the data were of poor quality with substantial problems

---

1/ Also, no account is taken of the quality of the labour force on its productivity as affected particularly by health and nutrition. It was felt that the level of aggregation was too high to justify any quality variable here.

of inter-country comparability. In any case for most countries, land may be considered a fixed factor as it in fact was in the simulation model.[1/]

The non-agricultural production function (YNA) was similarly estimated as a Cobb-Douglas function with labour and capital terms. The capital term is proxied here by total energy consumption in the country (ENERGY).[2/] Capital stock data do not exist except for very few countries and in any case are subject to serious conceptual and measurement problems. Labour force was calculated from the working aged non-agricultural population (15-64 years), the female participation rate and a constant male rate of 0.89 for this age group. This figure is the mean value for a subsample of the countries and the constancy assumption is not too serious since there is very little variation across countries for male rates.[3/] Thus the non-agricultural labour force was calculated by[4/]:

$$P^W_{na} = \frac{1}{2}(0.89 + FPR/100) \cdot \sum_{i=15}^{64} P_{nai}$$

No technical progress was assumed in either sector, in estimating the equations. However, in the simulation model, technical progress is

---

1/ This may, of course, be a dubious assumption for a country like Brazil. A regression with arable land included yielded a negative but insignificant term on the land variable.

2/ Measured in Coal—equivalents.

3/ The standard error is less than one tenth the mean.

4/ A further sophistication here would be to disaggregate the labour force into skilled and unskilled workers, thus implicitly taking account of variations in the stock of human capital. Experimentation here with various measures of the skilled and unskilled workforce did not justify this alternative specification as estimated coefficients often had the wrong *a priori* sign or were not statistically significant.

introduced exogenously. We report below the effects on the model's outcomes of changing technical progress terms in the two sectors.

The empirical results are reported in Table I. It can be seen that in both cases the over-level of significance as measured by R^2s and t-values is high.

Following several other papers 1/ we constrained the coefficients on the labour and capital terms to sum to one. In the section on sensitivity we report the results of an unconstrained estimate of the production functions and the model's behaviour with these.

Transforming the production function from its estimated per-worker form allows us to get the output elasticities on the labour terms. These are 0.773 in agriculture and 0.413 in non-agriculture. It will be seen that the size of the labour coefficient is greater in the agricultural than in the non-agricultural sector suggesting that under strong neo-classical assumptions, labour's "share" would be greater in agriculture than in industry, which is not an unreasonable assumption. However, what is more important in terms of the present model is that the relative contribution to the growth of output by the agricultural labour force is substantially more important in that sector than the corresponding relationship in the non-agricultural sector. Conversely, the relative importance of the respective labour force growth rates in terms of affecting

---

1/ For example, Kelley et al (1972), Yap (1976) and Simon (1976) all assume constant returns to scale.

ceterbis paribus per capita incomes will be higher in non-agricultural than in agricultural areas. Letting lower case letters represent rates of growth (e.g. e = rate of growth of energy, ya = rate of growth agricultural output etc.) it can be seen that with no technical progress income per head in each sector grows according to

$$ya - tr = \alpha_1 tr - \alpha_1 pa$$

$$yna - pna = \alpha_2 e + (1-\alpha_2)\frac{d\rho/dt}{\rho} - \alpha_2 pna$$

where ρ is the overall labour force participation rate in non-agriculture.[1/] If we ignore the $d\rho/dt$ term, which is likely to be small in any one period and ignore other interactions in the whole model then,

$$ya - pa = 0.227tr - 0.227pa$$

$$yna - pna = 0.587e - 0.587pna$$

Hence, high rates of urban population are relatively more harmful for average urban incomes than for agricultural incomes. Also, using sample means we can calculate that the marginal product of labour in agriculture is $112 whereas in the non-agricultural sector it is $668. Hence movement of labour from agriculture to industry would result in a net increase in nationwide per capita income. Of course *ceteris paribus*, rural incomes will increase and urban incomes fall. We will return to these aspects further on when we discuss the simulation model in more detail.

1/ α_1 and α_2 are the output elasticities on capital in the respective production functions.

5. Savings and Investment

One of the potentially more important interactions between economic and demographic variables is between the age distribution of the population and savings behaviour. The usual assumption is that an increase in the relative number of (non-working) young dependents will depress savings and hence have a long run dynamic impact on the growth rate of the economy. Indeed one of the major linkages in the pioneering study by Coale and Hoover (1958) was this assumed negative relationship. More recently in the models of Enke (1966, 1971, 1974) and GE's TEMPO model (1973) as well as Suits et al (1975), and Simon (1976), depressing effects of dependency have been assumed.

Yet the theoretical and empirical justification for this analysis is far from clear. Theoretically, the analysis of the impact of children on saving is based on the idea that while children consume they yield relatively little income so that consumption is increased at the expense of savings. A subsidiary argument runs that what savings they might stimulate is in the form of social overhead capital, particularly schools and health facilities which are regarded as "unproductive" relative to "productive" capital such as machines. This, of course, ignores any notion that human capital is productive. Yet as Kelley (1973, 1976) and Simon (1975), (1977) have argued the negativity assumption is far from unambiguous. First of all, the introduction of more children into a household may be at the expense of other forms of consumption or leisure[1/] not necessarily savings. Depending on how this

---

1/ This, indeed, is at the heart of the 'Chicago' economic theory of fertility.

reallocation takes place, the impact of an additional child may be positive, negative or zero. Secondly, the impact of more children may be to induce more work by parents or if the child works, he may contribute directly to family income and hence family savings. Moreover we might expect the impact of children on savings to vary with the level of income. As Gupta (1971) has noted, for a family at the subsistence level with little margin left for savings, an extra child means only more people sharing poverty. In higher income countries one may find mothers going to work specifically to finance their childrens' college education and other expenses. To the extent that this income will be largely earned during a period, it will register as savings.

Also when we take account of the underlying issue - whether high birth rates impair savings, the issue is even less clearcut. Changes in the birth rate effect not only the relative size of the young 'dependent' population, but also of the old dependent population and any statement that reducing the birth rate will increase savings must be qualified to account for the possible differential resource costs of these two groups.[1/] Introducing two sectors into the picture - a rural agrarian sector and an urban industrial sector - will obscure the relationship even more.

Empirically, there has been conflicting evidence here as well. The most often quoted reference in support of the negative impact hypothesis is that of Leff (1969) who found a negative relationship between

---

1/ See Kelley (1973).

dependency rates (particularly child rates) and savings per head on the savings ratio. However, Simon (1975) found a positive relationship between agricultural irrigation investment and population density, which indirectly points in the other direction, at least as far as the rural sector is concerned. But as regards the impact of population growth on total savings in LDCs, Simon concludes that "much additional research is necessary before it is possible to determine whether the overall effect of population growth on saving is positive or negative".[1/] In another study Hazledine and Moreland (1977) using the average change in energy consumption as a proxy for investment per head found either no or a positive relationship with the percentage of the population less than 15 years old. In Kelley's (1976) study of US families, he was only able to "conclude that the association between family size and savings in our sample is ambiguous".[2/]

Because of the ambiguity, then, of age structure on savings we adopt an agnostic approach to this variable which we shall measure here by the proportion of the population under 15 years old. The other variable - income per head - need hardly detain us.

We used as a dependent variable the World Bank's concept of gross national savings per head. It is well known that the measurement of savings is often subject to error since it is often calculated as a residual. This is particularly true of household or private savings where these are calculated often by taking several residuals.[3/] Also,

---

1/ Simon (1977) page 260.

2/ Italics original. His study involved a simultaneous system, however, and the partial effect of family size on saving was negative.

