A SYSTEMIC VIEW OF THE POPULATION OF CHINA, TODAY AND TO-MORROW

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ABSTRACT

The authors present models, written in Dynamo language, used for reconstituting the demographic evolution of China between 1953 and 1978, and for dynamic simulations of the Chinese population. These models incorporate standard features of demographic projections but also a highly disaggregated sub-system of the female fertility, by age of women and number of children ever born. The spontaneous evolution of population is easily analyzed; any number of changes in fertility and/or mortality can be simulated, together with their consequences on population figures.

The paper presents simulations of modifications in the trends of mortality and fertility. The effects of such modifications are discussed.

The authors show the importance of existing stocks of people (by sex, age and number of children) for understanding and predicting the evolution, "natural" or consecutive to governmental actions, in population parameters; the evolution can be accelerated or delayed due to structural constraints.

The short- and long-term effects of the possible evolutions in demographic parameters on the several stocks (population structures) are discussed, in the perspective of their usefulness for decision-makers. The disaggregation of the model allows to make sectorial projections for each simulated hypothesis.

The feasability of a stabilized population in China by the year 2000 is also discussed.

A RECONSTITUTION OF THE RECENT EVOLUTION OF THE CHINESE POPULATION

Position of the Problem

Population dynamics can essentially be thought in terms of many disaggregated stocks of people, the so-called structures, determined by flows, internal to the system (ageing) or between the system and the "outer world" (births, deaths and migrations). System Dynamics tools are thus perfectly suited to demographic modelling.

The strong inertia of population structures is well known : the evolution of a population is largely determined by its current distribution of people by sex and age. For instance, the number of births is a function of the number of women in childbearing ages, and these births will determine the number of women reaching childbearing ages twenty years later. Relevant simulations of the future population growth are thus only possible on the basis of very detailed data about present structures; however, this is precisely the kind of data usually unavailable in most countries of the world, includind China.

But this inertia has also a reverse consequence : whenever series of data, even incomplete, are available on structures, total population and events (births, deaths), it is possible to guess a range of likely values for unknown details - and the more available are data, the narrower is the range of guesses.

Nevertheless, the inertia of structures do not last forever; on the contrary, a given structure submitted to constants laws of evolution will result in some "final" convergent structure depending only on these laws (strong ergodicity theorem). In other words, this property of convergence could be used for guessing a structure whenever there are some evidences concerning its evolution : for instance an arbitrary initial age structure has only to be simulated until convergence, subject to measured or estimated parameters of fertility and mortality, for getting the most likely initial structure corresponding to these parameters.

Another characteristic of population dynamics is very relevant to modellers : detailed rates of events are not random. For instance, the death rate at a given age is correlated with the rates of next ages; each correlation is rather loose, but there are only a few contrasted patterns of rates across a variety of ages. And the same holds for fertility. Consequently, even with a poor information about deaths and births, it is possible to derive good estimates at a detailed level from these data and some mathematical model, requesting only a few parameters : model life tables (distributed between four or five "families"), functions of fertility.

Reconstituting the Population

The exercise of reconstituting the Chinese population between 1953 and 1978 has been described elsewhere from the point of view of demographers (Lambert, 1981). We will only briefly summarize the process, stressing some points relevant to modelling and simulation techniques.

Basic data were very poor : a census realized in 1953 (without a detailed published age structure) and scattered information on the number of births and deaths, mainly taken from official statements and articles in the People's Daily or in some periodicals.

Needed data were considerably more detailed : an initial structure of population by age (in single years) and sex, and yearly series of rates of mortality and fertility, at least for each five-year age group.

The first step, getting an age structure, is straightforward by using the classical approach of a set of polynomials applied to five-year age groups and giving single-year groups (Sprague's multipliers).

The estimates of mortality and fertility are obtained by trial and error, through an iterative process. Initially, several sources of knowledge (including clinical data and ethnological information) give an idea of the pattern of the phenomena : global shape of the curves (for instance, relative importance of the infant and juvenile mortality), indications on quantifiable parameters (for instance, brackets for the life expectancy or the mean age at childbearing).

