MIGRATION AND NATURAL INCREASE IN THE GROWTH OF CITIES

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FOREWORD

Roughly 1.8 billion people, 42 percent of the world's population, live in urban areas today. At the beginning of the last century, the urban population totaled only 25 million. According to recent United Nations estimates, about 3.1 billion people, twice today's urban population, will be living in urban areas by the year 2000.

Scholars and policy makers often disagree when it comes to evaluating the desirability of current rapid rates of urban growth and urbanization in many parts of the world. Some see this trend as fostering national processes of socioeconomic development, particularly in the poorer and rapidly urbanizing countries of the Third World, whereas others believe the consequences to be largely undesirable and argue that such urban growth should be slowed down.

Migration and natural increase are the two contributors to urban population growth. The complex question of which of the two is more important is analyzed in this article through the use of simulation techniques. Immediate effects are contrasted with long-run effects, and the age of the migrant is considered as an important factor, along with the crucial variable of rural population growth.

A list of the papers in the Population, Resources, and Growth Series appears at the end of this article.

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Migration and Natural Increase in the Growth of Cities

Problems too difficult to solve analytically may often be dealt with by simulation. But simulation will not always provide a solution; a problem too difficult for a closed form solution may also suffer from some inherent ambiguity. In such a case, simulation serves to reveal the ambiguity and to show the numerical consequences of different interpretations; one may come to understand that the difficulty of a problem resides less in the mathematics than in the verbal statement.

Our apparently straightforward question is whether migration or natural increase contributes more to the growth of cities. That any observer can distinguish the entry of a migrant from the birth of a baby is not enough to provide the unambiguous causal statement that we seek. To analyze one year's growth, we need only compare the count of net in-migrants with the count of births less deaths. But if the migrants are of an age to reproduce immediately, while those just born will not reproduce for at least 15 years, then that additional fact works for migration. And moreover the relative importance of the two may be different at different time intervals.

The rapid expansion of cities in the less-developed countries has been a focus of attention of policymakers and of several academic disciplines over recent decades. With Mexico City having passed 12 million, and headed towards 30 million by the end of the century, and Cairo at 9 million, administrators seek policies that will adapt the pace of growth to urban resources and jobs. The extent to which the growth is due primarily to the natural increase of the cities as against migration from the countryside arises naturally when policy regarding urbanization comes under discussion. Europe's cities of the Renaissance and long after had death rates so high that the only way they could increase was by migration. But they provide no model for present day cities, which urgently pose the question of how far control of the size of cities can be through migration and how far through natural increase.

THE IMMEDIATE ANSWER

One way of answering the question is by simply noting the present rates. Andrei Rogers starts with the fundamental identity $r = b - d + i - o$, where increase r is equal to births b minus deaths d plus in-migrants i minus out-migrants o. This is true for either the absolute numbers or for rates based on the current urban population; it applies to a single city or to any defined group of cities. The contribution of natural increase to the population after one year is $b - d$, and the

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contribution of migration is $i - o$. For India, the natural increase of cities about 1970 was 20 per thousand population and net in-migration was 17 per thousand. Thus natural increase was more important in the ratio of 20 : 17. United Nations data of this kind give an answer to the question of natural increase versus migration, which for the short run cannot be improved upon.

For the long run the answer may well be different. When a birth is added to the population, the child has a chance of growing up and becoming a parent in about 20 years; when a migrant aged 20 enters he or she can become a parent immediately. Insofar as migrants do not have the same age distribution as births (i.e., they are not age zero), some difference will result whatever the age distribution of migrants. But in addition we know from the work of Rogers (1979) and his group, as well as from official data from many countries, that migrants have a characteristic distribution with a concentration at the childbearing ages. This ought to be taken into account in trying to answer the question of how important migration is in comparison with natural increase.

But we have also to decide whether we are comparing one in-migrant with one birth, 1 percent of the migrants with 1 percent of the births, all of the migrants with all of the births, or all of the net migrants with all of the births beyond those needed for replacement of the population. Each of the four ways of making the comparison can be of interest, but one special concern is with the births that are above replacement level, these to be compared with the net migrants, the number entering less those leaving.

REPRODUCTIVE VALUE AND THE ULTIMATE STABLE POPULATION

To assess the contribution of migrants to the ultimate population we may consider the ages of the migrants and weight each individual by reproductive value. Either sex can be used, but the calculation for females is more meaningful. Table 1, for India, shows an average value per hundred migrants of 115.8, or 1.158 per person. Since birth and death statistics for India are uncertain, we have repeated the calculation for the Indian age distribution using reproductive values for Ceylon and Mexico, which give 108.4 and 128.9, respectively.