3/ For further elaboration here see Mikesell and Zinser (1973) and Yotopoulos and Nugent (1976) page 169.

since we wish our model to contain not only private but public savings the World Bank concept seemed appropriate since it shows the amount of gross domestic investment financed from a nation's output and hence is composed of public and private savings.1/

The savings function was estimated as the weighted average of two similarly specified savings functions for the two sectors, where the weights were the proportion of the population in each sector. This specification allows us to estimate separate marginal propensities to save for each sector as well as see whether the age structure variable has different impacts in each sector. The structure estimated was a Keynesian function in each sector with an added age distribution term:

<u>agriculture:</u> $$S_a = a_1 + b_1\left(\frac{YA}{Pa}\right) + c_1\left(\sum_{i=0}^{15} Pai/Pa\right)$$

<u>non-agriculture:</u> $$S_{na} = a_2 + b_2\left(\frac{YNA}{Pna}\right) + c_2\left(\sum_{i=0}^{15} Pnai/Pna\right)$$

where Sa and Sna are agricultural and non-agricultural savings per head.

Then aggregate savings per head are

$$S \equiv Sa \cdot \frac{Pa}{P_T} + Sna\,\frac{Pna}{P_T}$$

1/ It is calculated as the difference between gross domestic investment and the deficit on current account. See World Bank, <u>World Tables</u> 1976.

or $$S = a_2 + (a_1 - a_2)\frac{Pa}{P_T} + b_1\left(\frac{YA}{Pa} \cdot \frac{Pa}{P_T}\right) + b_2\left(\frac{YNA}{PNa} \cdot \frac{PNa}{P_T}\right) + c_1\left(\sum_{i=0}^{15} Pai/P_T\right)\cdot\frac{Pa}{P_T} + c_2\left(\sum_{i=0}^{15} Pna\ i/P_T\right)\frac{Pna}{P_T}$$

which was estimated.

The empirical results are reported in Table I. All t-values are significant and the R^2 is high. As can be seen, both agricultural and non-agricultural age structure variables are significant but with opposite signs. Hence the equations suggest that in rural areas increases in the number of children compete with savings whereas in the non-agricultural urban areas their impact is to increase savings perhaps through increased work efforts. This difference may perhaps be explained by the fact that children in agricultural areas may be regarded as an asset and therefore are substituable for other income bearing assets which would be financed from savings. In the non-agricultural sector where wage employment is more prevalent fewer substitution possibilities may exist. Also, in as much as our savings variable includes public savings and to the extent that governments have an urban bias, we would expect incremental investments in schools and hospitals to be directed in an urban direction.

As regards the marginal propensities to save, note that in the non-agricultural sector this is higher, at 0.268 than in agricultural areas where it is only 0.138. The range of the marginal propensities are reasonable, given other time-series and cross-section estimates.[1/]

1/ See Mikesell and Zinser (1973) for a good review.

Also, the higher urban than rural marginal savings propensity is consistent with the Keynesian hypothesis that it increases with the level of incomes in as much as non-agricultural incomes are higher than agricultural. This implies that, ceteris paribus, a redistribution of income from rural to urban areas will raise the aggregate savings ratio in the economy. This finding is consistent with an earlier study by Gupta (1970) who found that the marginal savings propensity for rural Indian households was less than that for urban households although the difference was not as great (0.30 and 0.39 respectively). This may perhaps be explained by the fact that he was using household data whereas we are using both public and private savings as well as the fact that our savings functions are agricultural and non-agricultural functions not rural and urban. Hence, institutional differences, particularly the inclusion of government as a non-agricultural sector may be responsible for this difference. The implied constant terms for the disaggregated functions are -197 for industry and 90 (229 - 139 = 90) for agriculture.[1/] Gupta's study also found this sign pattern. Alternatively stated, in urban areas, below a certain income level dissaving occurs whereas in rural areas perhaps because of the support of the extended family and other traditional institutions low levels of income do not induce dissaving.

Investment

In the agricultural and non-agricultural production functions the "capital" terms are measured by tractors and energy consumption

---

1/ Or in abstracting from the age distribution terms, the agricultural intercept is 13.17 and the non-agricultural -75.

respectively. These are measured in physical units. We therefore need a mechanism for converting savings, measured in dollars into investment in capital formation, measured in physical units. In principal this could be done by specifying investment demand functions for each industry, having some saving-investment allocative mechanism and then with the prices of tractors and various forms of energy, convert dollars into physical capital units. This would have involved a substantially more complicated framework than originally envisaged as well as encountered substantial data problems, particularly on the price side. As an alternative we specified a simple mechanism for implicitly allocating and converting savings into increments in physical capital units for use in the production functions.

We took as our measure of agricultural investment, the average yearly change (1965-70) in the stock of tractors (ΔTRACT) and in the non-agricultural sector the investment variable is the average yearly change in total energy consumption (ΔENERGY). Each of these was then run as functions of total savings in the economy in an attempt to capture the inter- as well as intra-sector investment patterns. The results of these linear regressions are reported in Table I which, judging by t-values and R^2's were satisfactory.

V. The Base Run Simulations

While the regression results described above shed some light on interactions between economic and demographic variables, the interrelationships are ultimately dynamic and complex. Hence the appropriate framework for analysis is to view the equations as part of a system. We accordingly incorporated them into a growth model. Because of non-linearities and lags in the system this could not be solved analytically so we simulated the system on the computer. The only two exogenous variables were the rate of growth of secondary education and the rate of technical progress in both sectors. The former is set at 4% and the latter was assumed the same in both sectors at 1%. The adult illiteracy rate in each period is calculated through the population accounting structure by assuming that the stock of "literate" people grows at r times the rate of growth of secondary education weighted by the population in the appropriate age secondary school age group (taken as 15-19) as a proportion of the population under 15 years. The formula used was:

$$\mathrm{Illit}_t = \mathrm{Illit}_{t-1} \cdot \left\{ 1 - r \left(\frac{\sum_{i=15}^{19} (Pa_i + Pna_i)}{\sum_{i=1}^{15} (Pa_i + Pna_i)} \right) \right\}$$

Apart from this, the model is closed and is solved recursively.1/

Given an initial rural and urban age distribution and levels of education and LF, FPR is calculated then q_0 from the Coale-Demeny life tables and hence FR. With initial levels of income in each sector RUM can then be calculated and hence knowing fertility, mortality rates (from the model life tables, given LF) and migration the age distributions in non-agricultural and agricultural areas are known for the next time period, as are the labour forces in each sector. Investment

---

1/ With the exception of fertility and female labour force participation which are solved simultaneously.

is known after determining savings and hence capital and thus sectoral output. Hence next period's sectoral per capita incomes are known and the simulation can be repeated for another year.

The model is "initialised" on the average values of the variables for the sample of countries underlying the regression results. Hence we hypothesize a "stereotype" country. One year simulations were run for a 30 year period during which it is assumed that the structural parameters of the model do not change. This, of course, is a strong assumption so that the _ceteris paribus_ aspects of these exercises can not be over-emphasised.

Longer simulations say 75 or 100 periods were not considered meaningful since the values of most variables would be far out of the range of the original sample underlying the model. The model is forced to give the exogenously specified first period values of the endogenous behavioural variables by adjusting the constant term in each equation.[1/]

In considering the simulations which follow it is helpful to bear in mind the following relationships regarding sector income growth. Let us first write down the behavioural equations in algebraic form :

1/ The exception was the life expectancy equation constant which we recall is an asymptote. The initial sectoral savings rates were imposed _a priori_ at 0.15 in each sector since the rates predicted by the estimated functions were deemed unreasonable at 0.026 and 0.22 for non-agriculture and agriculture respectively, constant terms were again adjusted.