For the first year of simulation, the level of the selected curves of mortality and fertility is found by searching for parameters enabling to reproduce correctly the total number of events. For instance, the nature of mortality in China is nearest to the "B" family of the OECD model life tables; taking into account the size and structure of the 1953 population, a total around 9.8 millions of deaths according official sources can only be obtained with a life expectancy at birth of 47.7 years; this figure is only a synthetic estimate, based on a complete set of rates of mortality by age. The same is true for fertility, where a complete set of 36 age-specific rates is derived from a Pearson's gamma function based in fact on only two parameters, a mean age at childbearing (around 27 years) and an average number of children per woman at the level of 4.50. This estimate results in turn of the trial and error procedure, using the mean age estimate and aiming at a correct reproduction of the total number of births.

The detailed population of the next year is easily deduced from the initial structure and the natural movement estimated by the above-mentionned method. The simulation continues in this way, year after year, in the best case. In many cases, however, even data on births and deaths are lacking or unreliable, and the trial and error procedure is made more complex by the fact that intermediate trends should also be guessed on the mere base of qualitative information (such as the awareness of poor harvests, and so on). Actually, the reconstitution of a likely evolution of the Chinese population between 1953 and 1978 requested above one hundred simulations before getting a "path" compatible with every reliable known information.

From a technical point of view, let us mention that this project was executed with a model written in Dynamo III/370 (running on an IBM 370/168 and later on an IBM 4381). While the basic tools of demographic projections were included in the model, it implements some typical Dynamo features. For instance, we devised a mean for "un-smoothing" the trends in mortality. Given the reference model life table, an approximate level of mortality at both ends of the simulated period can be computed, giving a trend, translated in a number of years needed for the transition. Application of this smooth trend is obvious : it only needs a linear interpolation between transforms of the limit life tables, driven by the time. However, the actual evolution of mortality was rather chaotic; so, in order to follow the very large fluctuations observed, the model goes on interpolating between tables, but using a variable number of steps between ends. In other words, worsening conditions are translated as a longer period of transition, and the situation of the simulated year respectively by reference to the true calendar and to the size of the period of transition make the interpolation leaping backwards. The set of "instantaneous durations" was of course designed by trial and error too.

Some Results

The results presented below (Table 1) are only synthetic indicators based on the functionning of the model and compared to the available pieces of information. Let us keep in mind that the true "results" do not appear here, since they are in fact the thousands of detailed figures reconstituted by the model and dynamically related, year after year. It should be noticed that no simulated data differs from real ones by over one percent, except for the so-called "black years", for which there are no reliable estimates. The cumulated numbers of events along both series converge about within 0.5 per thousand, confirming that the reconstitution is plausible, even if there is no proof things happened exactly in this way.

In the Table 1, we present, for selected years, numbers of deaths and births given by Chinese sources ("observed") and computed in the model, along with the computed total population at end of year and two key demographic indices from the model.

Table 1. Synthetic Results of a Reconstitution of the Chinese Population, 1953-1978. Selected Years.

Year	Numbers (in millions) of				Total Popul. in millions	Child. per Woman (units)	Life Expectancy (years)
	Births		Deaths				
	observed	model	observed	model			
1953	21.3	21.29	9.8	9.89	583	4.50	47.7
1958	18.5	18.61	(13.5)	14.01	649	3.65	40.6
1963	29.0	28.93	6.5	6.51	674	5.30	60.9
1968	28.5	28.71	7.5	7.56	778	4.63	61.3
1973	25.0	25.03	6.3	6.35	880	3.59	66.3
1978	17.5	17.49	6.1	6.15	952	2.35	68.2

A sharp decline in both fertility and mortality is clear from these figures. Consequences on age structure are predictible; for instance, the share of the population under 20 years fell from 48.7% in 1953 to 44.3% in 1978. A continued trend towards low fertility, an important political goal for Chinese officials, will still have more important consequences, with repercussions on the number of people in reproductive ages, delayed by one generation. Conversely, a rise in fertility among age groups not yet reduced in size could generate an oscillating system where waves of large birth cohorts would alternate with smaller ones and lead to irregularities difficult to manage for any social system. For instance, the number of children reaching school ages can vary by a factor of 2 over a short period of time : the number of births dropped from 21.5 millions in 1957 to 13 millions in 1960 but was back over 29 millions in 1963, only three years later.