The schedule of reproductive value is the left eigenvector of the projection matrix, and that is the way it was calculated in Keyfitz and Flieger (1968). An equivalent to within a constant multiplier is contained in a formulation due to R. A. Fisher (1958): if a female child just born is thought of as having borrowed a life, which she will repay with interest by bearing children, then reproductive value at any age is the discounted expected amount of the loan yet to be repaid. It can be shown that such a form gives the relative contribution of each age to the ultimate trajectory of the population if it retains its age-specific rates of birth and death.

The three sets of reproductive values shown in Table 1—hypothetical for India and observed, with greater or less accuracy, for Ceylon and Mexico—all have similar shapes. Each starts just above unity in the first age group, rises to a peak in the age group 15–19, then declines to zero at the end of reproductive life. It is the discount factor that causes the function to rise in the first 15 or so years of life, after which the discounting is more than offset by the declining number of prospective children. While the calculation here has been made for women and their daughters, the calculation for males and their sons is similar.

The table shows that the age distribution of the migrants makes them contribute somewhat more per capita to the ultimate population than would the same number of births, the reproductive value of a birth being unity on the scale here used. Migrants tend to be concentrated in the ages of maximum reproduction, so that one migrant is equivalent to about 1.2 babies in effect on the ultimate size of the population. If they were all 15–19 years of age, each would be equivalent to 1.6 to 1.9 babies.

The value of a person taken at random from the stable age distribution can be shown to equal $1/(b\kappa)$ babies (Keyfitz 1977, p. 145), where b is the stable birth rate and κ is the mean age of childbearing in the stable population, which for India is about $1/(0.045)(27) = 0.82$ babies. This seems to show that the age distribution of migrants is more favorable to fertility than the stable age distribution by about 50 percent. Roughly we can say that adding one birth, adding one person selected at random from the stable age distribution, and adding one migrant have effects in the ratio 1 : 0.8 : 1.2.

TABLE 1
Age Distribution of Inmigrants to Indian Cities and the Contribution of Each Age to the Ultimate Population as Indicated by Reproductive Value

Age	Migration: Percent Distribution by Age	Reproductive Value per Person		
		India (hypothetical)	Ceylon	Mexico
0–4	12	1.3	1.1	1.2
5–9	9	1.5	1.3	1.4
10–14	7	1.7	1.5	1.7
15–19	14	1.8	1.6	1.9
20–24	23	1.5	1.5	1.8
25–29	10	1.0	1.1	1.4
30–34	6	0.6	0.6	0.9
35–39	4	0.3	0.3	0.5
40–44	3	0.1	0.1	0.2
45–49	2			
50–54	1			
55–59	2			
60–64	2			
65–69	2			
70 +	3			
Total	100			
Reproductive value per 100 women of specified age distribution		115.8	108.4	128.9

Projections of a biregional population, that is, of the system of urban and rural populations, will provide a better means of analyzing urban in-migration. The analysis by reproductive value in Table 1 was based on single-region theory and stable growth. Moreover the procedure entails the difficulty that it assigns to the *difference* between births and deaths the reproductive value of births. It is as though one allows each death to offset one birth, despite the fact that the population loses no reproductive value at all for deaths that occur after the end of the reproductive period, as most do. It is not logical to evaluate the net natural increase as we have done, yet if we set the reproductive value of the births less the (very small) value of the deaths, against that of the migration, then the effect of natural increase so defined would exceed that of the migrants by a considerable margin. Rather than patch what has been done above we shift to a new and more clear-cut macrosimulation approach. This approach compares the effect of removing various fractions of the in-migrants and the natural increase, respectively, in projections over various periods of time.

PERMUTING THE INPUTS TO A BIREGIONAL PROJECTION

A simple way to find the contributions of the demographic inputs in the growth of cities is to permute these inputs. At first we focus on migration and natural increase. One can project the population of the cities of India in the normal manner, then reduce births to the point where natural increase is zero, and compare the two to find the effect of natural increase. The difference in the population after a certain period of time, say 50 years, would show the effect of natural increase alone. One would then allow natural increase to resume its observed rates and make migration zero; the difference between the output of this and the initial normal projection would give the effect of migration.

One can think of many ways of forcing the natural increase down to zero. The one used here held the death rates unchanged and divided age-specific birth rates by R_0, the net reproduction rate. Similarly for migration we lowered both flows—the entrants into the city and those outward to the village—to the point where they both became zero, without altering the age-specific rates of migration relative to one another, or the ratio of outflow to inflow.