(1) $\ell n(FR) = A1 + B1\ \ell n(FPR) + C1\ \ell n(YP)_0 + D1\ \ell n(Illit) + E1\ \ell n(LF)$

(2) $\ell n(FPR) = A2 + B2\ \ell n(FR) + C2\ \ell n\ (Pa/PT)_0 + D2\ \ell n\ (CHED)$

(3) $FLF = A4 + B4(1/YP) + C4\ Illit$

(4) $RUM = A3 + B3(YNA/Pna - YA/Pa)/(YA/Pa) + C3(Pa/P_T) + D3(Illit)$

(5) $YA = A9\ Pa^{1-\alpha_1} \cdot TRACT^{\alpha_1}\ e^{\lambda t}$

(6) $YNA = A10(\overset{w}{Pna})^{1-\alpha_2}\ (ENERGY)^{\alpha_2}\ e^{\lambda t}$

(7) (a) $SPA = A6 + B5(YA/Pa) + C5\ (\sum_{i=0}^{15} Pa_i/Pa)$

(b) $SPNA = A6 + B6(YNA/Pna) + C6\ (\sum_{i=0}^{15} Pna_i/Pna)$

(c) $SP = SPA \cdot (Pa/P_T) + SPNA \cdot (Pna/P_T)$

(8) $\Delta TRACT = A7 + B7 \cdot SP \cdot P_T$

(9) $\Delta ENERGY = A8 + B8 \cdot SP \cdot P_T$

Letting lower case letter represent rates of growth (e.g. e = rate of growth of energy, tr = rate of growth of tractors, etc.) recall from our discussion of the production functions that income per head in each sector grows according to

$$ya - pa = \alpha_1\ tr - \alpha_1\ pa + \lambda$$

$$yna - pna = \alpha_2\ e - \alpha_2\ pna + (1 - \alpha_2)\ \frac{d\rho/dt}{\rho} + \lambda$$

where $\rho = \overset{w}{Pna}/Pna$. If we ignore $d\rho/dt$ which is likely to be small in any single period, then it will be seen that income per head in each sector is an increasing function of capital growth but a decreasing function of population growth. This is the familiar <u>ceteris paribus</u> effect present in all models. However, since the coefficient on the population growth terms are negative and those on the capital and technical progress terms positive, whether $ya - pa > 0$ and $yna - pna > 0$

depends on the relative size of all three terms. While we cannot say *a priori* how these terms will weigh up, we normally observe positive growth, albeit very low in many LDCs. More interesting, however, is not if income per head growth is positive but whether it is increasing or decreasing overtime. We will expect that in both sectors population growth rates will be declining since FR normally declines with development. However, this will be offset somewhat by increases in life expectancy and particularly in urban areas where in-migration rates may be increased with development. Again, the size of these growth terms must remain an empirical question particularly when it is remembered that our populations are defined in terms of economic sectors rather than geographic location. Hence, it may not be surprising to find low rates of population growth in agriculture.

The growth in the capital terms is even less straightforward. Since the model is largely symmetric as regards tr and e we only present analysis here for tr. Since,

$$tr \equiv \frac{\Delta TRACT}{TRACT}$$

by inverting the production function and solving for TRACT, this can be re-written as,

$$tr = \Delta TRACT \cdot G \left(\frac{YA}{Pa}\right)^{-1/\alpha_1} Pa^{-1}$$

and introducing the savings and investment functions (incorporating the age structure variables in the constants) gives:

$$tr = \{C + B7 \cdot [B5 \cdot \frac{YA}{Pa} + B6 \cdot \frac{YNA}{Pna}] \cdot P_T\} \; G(\frac{YA}{Pa})^{-1/\alpha_1} \; Pa^{-1}$$

and differentiating with respect to time yields:[1/]

$$\frac{dtr}{dt} = B7 [B5 \cdot (\frac{dYA/Pa}{dt} + \frac{dP}{dt}) + B6 \cdot (\frac{dYNA/Pna}{dt}) + \frac{dP}{dt})] G(\frac{YA}{Pa})^{-1/\alpha_1} \; Pa^{-1}$$

$$+ \{\sim\} \; (-\frac{1}{\alpha_1}) \; \frac{dYA/Pa}{dt} \cdot Pa^{-1}$$

$$+ \{\sim\} \; G(\frac{YA}{Pa})^{-1/\alpha_1} \; (-1) \; \frac{dPa}{dt}$$

It can be seen that the first term is positive if per capita income growth in both sectors is positive and if the total population growth rate is positive. However, under the same assumptions the second two terms are negative so a priori we cannot predict a sign here unless we know the parameter values. As it turns out, the base run simulations show that both e and tr initially increase and then start to decrease during the simulation period.

As indicated above, the base run model was initialised on the mean values of the sample underlying the parameter estimates. Our stereotype country is one of 31 million people with an overall per capita income of \$317. Average agricultural income is \$146 and average non-agricultural income is \$551. Forty-two per cent of the population live in non-agricultural areas. The crude birth rate is 36.8 and the crude death rate is 12.9 with a life expectancy of 54 years. The propensity for the agricultural population to migrate to the non-agricultural sector is 16.46 per thousand.

1/ Where $\{\sim\}$ represents the term in brackets in the tr equation.

Table II - The Base Run†

```
******************************
BASE RUN                 0   0
******************************
```

AGRICULTURAL SECTOR

	RPOP	YA	YA/RPOP	RFR	DELTRA	DPR	DYA	SPA	RUM
1968	18.18	2651.03	145.85	89.68	0.0508	0.0145	0.0327	21.8781	-0.01646
1973	19.45	3120.33	160.40	88.69	0.0626	0.0131	0.0344	23.2609	-0.01874
1978	20.74	3710.15	178.91	87.36	0.0738	0.0123	0.0362	27.2494	-0.02141
1983	21.95	4432.75	201.97	85.98	0.0799	0.0098	0.0357	29.6332	-0.02429
1988	22.91	5268.00	229.91	84.54	0.0827	0.0070	0.0342	34.0417	-0.02760
1993	23.62	6214.80	263.10	83.08	0.0836	0.0049	0.0328	39.5262	-0.03119
1998	24.10	7278.10	301.94	81.64	0.0831	0.0027	0.0309	45.4892	-0.03487

```
******************************
```

NON-AGRICULTURAL SECTOR

	YNA	UPOP	YNA/POP	YNA/UWPOP	DE	SPNA	DUP	DYNA	DWP	UFR
1968	7305.98	13.27	550.75	1619.45	0.0517	82.6129	0.0367	0.0567	0.0396	71.68
1973	9671.92	15.89	608.69	1794.86	0.0625	97.6253	0.0371	0.0618	0.0365	70.89
1978	13199.40	19.09	691.40	2052.47	0.0730	119.8956	0.0375	0.0666	0.0332	69.83
1983	18307.63	22.91	798.98	2436.06	0.0789	150.4543	0.0366	0.0705	0.0342	68.72
1988	25802.65	27.38	942.52	2909.30	0.0818	187.7272	0.0357	0.0723	0.0347	67.57
1993	36625.77	32.59	1123.76	3486.05	0.0828	234.8383	0.0353	0.0729	0.0345	66.40
1998	52000.57	38.71	1343.45	4188.56	0.0825	292.7920	0.0344	0.0720	0.0328	65.25

```
******************************
```

SUMMARY STATISTICS

	POP	GDP	SP	GDP/POP	DP	DY	DYP	INEQ
1968	31.44	9957.01	47.50	316.69	0.0239	0.0503	0.0264	1.2786
1973	35.34	12792.25	56.69	361.95	0.0239	0.0551	0.0311	1.2385
1978	39.83	16909.54	71.66	424.56	0.0244	0.0599	0.0356	1.2071
1983	44.86	22740.38	91.35	506.91	0.0235	0.0637	0.0402	1.1778
1988	50.29	31070.65	117.70	617.83	0.0226	0.0659	0.0433	1.1534
1993	56.21	42840.57	152.77	762.10	0.0225	0.0671	0.0446	1.1293
1998	62.81	59278.67	197.89	943.76	0.0223	0.0669	0.0447	1.1036

	FR	ILLIT	CHED	LF	CBR	CDR	FFR	%NON-AG
1968	81.360	55.050	20.564	53.56	36.792	12.919	33.038	42.191
1973	79.924	51.491	25.499	54.63	36.432	12.506	30.371	44.959
1978	78.270	48.931	29.612	55.49	36.050	11.673	28.337	47.932
1983	76.535	46.828	33.725	56.23	34.603	11.099	26.476	51.077
1988	74.729	45.168	37.838	56.86	33.285	10.694	24.707	54.437
1993	72.864	43.647	41.951	57.41	32.993	10.490	23.086	57.979
1998	71.039	42.321	46.064	57.89	32.620	10.366	21.602	61.624

† Key to variables: RPOP = Pa, UPOP = Pna, RFR = FR_r, UFR = FR_u, DELTRA = tr, DPR = pa, DYA = ya, DE = e, DUP = pna, DYNA = yna, DWP = $\frac{d\, P^w_{na}/dt}{P^w_{na}}$, DP = p, DY = y.