Advanced Modelling of Fertility

Whenever the synthetic indices of fertility change strikingly, it means that the reproductive behaviour of people is modified, especially the parity, i. e.

the rank of birth : proportions of women having one, two, etc.. children also change, so do the probabilities of getting an additional child for every actual number of children. Beside this technical consideration, the offspring of each individual woman has for long been a sensitive issue for the Chinese decision-makers. Consequently, it seemed relevant to try to simulate not only the global fertility, but also to estimate proportions of women by parity and the evolution of this particular structure. Since, obviously, the parity is a function of the duration of "exposure to the risk of childbearing", this distribution has to be simulated by age. An advanced version of the initial model enabled us to guess the structure of Chinese women distributed by age and parity (limited to the fifth rank) at the time of the 1953 Census and to follow its evolution along the whole period of simulation. The exercise was conducted by the same trial and error process used previously and it would be tedious to describe it at length. It could be felt more hypothetical than the global exercise, e. g. because of a greater sensitiveness of fertility curves by parity to departures of the model parameters (themselves less known) from the real ones. However, this disaggregated model is also submitted to additional constraints : the parameters computed and tested in the global model have to be reproduced by the synthesis of the disaggregated model. For instance, the mean age at childbearing for the whole female population is checked against the weighted average of mean ages for each parity group. With this proviso in mind, the hypothetic structure by parity we derived for the Chinese population of 1978 should be understood as one possible scenario, but a very likely one because alternative scenarios respecting the same constraints are not evident.

We will not present here results of the advanced model, which are only relevant for demographers (its features are included in the further discussion).

A MODEL FOR THE FUTURE

The Model

The first model, presented above, served as a tool for initializing another model, dedicated to forecasting. The reason for building a different model is simple : we desired to use it on micro-computers but the severe limitations on the size of micro-computerized models do not allow to implement it. We rewrote thus totally the model, dropping all the complex systems used in the reconstitution of the population and keeping only the resulting structures. We were so in a position to write a simplified model in the Professional Dynamo version 2 plus language (running on an IBM PC/AT, it uses only 57K of core). Of course, only simple scenarios can be simulated, but they are demonstrative enough of the abilities of this technique as an helping tool for decision-makers.

The actual model embodies mainly a population module where the total population is distributed by sex and single years of age; women in reproductive ages are also distributed by parity; the flows of individuals are controlled by sets of age-specific rates of mortality and fertility; there is no provision for migrations. Of course, any change in the parameters governing the flows can be simulated, and the output of population in terms of school enrolment, working force, and so on, is available. For the present paper, we only used hypothetical coefficients for the sake of the demonstration, but any set of realistic coefficients can easily be substituted for meeting real conditions.

Inertia or The Weight of the Past Times

We have shown the erratic and typically non-linear pattern of evolution of both mortality and fertility in the past thirty years. An easy demonstration of the inertia of demographic phenomena lies in an "everything constant" scenario. In this case, we first simulated the next fifteen years under the simple hypothesis of constant mortality and fertility patterns, i. e. a life expectancy at birth of 68 years and a final descent of 2.35 children per woman. Table 2 shows, at selected years, the evolution in the number of births and deaths. Births reach a maximum during the nineties, due to the coming in age of the large births cohorts of the sixties, and then begin to fall; deaths are steadily growing, due to both the ageing of the population and the absolute growth of its size; for the same reason, in spite of an actually constant mortality, the crude death rate grows. However, with the constant hypothesis, these two opposite trends in numbers of deaths and births never converge. The annual growth rate of the whole population, around 1% in 2001, would still decline but would stabilize around 0.5% and stay indefinitely at this level.

Table 2. Total Population, Births and Deaths, China, 1986-2001, Selected Years. Constant Hypothesis (figures in millions).