Thus in the fourfold scheme of Table 2 each element is the total population as projected by age and sex to some future date, say 2020, from the base 1970. The

TABLE 2
Projection of the Population of India's Cities to the Year 2020, with the Four Possible Permutations of Observed and Zero Natural Increase and Migration (millions of people)

Natural Increase	Migration: Observed	Migration: Zero	Difference	
Observed	A 477.6	B 256.2	221.4	Average 210.7 due to migration
Zero	C 369.0	D 169.0	200.0	
Difference	108.6	87.2		
	Average 97.9 due to natural increase			
	Difference of differences: 21.4 = interaction			

comparison of A and B shows how much difference migration makes when natural increase is retained at its observed level. The comparison of C and D shows how much difference migration makes at the zero level of natural increase. That gives us two numbers for the effect of migration: $A - B$ and $C - D$, whose difference, $A - B - C + D$, is called interaction. If $A - B$ and $C - D$ are not significantly different they may simply be averaged:

$$\tfrac{1}{2}[(A-B)+(C-D)]$$

to provide the best estimate that the table can furnish of the effect of migration. Similarly the best estimate of the effect of natural increase is

$$\tfrac{1}{2}[(A-C)+(B-D)].$$

The multiregional projection with the fixed rates of 1970 to the year 2020 for India gives for the cities in total 477.6 million as the quantity A of Table 2. Let us see how this outcome would be altered by a change in the conditions of the projection.

We need the number of people there would be on a projection with zero migration and zero natural increase, D in Table 2. The projection is made with the birth and death elements of the one-region model, the births having been reduced in the ratio of the net reproduction rate. Under this condition, that is, if the replacement rate were to drop immediately to unity so the birth rate would fall instantly to the level at which each woman on the average would have one daughter surviving to reproductive age, the number of people that would be found in the year 2020 would be 169.0 million. That the population would not become stationary immediately is an example of the phenomenon called momentum (Keyfitz 1977, p. 155). At successive times we would have:

1970	109.1
1985	131.8
2000	154.4
2020	169.0
2075	169.1

when both migration and natural increase are controlled down to zero and replacement, respectively. In this instance the ratio of the ultimate to the take-off population is 1.55; it justifies the assertion that if India's urban birth rate were to drop to that required for each couple to be replaced by one couple and no more (implying about 2.5 children on the average to all couples at present mortality levels), the population would continue to increase until it approached a level 55 percent above its 1970 count, all this in the absence of migration.

Table 2 shows the four numbers that come out of the calculation and that in principle permit the comparison of the effects of fertility and of natural increase. Now we have the effect of migration, with observed natural increase, as $A - B =$ 221.4 million at the end of 50 years; the effect of natural increase, with observed migration, as $A - C = 108.6$ million. Thus it seems as though migration is over twice as important as natural increase. We can also find the difference in each variable at the zero level of the other, and with this the migration effect is $C - D$ and the natural increase effect is $B - D$. The two sets of numbers are reasonably close, with an interaction of only 21.4, so it seems justifiable to average them. The average is a difference of 210.7 for migration and 97.9 for natural increase. Now migration is twice as important as natural increase, in contrast to what we found earlier.

The relative effect of migration is also double that of natural increase after 100 years. The bottom line of Table 3 shows that migration by itself makes a difference (on the average) of 836 million, and natural increase by itself makes an average difference of 413 million; migration is 2.02 times as important.

But the farther we go forward in time the relatively larger becomes the interaction between natural increase and migration. That interaction, the difference between the effect of migration with natural increase at the high level and the effect of migration with natural increase at the low level, is about $1/20$ the migration effect after 15 years, rising to one fifth after 100 years. After the migrants enter they begin to contribute to natural increase, both in the model and in real life, and so make an interaction that increases steadily with time.

EFFECTS OF MARGINAL CHANGES IN THE INPUTS

If removing all migration from the projection makes about twice as much difference in the population after 50 or 100 years as removing all natural increase, then one would think that migration would also be twice as important as natural increase at the margin: removing 10 percent of the migration ought to make twice as much difference as removing 10 percent of the natural increase. However, this is not so, and the intermediate rows of Table 3 show what happens marginally at the several levels.

TABLE 3
Modification of Inputs to Projection for India by Multiplying by Factors 1.00, 0.90, . . . , 0.00, Showing the Urban Population that Results