We turn now to the behaviour of the model during the base run. This is represented in Table II where the time paths of all the model's major variables are presented. On the demographic side, it can be seen that the "stereotype" country continues through the second phase of a demographic transition with a fall in the crude birth rate of about four per thousand and two per thousand in the crude death rate. The CBR in the end period is high relative to what one might expect from a simple cross-section tabulation of present-day birth rates with per capita income, (32.6 at $943). This is partly because we have only included developing countries in our sample so that the very high income, low birth rate countries were not included. If they had been included the income elasticity in the fertility equation would almost certainly have been larger. Secondly, as indicated earlier, the inclusion of variables other than income in the fertility equation reduces the income coefficient. Hence, simple models in which fertility is only a function of income may overstate the tendency for it to fall with development and we should be reluctant to accept the argument that efforts to reduce the birth rate exogenously are misdirected because with 'enough' development the birth rate will look after itself. Concomitant with the tendency for fertility to fall is a fall in the rate of female labour force participation.

The inter-sector migration rate doubles during the base run from 1.6% to 3.5% with the result that the growth rate of the agricultural population is nearly zero by the thirtieth period. The increase in the migration rate is caused by a worsening in the agricultural - non-agricultural income disparity, the decrease in illiteracy and the increasing importance of the 'pull' factor (Pa/P_T) in this equation. The result of the migration pattern is to keep the growth rate of the non-agricultural population at fairly high levels despite the tendency for the fertility rate to fall. The proportion of the population in urban areas increases from forty-two to sixty-two per cent in the thirty years.

On the economic side, we see that the growth rates of both agricultural and non-agricultural products first increase and then decrease, although the decrease of yna comes only in the last five years of the simulation. Throughout, yna > ya. This inverted-U shape of the time paths is due to firstly the tendencies for pna and pa to fall and secondly to the inverted U-shaped time paths of tr and e. Recall our discussion above about the possibility that tr and e can either increase or decrease over time depending on the relative sizes of the terms.

In terms of per capita incomes, the growth rate of agricultural per capita product increases from 1.8% to 2.8% while that in non-agriculture starts at 2% and winds up at 3.8%. Hence the increase in inter-sector disparity noted earlier. While the percentage difference in average incomes is the relevant measure of income disparity for the migration equation, a somewhat better statistic to measure rural-urban inequality was first proposed by Kuznets (1955) and later used by Bhattacharyya (1975). This we calculate by:

$$INEQ = (YNA/Pna - YA/Pa) \div YP$$

Using this number we see that INEQ falls from 1.278 to 1.1036 a decrease of nearly 14%. This pattern contrasts with that of the simple percentage difference in sectoral incomes used in the migration equation because the movement of people to the non-agricultural areas means that fewer are poorer and more are better off so that overall inequality declines. Of course, our measure of inequality, as indeed the model, does not take account of any inequality which takes place within the two sectors. Furthermore, we neglect three potential influences on inequality. All migrants to the non-agricultural sector are assumed to be employed since we have no labour market as such. Secondly there is no price mechanism so that there is no possibility for the terms of trade between the primary and industrial sectors to turn against the primary sector reducing the real income of agricultural workers. Thirdly, there is no improvement in the quality of the labour force through education. Nevertheless, as Adelman and Morris (1973) report, economic dualism is an important correlative of income inequality in developing countries.

Looking next at savings behaviour it can be seen that while the average propensity to save in agriculture stays pretty even at around 15%, that in non-agriculture grows from 15% to 21.8% in the final year.[1/] This pattern is easily explained by the fact that in agriculture the initial average and marginal propensities were similar whereas in the other sector the marginal propensity was substantially above the average.

Lastly, looking at the economy as a whole, we note that GDP growth rises from around 5% to 6.7% while the growth rate of the population falls from 2.4% to 2.2%. This means that the growth rate of per

---

1/ Recall that the initial period we assumed saving rates of 0.15 in each sector.

capita income rises from 2.6% to 4.5% during the thirty year simulation. Hence, YP increases from $317 to $944.

VI Policy Experiments with the Model

We turn in this section to the examination of a number of policy questions by means of experiments with the model by imposing exogenous changes on some variables. These simulations are meant to capture the effects of successful implementation of the various policies. In all of them, no costs of implementation have been included. This is not an unusual procedure for experiments with models of this kind, but nevertheless one must bear this in mind when making comparisons between different experiments. We report in Table III the percentage changes from the base run in selected variables in the final year of the simulation. Where a variable's time pattern throughout the simulation differed quanlitatively from the final year value this is noted in the text.

1. Educational Investment (CHED)

For a number of reasons, education has long been considered a potential tool for improving inequality. The usual mechanisms by which this operates (e.g. increasing the skills of individuals in the labour market) and the impact education may have on the size distribution of income do not fall within the scope of this model. On the other hand the illiteracy rate is an independent variable which affects fertility, life expectancy and migration in the model, and the secondary school enrolment rate affects female labour force participation rates.

Table III Percent Changes in Selected Variables from the Base Run values with Various Policies in year 30

Policy	YA/Pa	YNA/Pna	YP	SP	INEQ	FR	LF	RUM	%Non-Ag
1. CHED	-1.54	-5.09	-4.78	-5.93	-1.40	0.41	3.08	-1.47	-0.20
2. LF	-0.52	0.59	0.51	0.58	0.4	-9.45	20.93	0.91	0.08
3a FR	5.80	17.91	18.46	22.11	2.49	-21.45	0.13	11.49	2.47
3b RFR	3.79	2.0	5.36	7.64	-3.68	-20.14 1/	0.03	4.39	4.55
3c UFR	-0.28	7.24	3.88	3.08	5.34	-20.47 2/	0.02	1.45	-3.28
4a tr	1.96	0.42	0.37	0.35	-0.39	-0.04	0.0	-1.55	-0.35
4b e	2.52	9.52	9.65	12.0	1.74	-1.03	0.11	6.65	1.29
5. λ	47.35	64.77	64.24	78.31	3.40	-5.41	0.45	12.44	1.87
6a RUM=0	-11.36	29.24	-10.82	-9.02	58.11	1.3	-0.15	-100.0	-41.48
6b RUMx0.5	-6.05	11.48	-4.30	-3.40	21.81	0.49	-0.06	-53.86	-17.20
6c RUMx1.5	7.05	-7.99	2.71	1.91	-14.66	-0.30	0.03	62.27	14.85

1/ value of RFR change

2/ value of UFR change

In this experiment we raised the growth rate of secondary school enrolment by two percentage points so that by model year 1988, 98% of the relevant population was attending secondary school. In contrast, in the base year only 38% attend secondary school in 1988 and only 46% in the thirtieth year. The effects on illiteracy are similar, in the base run 45% of the adult population are still illiterate after twenty years while in this experiment that figure is reduced to 34%.

The effects of this policy work mainly through the demographic rates where life expectancy and hence the death rate are affected relatively more than fertility and the birth rate which is virtually unchanged.

The fall in the CDR means that population growth increases and with it overall and sectoral per capita incomes. This is compounded by a decrease in the migration rate as inter-sectoral incomes equalise . This fall in YP is responsible for the lack of decline in fertility despite the fall in illiteracy. Since non-agricultural incomes are affected relatively more than agricultural incomes, there is a slight tendency for the migration rate to decrease. Inequality, however, as measured here by INEQ, falls by 1.4% in the last period.