Year	Total Population	Births	Deaths
1978	952	17.5	6.1
1986	1044	21.3	7.7
1989	1087	22.4	8.4
1992	1136	25.7	9.0
1995	1185	25.7	9.8
1998	1231	24.2	10.4
2001	1270	22.5	11.0

The parameters of fertility and mortality used in the constant hypothesis are not especially low; however they represent a sharp decline by reference to the high levels which determined the Chinese population structure for centuries, until the early sixties. That means a drastic change in the determinants of the structures, reflected by a slow but perceptible drift in the age distribution of the population. Table 3 shows the repartition between conventional age groups of "young", "adult" and "old" people. From this table, it is clear that the ageing of the total population is mainly due to the diminution of the

Table 3. Relative Structures (per thousand people) of the Chinese Population, 1986-2001, Selected Years. Constant Hypothesis.

Year	Proportion of Age Groups			Dependency Ratio (units)
	Young (under 20)	Adult (20-59)	Old (60 and over)	
1978	443	484	73	1.065
1986	398	516	86	.937
1989	373	537	90	.864
1992	353	552	95	.810
1995	342	559	99	.790
1998	343	554	103	.806
2001	346	548	106	.825

Table 4. Absolute Structures (in millions) of the Chinese Population, 1986-2001, Selected Years. Constant Hypothesis.

Year	Size of Age Groups		
	Young (under 20)	Adult (20-59)	Old (60 and over)
1978	421.7	460.8	69.5
1986	415.7	539.1	89.6
1989	405.7	583.5	98.3
1992	400.6	627.3	107.7
1995	405.7	661.9	117.4
1998	422.4	681.6	127.0
2001	438.8	695.7	135.3

share of younger people, rather than to the growth of the share of older people. This double move is made apparent by the dependency ratio, a conventional measure of the burden on people at "active" ages (i. e. adults) due to people in "inactive" ages : the dependency ratio declines very fast to a minimum in the mid-nineties.

However, we should be aware that relative structures visualize the evolution of population, but do not directly reflect what is most meaningful from the point of view of decision makers, i. e. the absolute size of the age groups (population in school ages, in active ages, and so on). Indeed, we can observe from Table 4 that the overall growth of the population overcompensates the fall in the proportion of youngsters from the mid-nineties. For instance, China will reach its ever-biggest number of young people around the year 2000, while their share in the population would be near its historical minimum.

Going into Uncertainties : Changes in Mortality?

According to an hypothesis of decreasing mortality, we simulated the evolution of population if the observed trend of improved conditions of mortality would prevail, reaching in 2001 the level of life expectancy to birth of 74.0 year (i. e. the level of mortality observed in some countries, like Sweden or the Netherlands, around 1985). Though such an evolution is quite important, the impact on the total population is not very significant, as shown by Table 5, compared with Tables 2 and 3 : only an additional 24 millions people, or an increase under 2 per cent, and the changes in the age groups distribution is still less noticeable. This is another way to demonstrate the inertia of structures inherited from the past. In fact, even when the overall mortality is yet rather low, progresses do first benefit to infant, younger children and

Table 5. Total Size (in millions) and Relative Structures (per thousand people) of the Chinese Population, 1986-2001, Selected Years. Hypothesis of Decreasing Mortality.

Year	Total Population	Proportion of Age Groups		
		Young (under 20)	Adult (20-59)	Old (60 and over)
1986	1048	398	516	86
1989	1093	373	536	91
1992	1144	353	551	96
1995	1197	343	557	100
1998	1247	344	551	105
2001	1294	347	545	108

older people. The impact of such a progress on the adult population is only noticeable later, when the additional surviving children come in age.

Uncertainties under Control : Fertility Changes and Population Policies

A well-known objective of Chinese authorities is to reach as soon as possible a zero population growth (ZPG). The present situation is rather favourable, with a very low fertility by reference to Third World countries. But, as shown above, population will still grow at the rate of one per cent per year at the beginning of the 21st Century, and later continue indefinitely to grow at a lower pace.

In order to get a first idea of what would be possible, we have simulated some rough scenarios of population policy, namely the "no third child" and "no second child" policies. For this present paper, we limited ourselves to simulate an instantaneous change, i. e. the hypothesis where the policy is fully implemented - and fully effective - starting in 1986 (it is of course technically easy to simulate both a steady evolution over years and any proportion of failure of the policy). That means that, from 1986, the simulated reproductive behaviour of childless women is unchanged, as is the behaviour of mothers of first parity in the "no third child" scenario; consequently, since no every woman is married or mother, the synthetic indices of "number of children per woman" would respectively amount to 1.7 and to 0.9. As a reference, let us say that 1.7 children per woman is the approximate level of fertility in France in the early eighties (one of the highest levels in Europe), and that 0.9 children per women is the level reached in the mid-eighties by a few big European cities like Hamburg or Torino.