Factor (1)	Inputs as Observed (2)	Result of Changed: Migration (3)	Nat. Inc. (4)	Both (5)	Average Effect of: Migration (6)	Nat. Inc. (7)	Ratio (6)/(7)	Interaction
Year 1985								
1.00	186.53	186.53	186.53	186.53	0.0	0.0	0.0	0.0
0.90	186.53	183.17	184.76	181.42	3.35	1.75	1.909	0.02
0.80	186.53	179.70	183.00	176.24	6.79	3.49	1.944	0.07
0.70	186.53	176.12	181.24	170.99	10.33	5.21	1.981	0.15
0.60	186.53	172.43	179.48	165.65	13.96	6.91	2.020	0.27
0.50	186.53	168.61	177.71	160.23	17.70	8.59	2.060	0.44
0.40	186.53	164.66	175.95	154.73	21.54	10.25	2.102	0.65
0.30	186.53	160.58	174.19	149.15	25.50	11.88	2.145	0.91
0.20	186.53	156.36	172.43	143.47	29.56	13.49	2.191	1.21
0.10	186.53	151.99	170.66	137.70	33.75	15.08	2.238	1.57
0.0	186.53	147.48	168.90	131.84	38.05	16.63	2.288	1.99
Year 2000								
1.00	290.80	290.80	290.80	290.80	0.0	0.0	0.0	0.0
0.90	290.80	283.31	286.20	278.76	7.46	4.58	1.630	0.05
0.80	290.80	275.38	281.62	266.40	15.32	9.08	1.688	0.20
0.70	290.80	266.96	277.08	253.72	23.60	13.48	1.750	0.48
0.60	290.80	258.04	272.56	240.69	32.31	17.80	1.816	0.89
0.50	290.80	248.58	268.07	227.30	41.50	22.00	1.886	1.45
0.40	290.80	238.54	263.62	213.54	51.17	26.09	1.961	2.18
0.30	290.80	227.89	259.19	199.39	61.35	30.06	2.041	3.11
0.20	290.80	216.59	254.79	184.83	72.09	33.89	2.127	4.25
0.10	290.80	204.59	250.42	169.84	83.39	37.57	2.220	5.62
0.0	290.80	191.86	246.08	154.40	95.31	41.09	2.319	7.27
Year 2020								
1.00	477.63	477.63	477.63	477.63	0.0	0.0	0.0	0.0
0.90	477.63	463.68	465.80	451.95	13.90	11.78	1.180	0.10
0.80	477.63	448.36	454.19	425.35	29.05	23.23	1.251	0.44
0.70	477.63	431.53	442.79	397.76	45.57	34.30	1.328	1.07
0.60	477.63	413.03	431.61	369.09	63.57	44.98	1.413	2.08
0.50	477.63	392.69	420.65	339.25	83.17	55.21	1.506	3.54
0.40	477.63	370.34	409.90	308.15	104.52	64.96	1.609	5.55
0.30	477.63	345.75	399.36	275.69	127.77	74.17	1.723	8.21
0.20	477.63	318.71	389.03	241.76	153.10	82.77	1.850	11.65
0.10	477.63	288.95	378.92	206.24	180.68	90.71	1.992	16.00
0.0	477.63	256.19	369.01	169.00	210.72	97.90	2.152	21.43
Year 2070								
1.00	1418.56	1418.56	1418.56	1418.56	0.0	0.0	0.0	0.0
0.90	1418.56	1381.86	1356.79	1320.51	36.49	61.56	0.593	0.42
0.80	1418.56	1338.16	1297.84	1219.48	79.38	119.70	0.663	2.05
0.70	1418.56	1286.07	1241.59	1114.62	129.73	174.21	0.745	5.52
0.60	1418.56	1223.94	1187.94	1004.95	188.81	224.80	0.840	11.63
0.50	1418.56	1149.74	1136.79	889.34	258.13	271.09	0.952	21.36
0.40	1418.56	1061.06	1088.04	766.49	339.53	312.54	1.086	35.94
0.30	1418.56	954.96	1041.60	634.91	435.15	348.51	1.249	56.90
0.20	1418.56	827.89	997.38	492.86	547.60	378.11	1.448	86.15
0.10	1418.56	675.54	955.27	338.35	679.97	400.24	1.699	126.10
0.0	1418.56	492.68	915.20	169.07	836.00	413.49	2.022	179.75

Each line of Table 3 provides a 2×2 table corresponding to Table 2. For instance, in changing from 100 percent to 90 percent of the observed level and projecting to the year 2070, the effect of migration at the observed level of natural increase is $1418.56 - 1381.86 = 36.70$ million people; at the lower level of natural increase, it is 36.28 million; the average (worked out by computer to more decimal places) is 36.49 million. Similarly, the other differences give 61.56 for the average effect of the reduction in natural increase. The ratio of the effect of the marginal change in migration to that in natural increase is now $36.49 : 61.56 = 0.593$.

This is strikingly different from what we found when we experimented with the complete removal of migration and natural increase respectively. Thus the effect by 2070 due to migration (last line of Table 3) is 836.00 million, that due to natural increase 413.49 million, the ratio of the former to the latter 2.022.

Natural increase variation had been obtained by multiplying births by a ratio such that the net reproduction rate was reduced to unity for the total elimination of increase, and by interpolating between the observed natural increase and unity for the other instances of Table 3. The result by 2070 when 10 percent of natural increase is removed, is a reduction of 1418.56 − 1356.79 = 61.77 million at the start, and this marginal effect keeps falling until it is only 40.07 million at the difference between 10 percent of the natural increase and zero.

On the other hand, the population in the year 2070 drops by 1418.56 − 1381.86 = 36.70 million for the first 10 percent fall in migration, and by 675.54 − 492.68 = 182.86 million for the last 10 percent fall. Thus the marginal effect of migration increases, contrary to what happens with natural increase (Table 4).

