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MIGRATION AS A MEANS OF POPULATION CONTROL

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The more crowded West Indian islands lose citizens each year through emigration, and they are small enough that appreciable relief of population pressure is thereby afforded. The island of Java each year sends some of its inhabitants to Sumatra and elsewhere under official sponsorship, part of the rationale for the policy being the relief of population pressure. A recent definitive study covers the movement in detail (Widjojo, 1970, especially pp. 231-235).

In these and other instances where emigration has been promoted as a population policy, it has been recognized that the amount of relief ultimately attained depends on the ages of the migrants. The initial effect on the total population is the same for a person of eight or of 80 years of age, but the long-term effect may be quite different. It has been argued that the out-movement of a relatively small number of couples at fertile ages would hold the total population constant, but no theoretical analysis is available on this point. The purpose of the present paper is to ascertain the ultimate numerical effect of outmigration, in particular the effect of outmigrants at fertile ages as against other outmigrants, and to see how many outmigrants annually would hold the home population constant.

Many countries of the Americas and Africa have open spaces that they aspire to fill by internal migration. The possibility of thus relieving pressure in their more densely

settled areas, including their cities, causes some to assert that birth control is not needed in those crowded areas. Getting people to move requires overcoming the contemporary disinclination to pioneer settlement, and it also requires heavy expenditure on behalf of each settler for at least the first year or two. Because of the difficulty of recruitment and support, the number of such settlers that would be needed to substitute effectively for birth control in the crowded areas is of interest.

Since the results of this paper are purely abstract they apply to immigration as well. Tabah and Cataldi (1963) consider the effect on a population of streams of immigrants of different ages.

Theory and definitions

Our first observation is that no amount of outmigration over any limited period of time affects the ultimate rate of increase. This ultimate rate, denoted r , is determined only by the age-specific birth and death rates, and is entirely unrelated to the initial population, and cannot be modified by removal of part of it. The equation for the intrinsic or ultimate rate of increase for either sex is

$$\int_0^{\infty} e^{-ra} l_a m_a da = 1. \quad (1)$$

where l_a is the probability of surviving from birth to age a , so that $l_0 = 1$, and $m_a da$ is the probability of having a child between ages a and $a + da$.

On the other hand an outmigration stream that continues indefinitely will have an effect on the rate of increase. This case will be taken up later, but first let us consider the effect of outmovement at a particular age and in one single year on the level of the ultimate population trajectory.

Suppose that the number of persons of age a to $a + da$ is $p_a da$ at time zero, and confine the argument to females. We know from theory (Lotka, 1939, and elsewhere) that the action of fixed age-specific rates of birth and death on this initial population will ultimately result in geometric increase, however irregular the initial age distribution, and that the geometric increase will be at the rate r compounded momentarily, r being the real root of (1). The curve of births in this ultimate geometrically increasing population is

$$B(t) = Qe^{rt}, \quad (2)$$

where Q is a constant. It may easily be shown that this number of births annually corresponds to a population of all ages $P(t)$, where

$$P(t) = Q \left(\int_0^{\infty} e^{-ra} l_a da \right) e^{rt}, \quad (3)$$

The contents of the parentheses in (3) may be called $1/b$, b being the ultimate or intrinsic birth rate, so that (3) becomes

$$P(t) = \frac{Q}{b} e^{rt}. \quad (4)$$

One-time Emigration

Our task is to see how the population at time t is different as a result of amount of immigration Δp_x at time zero. (For emigration Δp_x would be a negative quantity.) The parameter r is unaffected, and so is b , the latter depending only on the life table and on r . If we can find how Q is altered by the change Δp_x in the age distribution of the population, then (4) will tell us by how much Δp_x raises or lowers the curve $P(t)$.

The value of Q (Lotka, 1939, p. 85) is the integral

$$Q = \frac{1}{\kappa} \int_0^{\infty} e^{-rt} G(t) dt, \quad (5)$$

where κ is the mean age of childbearing in the stable population, and $G(t)$ the number of births at time t arising out of the original population of age distribution p_a . Explicitly the function $G(t)$ is

$$G(t) = \int_0^{\infty} p_a \left(\frac{l_{a+t}}{l_a} \right) m_{a+t} da. \quad (6)$$

The ultimate effect on $P(t)$ of the alteration in population Δp_x at age x will conveniently be traced in two steps. First we will see what the effect on the births $G(t)$ is, using equation (6), and then see what difference this changed $G(t)$ in turn makes for Q , using equation (5).