While the fall in per capita income due to this policy may have been offset if the model contained more positive feedbacks between education and, say, productivity, the experiment nevertheless points to tendencies which may be relevant, particularly in the medium term. After all, any improvement in the quality of the labour force will not affect output for five or ten years at least and certainly the eradication of adult illiteracy is a matter of a generation.

2. Improvement in Health (LF)

An improvement in the health of the population due to the eradication of communicable diseases, better access to health facilities and better sanitation will be reflected in an increase in longevity. Indeed, the start of the demographic transition in many less developed countries today, and the consequent increase in the growth rate of the population, it is said, can be traced to the rapid introduction of western medical technology. A decrease in mortality may pose a policy dilemma, since the increase in population growth may, at least in the short run, lead to a decrease in the overall standard of living as measured by per capita income.

As a proxy for a successful community health campaign we exogenously imposed a one per cent growth rate in life expectancy over and above the endogenously predicted value.[1/]

The result of this was that in the final year, life expectancy was 21% higher than in the base run (70 as opposed to 58 years). However, the reduction in mortality had a compensatory effect on fertility with the result that there was only a small increase in the growth rate of the population. For example in the final year the population growth rate was 2.46% versus 2.23% in the base run.

1/ However, LF was not allowed to exceed 70 years.

Moreover the age structure of the population was only marginally effected so that savings were hardly changed. In general the economic impact of an improvement in health was negligable with per capita products in agriculture and non-agriculture hardly effected at all. Similarly there was very little effect on migration rates. Hence, the simulations suggest that the policy dilemma suggested above may be non-existent. Indeed, there is even a very small increase in YP of a one half of one per cent. Added to this, must be the savings in health costs not only as a result of decreased morbidity but also due to lower fertility and hence fewer pregnancies.

3. Family Planning (FR, RFR, UFR)

One of the most important questions involves the impact of family planning programmes on the economy, and many previous papers, notably Enke (1971) (1974), have attempted to demonstrate that fertility reductions result in increased income. A potentially more interesting question, which is rarely explored, is whether family planning resources are better directed at rural than at urban areas. In order to simulate the effects of an effective family planning policy we ran experiments in which for the first twenty periods of the simulation the endogenous fertility rate was reduced by one per cent per year over and above what it would otherwise have been. This was performed for the overall, the rural, and the urban rates. Since feedbacks exist between the fertility rates and the economy, the percentage reductions are somewhat greater than 1% with respect to base run values.

Looking first at the reduction in overall fertility, we see that the non-agricultural sector benefits more than the agricultural sector. Per capita income in the former is up 18% over the base run while in the latter it is up slightly less than 6%. As a result, INEQ increases as does the migration propensity. With a reduction in the CBR of about 17% and an increase in YP of 18.5% the model suggests an 'elasticity' of approximately minus one between birth rate and per capita income reductions.

Turning now to the sectoral reductions, our simulations suggest that rural family planning is not only more equitable but also has more impact on overall per capita income than urban oriented family planning. On the other hand, urban fertility reductions increase urban incomes relatively more than rural reductions increase rural incomes. This is because in the agricultural sector, the workforce is taken to be the entire population whereas in the non-agricultural areas the working population s over 15 years old so that it takes 15 years for reductions in a cohort to work through to the production function.

The rural oriented policy raises not only agricultural but also non-agricultural income whereas the urban policy actually slightly decreases agricultural incomes relative to the base run. This is because the rural policy decreases the dependent rural population thereby stimulating savings which are chanelled into both sectors in the form of higher investment. By contrast, the urban policy mitigates against savings since a lower percentage of young people discourages savings in that sector. Hence the rural policy raises YP by some 5% over the base run whereas the urban policy increases it by a lower figure of 3.8%. As mentioned, the rural policy is also more equitable and INEQ declines by 3.7% versus an increase of over 5% relative to the base run with the urban policy.

4. Investment in Agriculture vs. Investment in the Non-Agriculture (tr)(e)

The question of whether industrialisation should be necessarily encouraged as a development goal is sometimes raised, particularly in view of equity considerations. In an effort to cast light on this we introduced a 10% increase in agricultural or non-agricultural investment over and above what it would have been.[1/] Again, this is assumed to be costless.

The results of these two policies are interesting. As the marginal product of investment in non-agriculture is greater than in agriculture, the raising of ΔENERGY has a larger own-sectoral level effect than the raising of ΔTRACT. In addition to this, the urban strategy spills over into rural areas since with a higher marginal propensity to save, the rise in YNA/Pna stimulates savings and hence investment in rural areas. In fact the non-agricultural policy turns out to be more efficacious in raising agricultural incomes than the agricultural investment policy! This result came about despite the lack of a price mechanism in the model which may have generated this result. By contrast, the agricultural strategy has only a very small effect on savings and in the non-agricultural area in terms of income. On the other hand, the industrial strategy is inequitable in terms of

---

1/ Hence, $\Delta TRACT_t = \Delta TRACT_t \cdot (1.10)$ or $\Delta ENERGY_t = \Delta ENERGY_t \cdot (1.10)$

INEQ and migration is stimulated so that by the end of the run the propensity to migrate is 6.6% up on the base run.

5. Technical Progress (λ)

Partly to test the sensitivity of the model to the exogenously imposed technical progress rates and partly to see the differential effects this variable has in the different sectors of the model, we increase λ by one percentage point in both sectors. The results here are, again, not surprising. Non-agriculture benefits relatively more than agriculture so that per capita income in the former is up nearly 65% versus only 47% in the latter. These increases, over a 30 year period illustrate the feedback between the economic and demographic variables because the fertility rate falls by 5.4% and the death rate by 1.5%. The resultant decrease in population growth stimulates, in turn, the growth in incomes. The different effect on incomes in rural and urban areas results in an increase in INEQ and a concomitant increase in the migration propensity of 10% over the base run value for the final year.

6. The Rate of Migration (RUM=0)(RUMx0.5)(RUMx1.5)

In the standard dualism literature, as indicated earlier, migration from the low (or zero) productivity agricultural to the higher productivity "modern" sector is seen as a mechanism by which overall living standards can be raised. To see the effects of migration we ran three experiments. In the first one, all migration was stopped. In the second, the migration rate was reduced by 50% and in the last, it was increased by 50% over and above the endogenous value for the run. The results of the two migration reduction experiments are qualitatively similar and symmetric in terms of sign pattern with the migration increase experiment. Accordingly we shall focus here only on the migration increase experiment.

As predicted by the dualism literatures, and consistent with the results of Yap (1976) and Adelman and Robinson (1978), migration has a beneficial effect on YP and on rural-urban equity. The influx of workers to the non-agricultural sector decreases the marginal product of labour in that sector and correspondingly increases it in agriculture. Hence average incomes move in the same directions. With more people now in the better-off sector, YP increases and overall equity with it. However, the magnitude of the effect of increasing the migration rate on per capita income is not very large. YP is only 2.7% up on the final year base run value. This is consistent with the findings of Yap and suggests that migration can hardly be considered an "engine of growth".

Set against this, of course, in any total analysis of migration must be its possible contribution to urban unemployment and hence inequality.[1/] However, within the context of this model this may not be that serious a problem. For example if employment opportunities were related to investment then job market pressure might be approximated by the difference between the growth rate of capital and the growth rate of the working population. In the Base Run this starts at 1.21% and rises to 4.97% in year 30. In the migration experiment the first year

---

1/ See Harris and Todaro (1970).

difference is 0.5% but the final year difference is 4.99%. Hence such an increase in migration may have a negligible effect on unemployment in the long term.

Finally, it should be pointed out that the migration experiments do not suggest that the transfer of people from high to low fertility areas has much impact on the size of the total population. In the experiment reported here, the change in the final year population was less than one tenth of one per cent and the birth rate down by only 0.25%. Of course in areas where the rural/urban fertility differential is higher, this effect, will be more important.