We simulated also the impact of these changes under different hypotheses of mortality. Table 6 presents only results under the hypothesis of decreasing mortality used for Table 5 (to reach a life expectancy of 74 years by the year 2000 is a realistic assumption). In this Table, we show for the same selected years what would be the total population of China if both scenarios are implemented in 1986.

The "no third child" scenario leads the population to a sustained, while lower, growth; the ZPG target would only by reached by the year 2023, with a total population of 1.297 billion people.

The ZPG target will be reached in 2001 with the "no second child" scenario : from 2002, we would observe a negative growth. Let us stress two conclusions from this finding. First, the ZPG is indeed possible at dawn of the Century. But the objective can only be met with untenable hypotheses : it seems somewhat irrealistic to believe in the possibility of a radical disappearance, effective right now, of any birth among women having yet at least one child, and of holding this constraint for years. The ZPG cannot be reached with less stringent demands on the population, except if an important worsening in the mortality conditions happens : but this is clearly neither desirable nor likely. A second conclusion we lack of place for documenting at long is the long-term consequences of such a fast change. Indeed, the growth rate will not be stabilized at its zero level, but become increasingly negative. A true continued ZPG would impose to decision-makers to react in the other direction by stimulating fertility at that time; however, due to the inertia of population phenomena, the trend would be reversed by coming back in the area of positive

Table 6. Total Population (in millions) and Population Growth (per thousand), China, 1986-2001, Selected Years. Hypothesis of Decreasing Mortality; Two Scenarios of Decreasing Fertility.

Year	Scenarios: "no third child" Total Population	Population Growth	"no second child" Total Population	Population Growth
1986	1048	9.1	1048	2.3
1989	1078	10.3	1056	2.8
1992	1112	10.4	1064	2.5
1995	1146	9.1	1071	1.4
1998	1177	8.0	1075	1.2
2001	1204	6.5	1077	0.6

Table 7. Relative Structures (per thousand), China, 1986-2001, Selected Years. Hypothesis of Decreasing Mortality; Two Scenarios of Decreasing Fertility.

	Scenarios							
	"no third child"				"no second child"			
	Age Groups			Dependency	Age Groups			Dependency
Year	0-19	20-59	60-+	Ratio	0-19	20-59	60-+	Ratio
1986	398	516	86	.939	398	516	86	.939
1989	365	543	92	.841	341	555	94	.803
1992	334	567	99	.764	305	592	103	.688
1995	314	581	105	.720	266	622	112	.608
1998	305	584	111	.711	239	640	121	.563
2001	297	586	117	.707	215	655	131	.528

growth, and so on, generating oscillations more and more difficult to manage.

Table 7 compares the evolution of the relative structures of the Chinese population under both scenarios. The reason of a further negative growth or oscillations if the system has to be influenced again by policies are clear from the dramatic fall in the proportion of youngsters, especially in the "no second child" scenario : this age group is only renewed (in proportion) by 54 per cent on this fifteen year period. That means that ageing adults will no more be replaced by young adults, and the fathers and mothers of to-morrow will be less numerous, bearing thus less children if fertility does not change. At the same time, the increasing number of older people will produce a greater number of deaths; the negative growth can thus only be more and more important for years.

The structure of population at the time of reaching ZPG is noticeably different :

	0-19	20-59	60-+	Dependency Ratio
"no third child" (ZPG in 2023)	231	591	178	.693
"no second child" (ZPG in 2002)	206	660	134	.515

The apparent paradox of getting an older population with a higher fertility is another illustration of the inertia of demographix phenomena. Indeed, during the twenty-one more years between 2002 and 2023, the faster growing population has time enough for the ageing of the large birth cohorts before 1963, while the decreasing fertility renews more slowly the stocks of adults. Moreover, the youngsters of 2023 are mainly the offspring of smaller birth cohorts, born in the eighties and nineties. On the whole, thus, the ZPG is reached with a significantly less favourable dependency ratio due to the progressive depletion of the adults stocks.