In (6) we enter $p_x + \Delta p_x$ in place of p_x for one particular single year of age $x - \frac{1}{2}$ to $x + \frac{1}{2}$, and so calculate the effect of an increment of population. (We could take instead the age interval x to $x + \delta$ rather than $x - \frac{1}{2}$ to $x + \frac{1}{2}$, and suppose an increase $\Delta p_x / \delta$, then let δ tend to zero. This would concentrate the increase in a moment of time, and so eliminate the approximation caused by a one-year interval.)

No other age than x will be involved, and the change from p_x to $p_x + \Delta p_x$ adds to the integral $G(t)$ the amount

$$\Delta G(t) = \left(\frac{l_{x+t}}{l_x} \right) m_{x+t} \Delta p_x, \quad (7)$$

where x is the (fixed) age at which emigration is considered to occur. This provides the first link in the chain, and we go on to see the effect of the change $\Delta G(t)$ of (7) on Q of (5).

The amount by which Q of (5) is increased by the increment $\Delta G(t)$ must be

$$\Delta Q = \frac{1}{\kappa} \int_0^{\infty} e^{-rt} \Delta G(t) dt = \frac{\Delta p_x}{\kappa} \int_0^{\infty} e^{-rt} \left(\frac{l_{x+t}}{l_x} \right) m_{x+t} dt. \quad (8)$$

The integral in (8) may be designated V_x , and it is the well-known reproductive value defined by Fisher (1930, p. 30). In words, V_x is the number of children expected to be born to a woman of age x , given the life table ℓ_{x+t} and the age-specific birth rate m_{x+t} for all $t \geq 0$, each child being discounted back to the present at the intrinsic rate r .

Entering V_x for the integral in (8) and then reverting to (4) we have

$$\Delta P(t) = \frac{\Delta Q}{b} e^{rt} = \frac{V_x}{b\kappa} e^{rt} \Delta p_x. \quad (9)$$

This is the required result; it gives the effect on the ultimate population of a change Δp_x in the population at the single year of age x .

Note that the ultimate effect per unit change in p_x is a factor multiplied by the exponential function e^{rt} . This is to be expected; the effect, like the ultimate population, is not a number but a trajectory, a constant times e^{rt} .

The expression (9) tells us that the effect on the ultimate population trajectory of removing Δp_x individuals aged x is $V_x/b\kappa$ times as great as the effectiveness of removing Δp_x individuals distributed by age as the stable population, and V_x times as great as removing Δp_x individuals of age zero.

Comparison of different ages

To compare the effect of the change Δp_x for different ages of x we need only compare the V_x , since b , κ and e^{rt} of (9) are all unaffected by the age at which the change takes place. The value of V_x has been calculated for a large number of human female populations, and its shape is familiar. On our definition it is unity at age zero by virtue of the equation (1), rises towards the age when reproduction begins, then falls sharply as the woman has her children, until about age 50, when the number of prospective children has become zero. Table 1 shows V_x for Barbados and Mauritius in 1965 and 1966 respectively.

Applying the result to transmigration policy, for example between Java and Sumatra, the maximum effect on the population of Java results from choosing outmigrants of age 17 or so, since this is the maximum point of the V_x curve for increasing populations (Coale, 1968). At this maximum the value of V_x is about 1.8 times as great as at age zero for countries like Mauritius and Indonesia. Sending out women beyond age 50 would have no effect at all, and beyond age 35 very little effect. The departure of one person immediately reduces the total number remaining in Java, and in exactly the same amount as the departure of another, whatever their ages. But the ultimate population arises out of the new generations, and our result (9) shows in what degree these later generations--50 or 100 years from now--are affected by the change Δp_x .

TABLE 1. Reproductive value V_x in five-year age groups for females in Barbados 1965 and Mauritius 1966 ($V_0 = 1$, i.e., the unit is the reproductive value of a newborn girl), along with other stable population parameters.