TABLE 4
Excerpt from Table 3 Showing First Differences of Rows, with Rural Population Remaining as Observed, Projection for India to 2070

		Inputs as	Result of Changed			Average Effect of		
	Factor (1)	Observed (2)	Migration (3)	Nat. Inc. (4)	Both (5)	Migration (6)	Nat. Inc. (7)	Ratio (6)/(7)
	1.00	1418.56	1418.56	1418.56	1418.56	0.00	0.00	0.00
Difference corresponding to 0.1 drop in factor			36.70	61.77	98.05	−36.49	−61.56	0.59
	0.50	1418.56	1149.74	1136.79	889.33	258.13	271.09	0.95
Difference corresponding to 0.1 drop in factor			88.68	48.75	122.85	−81.39	−41.46	1.96
	0.10	1418.56	675.54	955.27	338.34	679.97	400.24	1.70
Difference			182.86	40.07	169.28	−156.03	−13.25	11.78
	0.00	1418.56	492.68	915.19	169.06	836.00	413.49	2.02

The time-horizon enters our results in a disconcerting fashion, especially on the marginal effects of migration and natural increase. Thus by 1985 a 10 percent decrease in migration has 1.9 times as much effect as a 10 percent decrease in natural increase, by 2000 1.6 times, by 2020 1.2 times, by 2070 only 0.6 times. Should one average these effects, perhaps applying a discounting factor that would give less weight to relations more distant in time?

We need a more extensive study of the effect of rural natural increase and spatial distribution to explain the points above. Apparently other factors underlie Tables 3 and 4 and interfere with the interrelations in which we are interested; one suspects that the level and rate of increase of the rural population may be the interfering factors. To examine their effect, fractions of decrease in rural natural increase were taken between the level of observed and the level of replacement population growth as represented by a net reproduction rate of unity.

EFFECT OF RURAL NATURAL INCREASE

We thus make the entire calculation over again, following a suggestion of Andrei Rogers, with the rural population held at bare replacement. It turns out that the average effect of migration is typically one half that of urban natural increase, and in no case exceeds the effect of the latter. In short, when the rural population is low, migration is also low, and the city indeed grows mostly by its own natural increase. But we do not confine ourselves to making the rural increase zero; we can apply the series of factors 0.9, 0.8, and so forth to the rural natural increase as we did before to the urban. Then the same projection process gives the urban population at the end of each period. Each application of a factor provides a $2 \times 2 \times 2$ arrangement.

From Table 5 we extract:

$$\text{Effect of migration: } \tfrac{1}{4}[(A - B) + (C - D) + (E - F) + (G - H)]$$
$$= \tfrac{1}{4}[5335.8 - 5199.3]$$
$$= 34.1$$

$$\text{Effect of urban natural increase: } \tfrac{1}{4}[(A - C) + (B - D) + (E - G) + (F - H)]$$
$$= \tfrac{1}{4}[5388.0 - 5147.1]$$
$$= 60.2$$

$$\text{Effect of rural natural increase: } \tfrac{1}{4}[(A - E) + (B - F) + (C - G) + (D - H)]$$
$$= \tfrac{1}{4}[5477.8 - 5057.4]$$
$$= 105.1.$$

TABLE 5
Indian Urban Population at the End of 100 Years (i.e., by the Year 2070) under a 2^3 System of Perturbations

Urban Natural Increase	Rural Natural Increase as Observed Migration		Rural Natural Increase Decreased by 10% Migration	
	Observed	Decreased by 10%	Observed	Decreased by 10%
Observed	A 1418.6	B 1381.9	E 1309.7	F 1277.8
Decreased by 10%	C 1356.8	D 1320.5	G 1250.7	H 1219.1

Here is a surprising and important result: rural natural increase makes more difference to the size of the cities of India than either migration or the natural increase of the cities, or indeed than both together. The overflow from the countryside is decisive for the growth of cities. In any discussion of the degree to which the cities grow through their own natural increase, it has to be recognized that they grow much more through the natural increase of the countryside.

By what mechanism does the natural increase of rural parts affect the growth of the cities? The answer can be only that it affects them through migration. But our comparisons are orthogonal to one another. Does that not mean that migration to the cities is held constant while we vary the natural increase of the rural parts? No, our model is not orthogonal in that sense, but only in a weaker sense. When the rural natural increase is larger, in-migration does go up, both in the observed and in the 0.90 of the observed, because what is held constant is the *fraction* out-migrating age by age. A faster growing rural population means absolutely more migrants in our model, as in the reality.

The light here thrown on effects of different decisions could be useful for policy. A lowering of rural fertility that brings it 10 percent of the distance to bare replacement is three times as effective in holding down long-term city growth as a lowering of the rates of migration into the city by 10 percent. At least this is so with the relatively low level of urbanization shown by India.