VII. Summary and Concluding Remarks

The basic philosophy behind the methods employed in this paper are that the study of population growth and movement and its interactions with the economy must be studied within a general equilibrium framework. Furthermore, the parameters and indeed variables included, must be empirically based if the model is to have any relevance at all to reality. At the same time, we recognise the limitations of econometric model building and do not attempt to forecast events. The model employed here is much too simple to attempt that if, indeed, such an attempt is worthwhile. The simulations are merely mechanical solutions to the growth model; had analytical solutions been possible, they could have been used instead. However, we feel that, within the limitations and scope of the model, as noted in the text, a number of *ceteris paribus* exercises can be carried out and can cast light on the issues raised in the paper.

While the estimated model presented here is relatively simple, the parameter estimates have been estimated from a consistent data base. Moreover, we have drawn upon the relatively new field of economic determinants of demographic variables in estimating equations to endogenise demographic phenomena which are often left exogenous in simulation models. While our fertility and labour force participation rate functions are fairly standard, we have gone beyond the existing literature in our life expectancy and inter-sectoral migration equations. On the economic side we have estimated sectoral savings functions and found that the marginal propensity to save is lower in agriculture than in non-agriculture. We also tested to see the effect of a population's age structure on savings rather than assuming a particular direction as, Coale-Hoover and Simon do in their models. We found that a higher proportion of children compete with savings in agriculture but complement savings in industrial areas. This is consistent with the economic value of children in agricultural and non-agricultural regions of less developed countries. Lastly our estimated production functions showed that marginal products of labour were considerably higher in agriculture than in non-agriculture.

Simulations with the model answered a number of questions. As with other simulation models, the effect of reducing fertility is to accelerate income growth but we also saw that reductions in rural fertility were more equitable and raised the overall level of per capita income more than similar efforts directed to urban areas only. Migration was shown to play a role in bringing about a more equitable inter-sectoral distribution of income, but could hardly be called an "engine of growth" since a fifty per cent increase in the migration rate results in increasing overall YP by less than three per cent after thirty years. The direction of investment according to this model, may pose something of a problem to policy makers. Increases in industrial investment are inequitable but succeed in raising agricultural incomes more than equal percentage increases in agricultural investment. Overall income per head is also benefitted more by non-agricultural than by agricultural investment. Educational investment comes out equitable but at the cost of lowering over all income per head. This is due partly to the impact this policy change had on the death rate and because the model contains no positive effect of education on the quality of the labour force. Finally, an increase in health as measured by an increase in life expectancy was shown to have neutral effects on the economy and incomes suggesting that one supposed policy dilemma may not exist.

Appendix A : The Sample and Data Sources

The sample of thirty-nine countries is listed below. Most data were for 1968: Argentina, Bolivia, Brazil, Chile, Columbia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatamala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela, Algeria, Burundi, Morocco, Rwanda , Tunisia, Uganda, Tanzania, Nigeria, India, Indonesia, Iran, Pakistan, Philippines, Thailand, South Korea, Chad, Dhahomy, Ghana, Mali, Puerto Rico.

The sources of the data were as follows:

(a) Population by age and rural urban location; crude birth rate, crude death rate, life expectancy, total population: U.N. Demographic Yearbooks, various issues.

(b) Secondary School Enrolment rate, Illiteracy; UNESCO, Statistical Yearbook, various issues, and UNESCO, Statistics of Illiteracy, 1965.

(c) Gross National Savings: World Bank, World Tables 1976.

(d) Tractors and changes in tractors, population in agricultural sector, F.A.O., Production Yearbooks, various issues.

(e) GDP and the share of agriculture in GDP: U.N. Statistical Yearbooks, various issues.

(f) Energy consumption and changes in energy consumption: U.N. World Energy Supplies, 1961-70.

Appendix B : Sensitivity Analysis

Since the behaviour for non-linear simulation model of the kind described in this paper depends upon the balance of the coefficients, it is interesting to know how sensitive the model is to changes in the parameters. As the model contains twenty-two estimated coefficients (ignoring the constant terms and exogenous parameters such as λ) there are obviously a great many experiments one could carry out to see the effects of changing coefficients.

We accordingly limited out experiments to increasing and decreasing each of the twenty-two coefficients by 50% one at a time. The results of this in terms of the percentage change in selected variables over the base run figure for the thirtieth period are reported in Table IV. It will be seen from this table that in general the model is relatively stable with respect to changes in the parameters. Most of the percentage changes from the base run are no more than ±10% and more often the changes in terms of the income variables is around 5% or less. The exception to this pattern is the runs where the parameters in the production functions were changed, particularly in the non-agricultural function where increasing the coefficient on energy from 0.587 to 0.8805 results in a more than five-fold increase in per capita GDP. Of course such a change results in a production function with unrealistic coefficients and returns to scale well in excess of one (1.29) so that this result is not surprising. However, it does illustrate the potential importance of scale economies in the model.

In light of this, we re-estimated the production function *without* constraining the coefficients to sum to one. The results are reported below. The largest change in a coefficient occurs on the labour term in the non-agricultural production which is now 0.147 versus 0.413 in the constrained version. The size of this coefficient, however, must be regarded as low on *a priori* grounds. The labour coefficient in agriculture is also reduced from 0.773 to 0.695. Estimated returns to scale in agriculture are now 0.901 and in non-agriculture are 0.812. A t-test in the null hypothesis that the coefficients in each equation summed to one was performed and was rejected at the 1% level in non-agriculture but not in agriculture.[1/]

Re-estimated Production Functions

$$\ell n(YA) = \underset{(13.08)}{3.492} + \underset{(13.4)}{0.695}\ \ell n(Pa) + \underset{(6.3)}{0.206}\ \ell n(TRACT) \qquad R^2 = 0.89$$

$$\ell n(YNA) = \underset{(13.8)}{6.834} + \underset{(2.5)}{0.147}\ \ell n(P^{W}_{na}) + \underset{(14.9)}{0.665}\ \ell n(ENERGY) \qquad R^2 = 0.97$$

In order to see the effects on the model of replacing the production functions with these unconstrained ones, we re-ran the base run and the policy experiments discussed in the text. The main effect on the new base run is that income growth in both sectors is down relative to the old base run. Agricultural per capita product reaches just over \$270 now as opposed to \$300 and in non-agriculture per capita product is more than \$200 below the original base run value in year 30.

1/ The following t-values were computed where $\hat{\alpha}$ and $\hat{B}$ are the estimated labour and capital coefficients respectively.

$$t = \frac{(\hat{\alpha} + \hat{B} - 1)}{\sqrt{\hat{var}(\hat{\alpha}) + \hat{var}(\hat{B}) - 2\hat{Cov}(\hat{\alpha},\hat{B})}}$$

which was -1.87 and -6.7 for agriculture and industry respectively.