Age	Barbados 1965	Mauritius 1966
0-4	1.099	1.159
5-9	1.229	1.381
10-14	1.363	1.618
15-19	1.370	1.783
20-24	1.152	1.611
25-29	0.823	1.151
30-34	0.493	0.690
35-39	0.216	0.312
40-44	0.052	0.083
45-49	0.005	0.009
1000r	20.68	30.54
1000b	28.02	38.89
κ	26.99	27.30
e^{15r}	1.364	1.581
ℓ_{15}	0.94834	0.90358
e^{15r}/ℓ_{15}	1.438	1.750
R_0	1.767	2.349

Let us consider the departure of 1000 women 15-19 years of age from Mauritius, taking the constants from 1966. Then $V_{15} = 1.783$, $r = 0.0305$, $\kappa = 27.30$, $b = 0.03889$. The effect on the later population is from (9)

$$\begin{aligned}\Delta P(t) &= -\frac{V_{15}}{b\kappa} e^{rt} \Delta P_x \\ &= -\frac{1.783e^{0.0305t}}{(0.03889)(27.30)} 1000 = -1.679e^{0.0305t}.\end{aligned}$$

In contrast, if 1000 babies just born had been moved the ultimate effect would be $1/1.783$ as great, or $-942e^{0.0305t}$. If 1000 women representing all age groups in the stable proportion had departed the effect would be $-1000e^{0.0305t}$.

Thus the outmigration of 1000 women of the optimum age group, 15 to 19 at last birthday, is equivalent to the outmigration of 1783 babies just born, and the equivalent of 1679 women distributed through all ages in proportion to the stable population.

However, the ages here are critical. If the women are slightly older, say ages 25-34, then 1000 of them are less than the equivalent of 1000 women distributed through all ages as the actual population. It is true that women of 25-34 will in general leave with their babies, a qualification on the result that will be discussed later.

Note from Table 1 how much flatter the curve of V_x would be for Barbados than for Mauritius. Where for Mauritius the emigration of 1000 women 15-19 is the equivalent of 1783 newborn babies, for Barbados 1000 women 15-19 would be the equivalent of 1370 newborn babies. Possible advantages of age-selective outmigration for Barbados are smaller than those for Mauritius.

In order to see on what characteristics the peak value of V_x depends, we can manipulate the integral defining V_x , contained on the right-hand side of (8), to show that for ages younger than those of childbearing V_x takes the simple value e^{rx}/l_x . The maximum of V_x is somewhat greater than e^{15r}/l_{15} , shown at the bottom of Table 1. With rapidly growing populations the e^{rx} is a much larger factor than $1/l_x$. For slowly growing, low mortality populations migration at one age before childbearing has much the same effect as migration at another.

Amount of emigration required for given effect

The converse question is how many women of a given age x would have to leave in order to have a specified effect $\Delta P(t)$ on the population of an area at time t . This also can be obtained from (9); we need only solve for Δp_x , supposing $\Delta P(t)$ given. The solution is evidently

$$\Delta p_x = \frac{b_x \Delta P(t)}{V_x e^{rt}} \quad (10)$$

which has meaning for x almost to the end of reproduction. Table 2 shows how this varies with x , using the V_x for Barbados 1965 and Mauritius 1966, and calculating for 1000 population. The numbers in the columns may be compared with 1000r, which is the number of emigrants of the age distribution of the stable population that would have to be removed each year to cancel out the increase of 1000 population. Apparently removal of anyone under 30 is more effective than removal of a random member of the population; removal of anyone over 30 is less effective.

Note that the effect is produced by women in the pre-fertile ages rather than in the fertile ones. If we average ages 20 to 39 for either population in Table 1, we come out with a V_x less than b_k , so the emigration of women of these four age groups in equal numbers would be slightly less advantageous than a random selection from the whole population. It is imminent childbearing, rather than recent childbearing, that makes women the best candidates for outmigration if population control is the object.

When family structure is taken into account, the difference between emigration before and after childbearing becomes much less pronounced. A woman who leaves before childbearing has her births out of the country, whereas if she goes after childbearing she has them in the country but takes them with her when she leaves. In either case both she and her children are gone.