We have extracted from Table 5 three degrees of freedom for the main effects; there are also three degrees of freedom for first-order interactions. For example, that between migration and rural natural increase is

$$\tfrac{1}{4}[A - B - E + F] = \frac{4.8}{4} = 1.2$$

as estimated with the observed urban natural increase, and

$$\tfrac{1}{4}[C - D - G + H] = \frac{4.7}{4} = 1.2$$

as estimated with the urban natural increase reduced by 10 percent. The single degree of freedom for the second-order interaction (the difference 1.2 − 1.2) is zero to the number of decimal places preserved in this table. The smallness of the interaction is a necessary condition for the main comparisons to be meaningful.

Our next question concerns the number of people in the countryside as against the number in the city. The fractions migrating will yield a larger number of people if the rural population is large than if it is small, whatever its rate of increase. This further aspect, the spatial distribution between city and countryside, ought to be taken into account, as a fourth input to be applied at two levels for each level of the other variables.

THE FOUR-WAY TABLE

In the 2 × 2 × 2 × 2 table constructed below, rural-urban migration is denoted by MIG, rural natural increase RN, urban natural increase UN, ratio of rural to urban, that is, spatial distribution SD.

	SD_{obs}				SD_{decr}			
	RN_{obs}		RN_{decr}		RN_{obs}		RN_{decr}	
	MIG_{obs}	MIG_{decr}	MIG_{obs}	MIG_{decr}	MIG_{obs}	MIG_{decr}	MIG_{obs}	MIG_{decr}
UN_{obs}	A	B	E	F	I	J	M	N
UN_{decr}	C	D	G	H	K	L	O	P

The effects of a 10 percent reduction of the several inputs is estimated for 2020 and 2070 as:

		2020	2070
MIG:	$\frac{1}{8}[A-B+C-D+E-F+G-H+I-J+K-L+M-N+O-P]$;	12.6	32.2
UN:	$\frac{1}{8}[A-C+B-D+E-G+F-H+I-K+J-L+M-O+N-P]$;	11.4	58.3
RN:	$\frac{1}{8}[A-E+B-F+C-G+D-H+I-M+J-N+K-O+L-P]$;	10.5	100.02
SD:	$\frac{1}{8}[A-I+B-J+E-M+F-N+C-K+D-L+G-O+H-P]$.	29.2	104.4

Table 6 shows these effects and their ratios, with each effect as free of the other variables as can be arranged.

The rate of increase of rural parts and the relative population of the countryside, what we here call spatial distribution, cannot affect the natural increase of the city; in our model as in actuality it can only affect city size by acting through migration to the cities. Hence we can think of the last two variables, (3) and (4) of Table 6, as, in a sense, part of the migration effect. It is gratifying to note the relative constancy of the ratio of (2) to the sum (1) + (3) + (4), that is, urban natural increase taken as a ratio to the total of direct and indirect migration effects.

Many of our results differ greatly according to the time period considered. In some cases, this is understandable; it is inevitable that the effect of rural natural increase (variable (3) in Table 6) builds up over time, while the effect of just more people in the countryside (variable (4) in Table 6) is more immediately apparent; we need not worry that the ratio (3) : (4) goes from 0.06 to 0.96 at the margin between 1985 and 2070.

TABLE 6

Effects of (1) Migration (MIG), (2) Urban Natural Increase (UN), (3) Rural Natural Increase (RN), and (4) Spatial Distribution or Ratio of Rural to Urban (SD)