Table IV - Sensitivity Experiments

YA/RPOP	YNA/UPOP	YP	S^2	INEG	RFR	UFR	FR	LF	CBR	CDR	RUM	ZNON-AG	Coefficient and change 1/
-0.766	-2.373	-2.387	-2.854	-0.463	4.445	4.445	4.494	-0.022	3.555	0.086	-1.589	-0.320	$b_1 \times 1.5$
0.562	1.780	1.793	2.146	0.334	-3.135	-3.135	-3.168	0.016	-2.541	-0.051	1.182	0.234	$b_1 \times 0.5$
1.622	5.583	5.573	6.674	1.097	-10.144	-10.144	-10.228	0.053	-8.314	-0.375	3.685	0.656	$c_1 \times 1.5$
-1.480	-4.779	-4.759	-5.683	-1.025	10.217	10.217	10.312	-0.050	8.087	0.427	-3.212	-0.601	$c_1 \times 0.5$
0.371	1.123	1.140	1.364	0.199	-1.849	-1.849	-1.872	0.010	-1.495	0.007	0.747	0.158	$d_1 \times 1.5$
-0.370	-1.108	-1.123	-1.344	-0.201	1.888	1.888	1.912	-0.010	1.517	-0.002	-0.741	-0.157	$d_1 \times 0.5$
0.209	0.638	0.645	0.772	0.116	-1.075	-1.075	-1.088	0.006	-0.865	-0.002	0.424	0.088	$e_1 \times 1.5$
-0.208	-0.631	-0.638	-0.764	-0.116	1.085	1.085	1.098	-0.006	0.869	0.003	-0.421	-0.088	$e_1 \times 0.5$
-0.828	-2.715	-2.743	-3.349	-0.534	2.243	2.243	2.306	-0.030	1.829	0.054	-1.892	-0.394	$d_2 \times 1.5$
0.880	2.999	3.033	3.711	0.564	-2.213	-2.213	-2.276	0.032	-1.821	-0.052	2.066	0.416	$d_2 \times 0.5$
0.945	3.705	3.670	4.503	0.805	-3.033	-3.033	-3.098	0.041	-2.487	-0.185	2.548	0.428	$b_2 \times 1.5$
-0.612	-2.268	-2.249	-2.751	-0.511	2.110	2.110	2.154	-0.026	1.713	0.124	-1.575	-0.278	$b_2 \times 0.5$
-1.119	-4.127	-4.085	-4.995	-0.952	4.075	4.075	4.156	-0.049	3.296	0.252	-2.874	-0.508	$c_2 \times 1.5$
1.328	5.374	5.311	6.522	1.174	-4.316	-4.316	-4.405	0.059	-3.549	-0.282	3.688	0.598	$c_2 \times 0.5$
0.305	0.673	0.709	0.856	0.070	-0.332	-0.332	-0.349	-0.631	-0.237	1.885	0.416	0.119	$b_4 \times 1.5$
-0.304	-0.671	-0.705	-0.851	-0.072	0.349	0.349	0.366	0.640	0.245	-1.889	-0.417	-0.118	$b_4 \times 0.5$
12.036	2.286	2.228	2.055	-2.708	-0.547	-0.547	-0.248	0.027	-0.194	-0.062	-8.734	-1.856	$(1-\alpha_1) \times 1.5$
-8.873	-1.980	-1.649	-1.586	1.696	0.467	0.467	0.187	-0.021	0.146	0.041	7.738	1.730	$(1-\alpha_1) \times 0.5$
27.560	3.830	4.728	4.106	-7.426	-1.019	-1.019	-0.519	0.057	-0.411	-0.158	-17.534	-3.057	$\alpha_1 \times 1.5$
-21.112	-3.462	-3.399	-3.090	5.232	0.925	0.925	0.391	-0.044	0.306	0.113	20.524	3.225	$\alpha_1 \times 0.5$
8.376	39.599	39.909	49.943	6.249	-3.055	-3.055	-3.702	0.361	-3.019	-1.162	26.358	4.098	$(1-\alpha_2) 1.5$
-7.161	-27.421	-26.613	-33.048	-9.104	2.952	2.952	3.575	-0.460	2.895	1.478	-20.711	-3.702	$(1-\alpha_2) 0.5$
38.071	295.558	315.212	398.606	13.244	-12.341	-12.341	-14.640	0.960	-12.204	-3.437	157.519	16.033	$\alpha_2 \times 1.5$
-15.165	-52.319	-49.752	-61.491	-26.544	6.805	6.805	8.199	-1.258	6.600	4.083	-42.210	-7.946	$\alpha_2 \times 0.5$
2.108	4.520	4.751	5.734	0.447	-0.539	-0.539	-0.642	-8.210	0.180	25.790	2.647	0.736	$c_4 \times 1.5$
-1.814	-3.826	-4.008	-4.830	-0.419	0.589	0.589	0.681	8.181	-0.195	-22.700	-2.326	-0.660	$c_4 \times 0.5$
0.316	-0.447	0.168	0.118	-0.834	0.111	0.111	-0.019	0.002	-0.016	-0.008	5.702	0.771	$b_3 \times 1.5$
-0.340	0.494	-0.186	-0.130	0.923	-0.121	-0.121	0.021	-0.002	0.018	0.009	-6.323	-0.843	$b_3 \times 0.5$
1.762	-2.355	0.873	0.633	-4.383	0.582	0.582	-0.098	0.011	-0.081	-0.039	24.481	4.150	$c_3 \times 1.5$
-1.460	2.227	-0.835	-0.621	4.165	-0.510	-0.510	0.095	-0.011	0.078	0.038	-19.250	-3.714	$c_3 \times 0.5$
0.121	-0.173	0.064	0.048	-0.322	0.040	0.040	-0.007	0.001	-0.006	-0.003	1.291	0.296	$d_3 \times 1.5$
-0.121	0.175	-0.065	-0.049	0.325	-0.040	-0.040	0.007	-0.001	0.006	0.003	-1.291	-0.298	$d_3 \times 0.5$
0.935	2.059	2.033	4.628	0.344	-0.200	-0.200	-0.227	0.025	-0.180	-0.081	1.023	0.162	$b_5 \times 1.5$
-0.940	-2.050	-2.022	-4.548	-0.358	0.204	0.204	0.231	-0.026	0.183	0.084	-1.029	-0.162	$b_5 \times 0.5$
10.674	25.243	24.784	78.624	3.753	-2.216	-2.216	-2.462	0.253	-1.996	-0.867	11.591	1.510	$b_6 \times 1.5$
-8.642	-18.352	-17.837	-44.466	-4.053	2.037	2.037	2.252	-0.277	1.830	0.948	-9.414	-1.263	$b_6 \times 0.5$
0.025	0.070	0.061	0.277	0.022	-0.008	-0.008	-0.007	0.001	-0.006	-0.005	0.026	-0.005	$c_5 \times 1.5$
-0.026	-0.071	-0.061	-0.278	-0.022	0.008	0.008	0.007	-0.001	0.006	0.005	-0.026	0.005	$c_5 \times 0.5$
-0.034	-0.076	-0.074	-0.445	-0.014	0.008	0.008	0.008	-0.001	0.009	0.003	-0.037	-0.005	$c_6 \times 1.5$
0.035	0.076	0.075	0.445	0.014	-0.008	-0.008	-0.008	0.001	-0.009	-0.003	0.037	0.005	$c_6 \times 0.5$
7.301	1.124	1.236	1.097	-1.880	-0.297	-0.297	-0.139	0.015	-0.106	-0.041	-5.440	-0.957	$b_7 \times 1.5$
-9.490	-1.360	-1.508	-1.326	2.543	0.379	0.379	0.172	-0.019	0.132	0.054	8.170	1.238	$b_7 \times 0.5$
7.617	36.770	36.777	46.032	6.174	-2.878	-2.878	-3.460	0.342	-2.780	-1.129	24.508	3.632	$b_8 \times 1.5$
-6.711	-28.681	-27.445	-34.171	-10.482	3.145	3.145	3.713	-0.482	2.993	1.621	-21.495	-3.308	$b_8 \times 0.5$

1/ For key to coefficients see equations on page 45.

In terms of the policy experiments, we re-run the policy experiments and then, as before, compared these to the values of selected variables in the final year of the new base run. In all cases except the health and migration experiments the results were qualitatively the same but the percentage changes were slightly less.

In the health improvement experiment (reported below) the increase in population now means that per capita incomes in each sector fall faster with faster population growth. This effect is compounded by the deliterious effects of lower incomes on savings which in turn results in less capital formation, less income growth etc. Similarly in the migration experiments, two of which we report below, we now get the result that a decrease in migration increases overall income per head while an increase in migration decreases overall YP. This is because with the new coefficient on labour in non-agriculture and the substantial diseconomies of scale, a reduction in population growth (such as cutting migration by a half) increases average product more now than previously, so that the net result is an increase in overall per capita product.[1/]

While we would argue that the re-estimated coefficients are not acceptable on a priori grounds - particularly the labour coefficient in non-agriculture - these results nevertheless support the view that migration may not always provide the overall growth effects suggested by some authors Indeed, while migration was shown to play a stimulating role to overall income growth in the usual base run, we were unable to state that it was an "engine of growth".