TABLE 2. Emigrants of given age, leaving in one year, required to reduce ultimate population by $\Delta P(t) = 1000re^{rt}$, that is, by one year's natural increase among 1000 initial population; Barbados 1965 and Mauritius 1966 (female model)

	Barbados 1965	Mauritius 1966
	$1000bkr/V_x$	$1000bkr/V_x$
0-4	14.23	27.97
5-9	12.73	23.48
10-14	11.47	20.04
15-19	11.42	18.18
20-24	13.58	20.12
25-29	19.00	28.17
30-34	31.72	46.99
35-39	72.40	103.91
40-44	300.77	390.65
Mix of all ages in stable distribution	1000r 20.68	1000r 30.54

N.B. A standard for comparing the numbers of emigrants of specific ages required for a given effect is the number that would be required if they were distributed through all ages as the general population. At the bottom of each column 1000r for the population in question is shown; this is the number of outmigrants having a stable age distribution equivalent to the numbers of outmigrants of the several ages given above.

The calculations have been made for the female part of the population. Corresponding numbers can be produced for the male part wherever the age distribution of fathers at the birth of their sons is available. The two would usually be slightly different, mostly because of fathers averaging two or three years older than mothers and having higher mortality.

The argument used here, and in particular the result (9), tells us that part of any subsidy to emigrants should be allocated in proportion to V_x . Since sterilization has the same effect as emigration as far as subsequent generations are concerned, payment to individuals for allowing themselves to be sterilized should also be proportional to V_x . This is for individuals aged x of average fertility; allowance for selection of those more or less fertile at a given age is a matter for further analysis.

Constant Annual Emigration

The above discussion supposed a single event of outmigration. The objective was to compare the population effects of different ages of emigrants for migration taking place once only, and hence not affecting the rate of increase.

Consider now a stream of outmigration, expressed as a proportion f of the population leaving each year as it attains age x . This does affect the rate of increase r , and we revert to the characteristic equation (1) to ascertain by how much.

Analogy to sterilization and excess mortality

The effect of the emigration of f of the population as it attains age x is found by assimilating it to the sterilization of a randomly selected fraction f of the population as it attains age x . The sterilized individuals remain where they are, but make no further contribution to the subsequent generations.

The sterilization model is different from the original population (without emigration or sterilization) only in that its age-specific birth rates at ages beyond age x are lower by the fraction f . Let the function f_x be defined as equal to zero up to age x , and to f from age x onwards. Then the new fertility at age a is $(1 - f_x)m_a$. For either the emigration or sterilization intrinsic rate $\bar{r}$ we write (1) with $(1 - f_x)m_a$ in place of m_a :

$$\int_{\alpha}^{\beta} e^{-\bar{r}a} l_a (1 - f_x) m_a da = 1.$$

This equation also represents an excess mortality model. If the age-specific death rate at the year of age x increases by the amount f , then the survivorship function l_a would become $l_a(1 - f_x)$. The increase of mortality at the single age x , decrease of fertility from age x onward, and constant emigration at age x all have identical effects on the characteristic equation.

General solution

To solve the equation we first separate the integral into two parts, that up to age x and that above:

$$\int_{\alpha}^{\beta} e^{-\bar{r}a} \ell_a m_a da - f \int_x^{\beta} e^{-\bar{r}a} \ell_a m_a da = 1. \quad (11)$$

This implicitly gives the new intrinsic rate $\bar{r}$ in terms of the arbitrary f , the fraction emigrating at age x . No assumption about the magnitude of f or of any other symbol has been used in its derivation, except that $0 \leq f \leq 1$.

Solving for the proportion f of emigrants at age x required for attainment of a given $\bar{r}$, we find

$$f = \frac{\int_{\alpha}^{\beta} e^{-\bar{r}a} \ell_a m_a da - 1}{\int_x^{\beta} e^{-\bar{r}a} \ell_a m_a da}. \quad (12)$$

Equation (12) has no meaning if f is greater than unity, and hence x must be low enough that the integral in the denominator of (12) exceeds the numerator. No possible stream of emigration beyond a certain age will hold the increase of population down to an arbitrary $\bar{r}$.