	Average Effects of										
	MIG(1)	UN(2)	RN(3)	SD(4)	1/2	2/3	2/4	3/4	$\frac{1}{3+4}$	$\frac{2}{3+4}$	$\frac{2}{1+3+4}$
Year 1985											
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9	3.08	1.73	0.32	5.69	1.77	5.38	0.30	0.06	0.51	0.29	0.19
0.8	5.69	3.42	0.58	10.79	1.67	5.85	0.32	0.05	0.50	0.30	0.20
0.7	7.83	5.04	0.78	15.27	1.55	6.44	0.33	0.05	0.49	0.31	0.21
0.6	9.48	6.64	0.93	19.13	1.43	7.13	0.35	0.05	0.47	0.33	0.22
0.5	10.63	8.18	1.03	22.33	1.30	7.97	0.37	0.05	0.46	0.35	0.24
0.4	11.26	9.70	1.08	24.87	1.16	9.00	0.39	0.04	0.43	0.37	0.26
0.3	11.36	11.19	1.09	26.73	1.01	10.31	0.42	0.04	0.41	0.40	0.29
0.2	10.90	12.66	1.06	27.89	0.86	11.99	0.45	0.04	0.38	0.44	0.32
0.1	9.87	14.12	1.00	28.32	0.70	14.17	0.50	0.04	0.34	0.48	0.36
Year 2000											
0.9	6.82	4.49	2.21	13.88	1.52	2.03	0.32	0.16	0.42	0.28	0.20
0.8	12.71	8.74	4.00	26.23	1.45	2.19	0.33	0.15	0.42	0.29	0.20
0.7	17.64	12.75	5.37	37.00	1.38	2.37	0.34	0.15	0.42	0.30	0.21
0.6	21.54	16.58	6.37	46.14	1.30	2.60	0.36	0.14	0.41	0.32	0.22
0.5	24.37	20.22	7.00	53.60	1.21	2.89	0.38	0.13	0.40	0.33	0.24
0.4	26.08	23.70	7.31	59.31	1.10	3.24	0.40	0.12	0.39	0.36	0.26
0.3	26.61	27.05	7.33	63.20	0.98	3.69	0.43	0.12	0.38	0.38	0.28
0.2	25.89	30.30	7.08	65.21	0.85	4.28	0.46	0.11	0.36	0.42	0.31
0.1	23.87	33.50	6.61	65.26	0.71	5.07	0.51	0.10	0.33	0.47	0.35
Year 2020											
0.9	12.57	11.44	10.51	29.22	1.10	1.09	0.39	0.36	0.32	0.29	0.22
0.8	23.63	21.93	18.93	54.86	1.08	1.16	0.40	0.35	0.32	0.30	0.23
0.7	33.07	31.55	25.37	76.85	1.05	1.24	0.41	0.33	0.32	0.31	0.23
0.6	40.80	40.38	29.94	95.06	1.01	1.35	0.42	0.31	0.33	0.32	0.24
0.5	46.68	48.53	32.75	109.41	0.96	1.48	0.44	0.30	0.33	0.34	0.26
0.4	50.59	56.07	33.97	119.74	0.90	1.65	0.47	0.28	0.33	0.36	0.27
0.3	52.37	63.14	33.72	125.93	0.83	1.87	0.50	0.27	0.33	0.40	0.30
0.2	51.84	69.84	32.20	127.77	0.74	2.17	0.55	0.25	0.32	0.44	0.33
0.1	48.83	76.31	29.58	125.08	0.64	2.58	0.61	0.24	0.32	0.49	0.38
Year 2070											
0.9	32.18	58.32	100.21	104.37	0.55	0.58	0.56	0.96	0.16	0.29	0.25
0.8	61.54	107.59	176.72	191.64	0.57	0.61	0.56	0.92	0.17	0.29	0.25
0.7	88.07	148.89	231.72	262.81	0.59	0.64	0.57	0.88	0.18	0.30	0.26
0.6	111.68	183.23	267.30	318.60	0.61	0.69	0.58	0.84	0.19	0.31	0.26
0.5	132.19	211.63	285.47	359.39	0.62	0.74	0.59	0.79	0.20	0.33	0.27
0.4	149.27	235.09	288.19	385.17	0.63	0.82	0.61	0.75	0.22	0.35	0.29
0.3	162.47	254.62	277.42	395.52	0.64	0.92	0.64	0.70	0.24	0.38	0.30
0.2	171.09	271.30	255.13	389.48	0.63	1.06	0.70	0.66	0.27	0.42	0.33
0.1	174.21	286.32	223.42	365.50	0.61	1.28	0.78	0.61	0.30	0.49	0.38

But other parts of the variation with time are less comprehensible, and especially the ratio of the variables (1) and (2), which are of the greatest interest. That at the start (1) is greater at the margin and by 2070 it drops down to 0.55 is disconcerting. Can we not find some function of the effect that is more constant? We might for instance study not the absolute numbers, which are what underlie Table 6, but the rates of increase.

When the items of Table 6 are computed in terms of rates—so as to tell us whether migration or natural increase has the greater effect on city rates of growth—we find the importance of migration diminished. But unfortunately the shifts with time are greater than before.

That all effects increase over the course of time is understandable, but the ratios are puzzling. One might have thought that the ratio of migration to urban natural increase would go down with time, since the migrants not only enter in a steady stream, but to them is added their natural increase, also counted as migrants in the way the calculation is done. But we must bear in mind that the rural population diminishes relatively over the course of time, and this diminishes the number of in-migrants. Also the out-migrants from the city increase as the city population grows, and this cancels out much of the in-migration.

MIGRANTS AND THEIR DESCENDANTS

The process that is here described imputes implicitly all natural increase of migrants to migration, and all natural increase of the initial population to natural increase. This is not seriously affected by the fact that there is interaction, even though that interaction becomes large after 50 or so years. The process we have used merely divides the interaction equally between the factors.

Consider a purely hypothetical situation where the natural increase of present residents is zero, and after arrival each incoming migrant couple has three children. Any method that would indicate that natural increase was 50 percent more important than migration seems unsatisfactory; our attributing the children to migration is clearly justified. But should the attribution apply to all later descendants? Perhaps we should regard children of in-migrants as the direct effect of migration, but grandchildren as part of natural increase. The multiregional projection program can be broken down to show separately children of migrants as well as the migrants themselves. We lack data on the fertility and mortality of the migrants, so we have to assign them the properties of the population at their place of residence. But subject to this and to the assumption of fixed rates through time, the results are clear cut.