A Brief Look at Population and Schooling

These comments on relative structures are still more meaningful when the absolute figures are considered. Table 8 shows the total number of young people in the Chinese population according to both scenarios, contrasted with an hypothesis of constant fertility at the 1978 level (i. e. 2.35 children per woman). These figures differs slightly from Table 2 because they were computed here under the hypothesis of decreasing mortality. From the point of view of social investments, it is clear from Table 8 that the "no third child" scenario is more favourable than the other two. Indeed, we can observe a steady decrease in the number of youngsters, not as dramatic as in the "no second child" scenario, and smooth by reference to the constant hypothesis.

These differences are meaningful for social organization : the planification of schooling and the entry in the labour force is obviously made easier when changes of size of the concerned populations are smooth, not too fast, and oriented in a constant direction. For instance, such changes make possible to plan improvements in quality or coverage of schooling, synchronized with the evolution of populations.

For exemplifying this dynamic interaction between population and social

Table 8. Population under 20 (in millions), China, 1986-2001, Selected Years; Hypothesis of Decreasing Mortality: Three Scenarios of Fertility.

Year	Fertility Hypothesis (number of children per woman) 2.35	1.7	0.9
1986	417.2	417.2	417.2
1989	408.1	393.1	370.6
1992	404.2	372.4	324.4
1995	410.7	360.1	285.0
1998	429.2	358.6	257.0
2001	448.5	357.9	231.0

policy, we simulated an arbitrary school system (but any other initial and simulated conditions can be used). In this exercise, we hypothetized that 95 per cent of the children enter school at 6 and dropouts occur so that 80 per cent of pupils complete their sixth year and 30 per cent their twelfth year, and we consider only the first twelve years of school. The "improved schooling" scenario implies that every child is admitted at school, with respective final rates of completion of six and twelve years fixed to 90% and 60%. Our simulation also supposed that five years are needed for fully implementing the total coverage of the population and the lower level of dropouts after six years, while the improvement of the schooling between six and twelve years is only achieved in fifteen years. The simulated reform is supposed to occur in 1986. Let us mention, from the technical point of view, that dropouts are neither simulated as an instant departure from school nor as a linear interpolation of proportions attending school, but by computing (in the model) linearized conditional probabilities, following the life table technique.

Table 9 presents the comparison between both scenarios for the case of a "no third child" policy in a context of decreasing mortality. Under initial conditions, the school population culminated to 211 millions pupils in 1981, then rapidly declining until 1986. One can observe that school attendance continues falling until the nineties; but in the "improved schooling" scenario, the school population in 2001 is back to its level of 1985. Contrastingly, the "constant schooling" scenario gives a loss above 16% of the total school population in 2001 (the loss is above 26% by comparison to the peak year 1981), meaning some "over-equipment" of schools (by reference to the initial situation).

Comparable simulations are possible for manpower planning, independently or in relation with alternate schooling policies, and, in this case, the qualitative

Table 9. School Population (in millions), China, 1986-2001, Selected Years; Two Hypothetic Scenarios of Schooling under Decreasing Mortality and Fertility Conditions.

Year	Schooling	
	Constant	Improved
1986	185.2	185.2
1989	166.7	171.5
1992	156.7	173.4
1995	150.8	174.8
1998	152.1	181.1
2001	155.5	187.5

composition of the labour force, as a consequence of the evolution in learning, can also be considered.

CONCLUSIONS

In this paper, we tried to show some applications of dynamic modelling useful for decision-makers in global situations where classical demo-economic approaches are limited by an apparent lack of suitable data and by the complexity of many non-linear dynamic interrelations. As a matter of fact, population and population-related problems are typically fit to a System Dynamics approach, due to their fundamental stocks-and-flows nature.

For the sake of demonstration, however, we limited ourselves to a few simple, or even simplistic, scenarios. It should nevertheless be stressed that our presentation is far from exhausting the possibilities of the models, even with the restricted size of micro-computers (for instance, another national model we build has no less than 820 variables modifiables for getting a variety of scenarios). Under this respect, System Dynamics modelling for population studies give a matchless flexibility and ease of use to researchers and planners.

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