We can express (12) in terms of a generalization of reproductive value V_x defined by the integral of (8). In this general reproductive value, say $V_{x,\bar{r}}$, future children

are discounted not at the intrinsic rate r of the observed population, but at the rate $\bar{r}$ at which the emigration policy is to aim:

$$V_{x,\bar{r}} = \int_0^{\infty} e^{-\bar{r}t} \frac{l_{x+t}}{l_x} m_{x+t} dt.$$

Then the alternative form of (12) is

$$f = \frac{V_{0,\bar{r}} - 1}{e^{-\bar{r}x} l_{xx,r}}. \quad (12)$$

The argument of this section pivots on the simple result (12). We will show that if $\bar{r}$ is put equal to zero we obtain the fraction f emigrating out of each cohort for stationarity. If f is small and $\bar{r}$ is close to r , we can reconcile (12) with (9) for one-time outmigration, now supposed repeated year after year. In one of its offshoots or another, formula (12) serves to show how much emigration is required to attain the demographic objective represented by a rate of increase $\bar{r}$, given the continuance of life table l_a and the birth rates m_a .

Applications

To apply (12) we need only know the Net Maternity Function $l_a m_a$. For Mauritius 1966 this is given in Table 3 in

TABLE 3. Net Maternity Function for Mauritius 1966, approximated in five-year age intervals by ${}_5L_y F_y$ (females), and calculation of $e^{-\bar{r}(y+2\frac{1}{2})} {}_5L_y F_y$ needed for estimate of fraction migrating to hold increase down to $\bar{r} = 0.02$ (Formula (12))

y	$e^{-0.02(y+2\frac{1}{2})}$	${}_5L_y F_y$	$e^{-0.02(y+2\frac{1}{2})} {}_5L_y F_y$	Cumulative $\int_y^{\beta} e^{-\bar{r}a} {}_5L_a F_a da$
10	0.7788	0.0014	0.0011	1.3365
15	0.7047	0.1858	0.1309	1.3354
20	0.6376	0.6236	0.3976	1.2045
25	0.5769	0.6061	0.3497	0.8069
30	0.5220	0.4730	0.2469	0.4572
35	0.4724	0.3239	0.1530	0.2103
40	0.4274	0.1201	0.0513	0.0573
45	0.3867	0.0154	0.0060	0.0060
Total		2.3493 = R_0	1.3365	

Example: Fraction of population aged 25 migrating required to hold increase down to 2 percent is

$$\frac{1.3365 - 1}{0.8069} = 0.417.$$

five-year age intervals. In the age interval y to $y + 4$ at last birthday we approximate the integral required for (12) by

$$\int_y^{y+5} e^{-\bar{r}a} l_a m_a da \doteq e^{-\bar{r}(y+2\frac{1}{2})} {}_5L_y F_y,$$

where ${}_5L_y = \int_y^{y+5} l_a da$, and F_y is the age-specific birth rate for women of age y to $y + 4$ at last birthday.

The intrinsic rate of Mauritius is estimated as 30.54 per thousand. How much emigration would be required for the modest goal of bringing it down to 20 per thousand? If the emigrants are $x = 25$ years of age, (12) tells us that with $\bar{r} = 0.020$ the fraction $f = 0.417$ of each cohort must leave on reaching this age. If the emigrants are $x = 20$ years of age the proportion that would have to leave is smaller: 0.279.

Thus to bring about a drop from the actual increase of 30.54 per thousand to one of 20.00 per thousand the departure of 41.7 percent of each cohort would be required if they leave at age 25, and of 27.9 percent if they leave at age 20. The poor returns on emigration as a means of population control are suggested by the fact that the departure of 30 to 40 percent of each cohort would only hold the population down to two percent annual increase, or a doubling every 35 years.