For the United States, if migration continues as indicated by the question on previous residence of 1970, we would have a stable equivalent of 130.0 million females in all, and of this 41.5 million would be in the South region, and 88.5 million in the North region. Of those in the South 6.5 million would have been born in some other region, and 35.1 million in the South. The final breakdown of those residing in the South is that 6.5 million are in-migrants, 4.7 million the children of in-migrants, 30.4 million second and later generation born in the South. For the North the breakdown would similarly be 6.2 million in-migrants, 6.0 million first generation born in the North, 76.3 million the second and later generation born in the North.

Thus in both cases the number of children born within the region of parents who had in-migrated is of the same order of magnitude as the number of in-migrants. If the age distribution of migrants to the cities (say of India) is similar, we approximately double the apparent consequences of migration by attributing to it the children of in-migrants rather than only the in-migrants themselves.

Once we accept that some of the children born in the city are the effect of in-migration, we have the question of where to draw the line. We could count as the effect of in-migration all children born to in-migrants within 5, 10, or 20 years of their entry into the city, or the whole first and second generation of children born to migrants in the city, or all later generations. We had better be careful about going back in time prior to the 1970 or other jumping-off point; if we count children of all earlier generations, then the whole urban population is the result of migration.

Among other improvements we could deal separately with in- and out-migrants. Thus we could vary each without varying the other, and do this for both in turn, to make a 2^5 rather than a 2^4 design. There is some question how much the out-migration from cities can be independent of the in-migration, since some of it is the direct result of in-migration—either return migrants who could not immediately find a job, or else older people who have spent some years in the city, and are now retiring to the countryside, perhaps able to buy land with their savings. We think on the whole it is sound to make the out-migration rates proportional to the in-migration.

SUMMARY AND CONCLUSION

Since anyone can tell the difference between a birth or death on the one hand and a migrant on the other, it ought to be simple to establish how much of their growth cities owe to natural increase and how much to migration. The article shows that the comparison can be framed in many different ways and that very different answers result.

The first and major distinction is between the immediate effect on the city population and the subsequent or ultimate effect. The immediate effect is found by simply counting instances; if, as in our example of India, natural increase of cities is 20 per thousand population and migration is 17 per thousand, then natural increase is clearly the greater contributor. But the immediate effect, which this approach reports, is not of as much interest as the later effect, for migrants are usually young adults just about to begin reproduction. Thus one can simply multiply the number of migrants by the reproductive value corresponding to their ages to show the increase in their relative effect.

But to compare these with births less deaths in effect assumes that each death cancels out one birth. For the majority of people who die at ages beyond reproduction, death removes no reproductive value at all; this suggests that one ought to compare the migrants not with the net of births less deaths but with gross births. But gross births plainly overstate the effect of natural increase.

The best means we have found for answering the question is to permute the inputs to a population projection. The projection can tell in effect what happens when births fall to bare replacement, that is, fall sufficiently that ultimately there would be no natural increase at all. It does this leaving migration at the observed rate, and then turns around and, leaving age specific birth and death rates as observed, tells what the subsequent population would be if there were no migration. The overall effect of migration on this basis turns out to be double the effect of natural increase for the long term, say, for the year 2020 and onwards, again using Indian data at the jumping-off point of 1970.

But if instead of taking inputs as observed and zero, we take inputs as observed and 0.90 of observed, thus obtaining marginal effects of migration and natural increase, the answer comes out very differently: now migration is no longer double the effect of natural increase, and in fact comes down to less than 0.6 of the effect of natural increase by 2070. In short, at the margin migration has far less impact than it has overall.

The next step in this series of simulations is to try each of the levels of urban natural increase and migration with zero rural natural increase. That provides the equivalent of a $2 \times 2 \times 2$ factorial experiment. Now natural increase is nearly twice as effective as migration, but much more important, the rate of rural natural increase has a greater effect than either. A crucial variable in the growth of cities is the growth of the countryside.

The absolute size of population of the countryside is then taken as a fourth variable. At the margin it has more effect than rural natural increase by the year 2070, and very much more effect earlier. The comparison of urban variables, when made orthogonally to the rural variables of size and natural increase, has the satisfying consequence of stabilizing the ratio of migration to natural increase effects.

What then are the circumstances under which migration wins out? Summarizing from Table 6, we see that

1. Migration is more dominant over natural increase in the short run than it is later
2. Migration has a stronger effect at the margin than it has on the average
3. The amount of migration is sensitive to the size of the rural sector, as follows from our having assumed fixed age-specific migration rates
4. When rural natural increase is allowed to vary, it has a major influence on city size, acting through migration. (It cannot affect urban natural increase in our model.) The absolute number of people in rural parts has an even greater effect
5. The direct plus indirect migration variables are about three times as influential on the ultimate size of cities as the natural increase of cities, and this applies both at the margin and on the average.

We do not pretend to understand all the results that our simulations have turned up. They are the consequence of complex interrelations among the projection variables and require further investigation. In this respect at least our simulations resemble the phenomena of the natural world.

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