1/ For example the new equation relating per capita income growth and growth in energy and population is (ignoring age-structure and technical progress)

$$yna - pna = 0.665e - 0.853pna$$

Percentage Changes in Selected Variables from "New" Base Run Values with Three Policies Year 30.

Policy	YA/Pa	YNA/Pna	YP	SP	INEQ
LF	-2.37	-4.61	-4.59	-5.87	-0.75
RUMx0.5	-7.15	23.67	4.11	7.58	28.02
RUMx1.5	8.47	15.05	-4.73	7.62	-18.52

References

ADELMAN, Irma, "Growth, Income Distribution and Equity-oriented Development Strategies", World Development, February 1975.

ADELMAN and MORRIS, Economic Growth and Social Equity in Developing Countries, Standford Press, 1973.

ANKER, Richard, "An Analysis of Fertility Differentials in Developing Countries, Review of Economics and Statistics, 1978.

ANNABLE, James E., "Internal Migration and Urban Unemployment in Low-Income Countries : A Problem in Simultaneous Equations", Oxford Economic Papers, November 1972.

BHATTACHARYYA, A.K., "Income Inequality and Fertility : A Comparative View", Population Studies, 1975.

CASETTI, Emilio, "Economic Growth and the Population Explosion : Simulation Experiments using a Growth Model with Population Endogenous", Journal of Development Studies.

CHENERY, H., amd SYRQUIN, M., Patterns of Development : 1950-1970, World Bank Oxford University Press, 1975.

COALE, A.J., "How the Age Distribution of a Human Population is Determined", Cold Springs Harbor Symposium on Quantitative Biology, 1975.

COALE, A.J., and DEMENY, P., Regional Model Life Tables and Stable Populations, Princeton, 1966.

COALE AND HOOVER, Population, Growth and Economic Development in Low-Income Countries, Princeton, 1958.

COLLIER and GREEN, "Migration from Rural Areas of Developing Countries : A Socio-Economic Approach", Oxford Bulletin of Economics and Statistics, February 1978.

ENKE, S., "Population and Development : A General Model", Quarterly Journal of Economics, 1963.

ENKE, S., "Economic Aspects of Slowing Population Growth", Economic Journal, 1966.

ENKE, S., "The Economic Consequences of Rapid Population Growth", Economic Journal, 1971.

ENKE, S., "Reducing Fertility to Accelerate Development", Economic Journal, 1974.

FEI, John C.H. and RANIS, G., Development of the Labor-Surplus Economy: Theory and Policy, Richard D. Irwin, 1964.

GUPTA, K.L., "On Some Determinants of Rural and Urban Household Saving Behaviour", Economic Record, December 1970.

HARRIS and TODARO, "Migration, Unemployment and Development : A two-Sector Analysis", American Economic Review, March, 1970.

HAZLEDINE, T., and MORELAND, R.S., "Population and Economic Growth : A World Cross Section Study", Review of Economics and Statistics, August, 1977.

HIRSCHMAN and ROTHCHILD, "The Changing Tolerance for Income Inequality in the Course of Economic Development", Quarterly Journal of Economics, 1973.

JORGENSON, D. "The Development of a Dual Economy", Economic Journal, June 1961.

KATOUZIAN, M.A., "A Two-Sector Model of Population Growth and Economic Development", Working Paper, University of Kent, 1974.

KELLEY, Allen C, "Population Growth, the Depending Rate and the Pace of Economic Development", Population Studies, 1973.

KELLEY, Allen C., "Savings, Demographic Changes, and Economic Development", Economic Development and Cultural Change, July 1976.

KELLEY, Allen C., WILLIAMSON, Jeffrey G., and CHEETHAM, Russell S., Dualistic Economic Development : Theory and History, University of Chicago Press, 1972.

KUZNETS, S., "Economic Growth and Income Inequality", American Economic Review, 1955.

KUZNETS, S., "Rural-Urban Differences in Fertility : An International Comparison", Proceedings of the American Philosophical Society, February 1974.

LEFF, N.H., "Dependency Rates and Savings Rates", American Economic Review, June 1971.

LEIBENSTEIN, A., A Theory of Economic-Domographic Development, Princeton : Princeton University Press, 1954.

LEIBENSTEIN, H., "An Interpretation of the Economic Theory of Fertility : Promising Path or Blind Alley?", Journal of Economic Literature 1974.

LEWIS, W.A., "Economic Development with Unlimited Supplies of Labour", Manchester School, May 1954.

MCFARLAND, William E., BENNETT, James P., and BROWN, Richard A., "Description of the TEMPO II Budget Allocation and Human Resources Model" G.E. Tempo, GE73TMP-13, April (1973).

MCINTOSH, J., "Growth and Dualism in Less Developed Countries", Review of Economic Studies, July 1975.

MCNICOLL, G., "Economic-Demographic Models" in Leon Tabah (ed.) Population Growth and Economic Development in the Third World Vol. 2, NSSP, Ordina Editions, Belgium, 1975.

MIKSELL and ZINSER, "The Nature of the Savings Function in Developing Countries : A Survey of the Theoretical and Empirical Literature", Journal of Economic Literature, 1973.

NELSON, R.R., "A theory of the Low-Level Equilibrium Trap", American Economic Review, December 1956.

NIEHANS, J., "Economic Growth with Two Endogenous Factors", Quarterly Journal of Economics, 1963.

OSHIMA, H., "The International Comparison of Size Distribution of Family Incomes, with Special Reference to Asia", Review of Economics and Statistics, November, 1962.

PAUKERT, F., "Income Distribution at Different Levels of Development : A Survey of Evidence", International Labour Review, August, 1973.

PRESTON, S.H., "International Comparison of Net Rural-Urban Migration Rates" mimeo, U.N. Population Division, 1978.

RODGERS, G.B., "Income and Inequality as Determinants of Mortality : An International Cross-Section Analysis", June 1977, unpublished typescript.

RODGERS, Gerry, WERG, Rene, and HOPKINS, Mike, Population, Employment and Inequality : BACHUE-Philippines, ILO, Saxon House, 1978.

SATO and NIHO, "Population and the Development of a Dual Economy", Oxford Economic Papers, November 1971.

SHULTZ, T.P., "Explanation of Birth Rate Changes over Space and Time : A study of Taiwan", Journal of Political Economy, March/April, 1973.

SIMON, J., The Effects of Income on Fertility, University of North Carolina, 1974.

SIMON, Julian L., "The Positive Effect of Population Growth on Agricultural Savings in Irrigation Systems", Review of Economics and Statistics, February 1975.

SIMON, Julian L., "Population Growth may be good for LDCs in the Long Run : A Richer Simulation Model", Economic Development and Cultural Change, January, 1976.

SIMON, Julian L., The Economics of Population Growth, Princeton University Press, 1977.

STANDING, Guy, Labour Force Participation and Development, ILO, 1976.

SUITS, Daniel B, et al "Birth Control in an Econometric Simulation" International Economic Review, February, 1975.

TODARO, M.P., Internal Migration in Developing Countries, ILO, 1976.

WIENTRAUB, R., "The Birth Rate and Economic Development : An Empirical Study", Econometrica, October, 1962.

WIESSKOFF, R., "Income Distribution and Economic Growth in Puerto Rico, Argentina, and Mexico", Review of Income and Wealth, 1970.

YAP, Lorene, "Internal Migration and Economic Development in Brazil", Quarterly Journal of Economics, February 1976.

YAP, Lorene, "The Attraction of Cities : A Review of the Migration Literature", Journal of Development Economics, 1977.

YOTOPOULOS and NUGENT, Economics of Development : Empirical Investigators Harper and Low, 1976.