The calculation of f given the initial l_a and m_a , and given also the $\bar{r}$ that it is desired to attain, is direct. The converse problem--given a proportion f of emigrants or sterilizees at age x , find the resulting intrinsic rate $\bar{r}$ --would have to be dealt with by iteration. In the special case

in which f is small and the new $\bar{r}$ is therefore very close to r , it may be shown that $\bar{r}$ is given approximately by

$$\bar{r} = r - \frac{f e^{-rx} \ell_x v_x}{\kappa}. \quad (13)$$

This is consistent with a version of (9) specialized to a small change in an initially stable population, repeated each year. Dividing and multiplying the right-hand side of (9) by p_x , and writing $-f$ for $\Delta p_x/p_x$, the proportion of the cohort migrating at age x , recalling that with stability p_x , the initial number at age x , is equal to $e^{-rx} \ell_x$ times the initial population $P(0)$, we have in place of (9)

$$\Delta P(t) = -P(0) e^{rt} \frac{e^{-rx} \ell_x v_x}{\kappa} f.$$

Dividing by $P(t) = P(0) e^{rt}$ to obtain on the left $\Delta P(t)/P(t)$ now gives

$$\frac{\Delta P(t)}{P(t)} = - \frac{f e^{-rx} \ell_x v_x}{\kappa}.$$

But an annual $\Delta P(t)/P(t)$ is equivalent to the change in the rate of increase $\bar{r} - r$. This completes the derivation of (13) from (9), supposing an initially stable age distribution and small emigration repeated from year to year.

Emigration for a stationary population

Our next problem is to find the amount of emigration that will hold the ultimate rate of increase down to zero. For this we need the value of f when $\bar{r}$ is replaced by 0 in (12).

Evaluation of (12) with $\bar{r} = 0$ offers no difficulty; the integral in the numerator is R_0 , the Net Reproduction Rate, and the integral in the denominator is the part of R_0 beyond age x . Hence we have

$$f = \frac{R_0 - 1}{\int_x^{\beta} l_a m_a da} \quad (14)$$

as the fraction of the age x that must emigrate per year to hold the ultimate population stationary, x again being low enough for f not to exceed unity. To see (14) independently of its derivation as a special case of (12) we note that to bring the Net Reproduction Rate down to 1 we need to lose $R_0 - 1$ births per woman from each birth cohort. The number of births per woman lost by removing a proportion f of women at age x is $f \int_x^{\beta} l_a m_a da$. Equating $R_0 - 1$ and $f \int_x^{\beta} l_a m_a da$ yields (14).

The proportion of emigrants f in (14) required to hold the line of stationarity does not explicitly involve r , the rate of increase of the initial (supposed stable) population, but only R_0 and the cumulative of the Net Maternity Function from age x onwards. It tells us that one age of departure younger than the beginning of reproduction α is as good as another, as far as the fraction f going out is concerned, and that for all such ages the f required is

$$f = \frac{R_0 - 1}{R_0}.$$

The absolute number of emigrants required if they were of age x

would be $f l_x$ for $x < \alpha$, multiplied by the number of births, supposed fixed in the present case.

This last has a derivation even more elementary than that of (14). On a per girl basis, the number of prospective babies is R_0 ; the removal of $(R_0 - 1)/R_0$ of the girls before they begin childbearing will cause $R_0 - 1$ fewer girl children to be born, leaving $R_0 - (R_0 - 1) = 1$ as the average.

The very large fraction that would have to emigrate each year to hold a population of high birth rate stationary is to be seen by entering Mauritius' 1966 $R_0 = 2.349$ for R_0 in (14). At the best, if the emigrants are all under the lowest age of reproduction, the fraction of each cohort that would have to leave before reaching age 15 would be $1.349/2.349$ or 57 percent. For Barbados 1965, $0.767/1.767 = 43$ percent would be required. It is mere fantasy to envisage such an amount of emigration continued indefinitely for any large population.

Even with such high proportions leaving, an increasing population will not become stationary immediately when the supposed emigration policy is initiated. It will continue to grow for some time, and its ultimate stationary level will be high in the degree in which the initial population has an age distribution favorable to fertility.

The argument supposes that women emigrating have the same average fertility as those who remain. If the emigrants are of greater education, and if fertility is negatively related to education, two conditions that prevail widely, then the effect of the emigration on the population size will be less than our formulas indicate.

One can easily envision sex ratio imbalances that similarly diminish the effect below what our formulas show. If a large number of men have already gone, then persuading some women to leave will not greatly reduce the subsequent births, since husbands for these women would have been scarce had they stayed. Conversely, sex-selective emigration may be at least as helpful as age-selective in reducing subsequent population.

Summary and Conclusions

We have found that one-time emigration of Δp_x individuals aged x affects a population numbering $P(t)$ at time t , where t is large, in the amount

$$\Delta P(t) = \frac{V_x}{b\kappa} e^{rt} \Delta p_x, \quad (9)$$

with V_x the reproductive value of women aged x (defined so that $V_0 = 1$), b the birth rate, κ the mean age of childbearing in the stable population, and r the intrinsic rate of natural increase.

To have an effect on the intrinsic rate an indefinitely continued stream of emigrants is necessary, and we derived a result for the fraction f of emigrants at age x required to bring the rate down to $\bar{r}$:

$$f = \frac{\int_{\alpha}^{\beta} e^{-\bar{r}a} l_a m_a da - 1}{\int_x^{\beta} e^{-\bar{r}a} l_a m_a da}. \quad (12)$$

For attaining stationarity by emigration the $\bar{r}$ of (12) would become zero, and the relative advantage of selection by age would be shown by the way f varies with x in the expression

$$f = \frac{R_0 - 1}{\int_x^B l_a^m da} \quad (14)$$

If x is below α the youngest age of reproduction, this comes down to the very simple form $(R_0 - 1)/R_0$. For a country whose $R_0 = 2.75$, some 64 percent of every cohort would have to leave each year, even if $x < \alpha$.

Java's female population increases at nearly 1,000,000 per year, so to cope with 1 percent of its growth in any particular year would take 10,000 outmigrants if these were of the ages of the population as a whole; $b \times$ times this number or 10,600 if they were girl babies just born; $b \times /V_{15}$ times 10,000 or 6000 if they were 15-19 years of age. This is on the one-time model of (9), taking each year as a separate issue.

The stream of outmigration required to hold the intrinsic rate of Java's population down to zero is given by formula (14) as a fraction of the number in a young cohort. If R_0 is 2.349, as in Mauritius, $1.349/2.349 = 57$ percent of each cohort would need to emigrate each year.

While the age effect mentioned in discussions of migration does exist on the model used here, its amount gives little encouragement to those who think that selecting fertile ages magically holds down subsequent population.

The record official outmigration from Java in one year was 60,000 persons of both sexes; so even if sharply selective screening by age were possible, the maximum transmigration historically attained would have offset about 5 percent of Java's present growth. Current movement is considerably below this (Widjojo, 1970; McNicoll, 1968). Migration to the other islands can realistically aim at the development of those islands, but hardly at the solution of Java's population problem.

Whether the proposed migration is over water as in Indonesia, or over land as in Brazil and Mexico, a similar conclusion applies to all countries which aspire to fill their empty spaces from the natural increase of their more crowded sections. If the crowded sections are to be kept from increasing without birth control, large amounts of outmigration will be necessary, as the preceding shows, no matter how precisely the outmigrants may be selected by age. Funding the movement of millions of migrants would have to be considered on a scale of priorities, and it need not turn out to be the most productive of the possible uses of capital. Moreover, the pioneering spirit that is eager to clear tropical forests seems lacking everywhere in this century; instead the pioneers are drawn to science and technology. The dominant migration on all continents is away even from older settled farming areas that are relatively comfortable; for city people to move into the jungle would require a major change in individual outlook and aspiration. Both Brazil and Mexico are about 50 percent urban, and the proportion as well as the number of their urban residents is increasing in a trend that is a dominant social fact of our day.

Contraception is a more promising solution to the population problem than migration, even for those countries in which land is still plentiful.

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ABSTRACT

That it makes a difference to ultimate population whether out-migrants are of fertile ages or not is wellknown. The present paper develops expressions for the effect on ultimate population of given numbers of out- or in-migrants, expressed as a function of their age. The main relations are (9) for one-time migration and (12) for a continuous stream of migrants, the former affecting only the level of the ultimate population, the latter affecting its rate of growth as well. The age-effect is appreciable, but is not sufficient to encourage a policy of moving people. Neither internal movement within a country nor movement to foreign countries is a substitute for contraception as a means of population control.