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Modelling urban-rural population growth in China

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Abstract. The Population of China is still growing despite a dramatic decline in fertility in the past two decades. There are marked urban-rural differentials in fertility and, as a result, the pace of urbanization has significant effects on population growth. In this research an attempt is made to model urban-rural population in China. A demoeconomic model of urban and rural sectors is calibrated to account for the long-term trend of urbanization in China. Two important components of urban population growth - rural to urban migration and transition - are considered. In previous research, rural to urban population transition was ignored and thus urbanization levels may be significantly underprojected. An accounts-based urban-rural population model, in which rural to urban migration and transition are driven by the foregoing demoeconomic model, is established in this research. These models are used to make urban-rural population projections for the period 1988-2087 under various fertility rate assumptions.

1 Introduction

China is a developing country with a population of over 1100 million, and its population is still growing with a current annual growth rate of 1.4%. Sound population projections are essential for well-founded planning of socioeconomic development. The problems of labour supply and population ageing can be revealed only through careful, long-term, age-specific population projection. A series of population projections for China have been produced since the early 1980s (Jiang and Lan, 1987; Song et al, 1981; Wang, 1988; Zhang, 1987). Significant differences in the population dynamics of urban and rural areas in China have been discovered. (Peng, 1991; Shen, 1993). Urban fertility declined much earlier and to levels lower than those of rural fertility. It is likely that urban China will face population ageing much earlier, and to an extent much more severe, than rural China because fertility in the urban areas is well below the replacement level. Detailed age-specific projections both for urban and for rural populations must clearly be helpful in revealing these implications. Wang (1988) was the first to carry out an urban-rural population projection for China, but the vital rural to urban migration components was disregarded in his model, Zeng and Vaupel (1989) used a multiregional (urban-rural) population model to study the impact of urbanization and delay childbearing on population growth and ageing in China. Rural to urban migration was considered in their model but rural to urban population transition, which does not involve physical movement and which will be considered below, was disregarded.

The United Nations (UN, 1989) has also produced projection s of urban and rural populations of China until 2025. The urban-rural growth differences method was used for this work. The proportion of urban population was projected first and the urban and rural populations were derived subsequently from the projected population totals.
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A multiregional demography approach has been used to estimate the mortality, fertility, and migration rates of the urban and rural populations of China in previous research (Shen, 1991). In this work it is recognized that migration rates reflect only pure rural to urban population migration. In reality, the urban population is increased partly by the creation of new cities and towns and the actual expansion of urban areas. This may be called rural to urban population transition and it probably accounts for about 60% of the rural to urban population shift. This may well indicate that rural to urban population transition is determined simply by administrative procedures. However, it may only apply to the definition of urban population used in the 1982 census, In the definition of urban population used in the 1990 census, and in the slightly different definition used in this research, attempts were made to exclude some agricultural populations in the administrative areas of cities and towns, We will return to this definition later in this introduction. Thus, rural to urban population transition should be roughly interpreted as the transition of population from agricultural employment to nonagricultural employment in the administrative areas of cities and towns. Of course, people engaged in nonagricultural employment in some areas will be counted as urban population when these places are designated as cities or towns, Even so, substantial transition from agricultural to nonagricultural employment is required to meet the criteria for the designation of a place as a city or town. The State Council of China has set up these criteria, including population size and fraction of nonagricultural population, for the designation of cities and towns. Any place may apply to the government for the status of city or town when it meets these criteria (DPS, 1988b). It seems that rural to urban population transition will continue to contribute to urban population growth in China.

However, it is necessary to take into account both these components of urban population growth in urban-rural population projections. A demoeconomic model will be established in this research to project total rural to urban population migration and transition on the basis of a dynamic general equilibrium model (Lee, 1984). It can be anticipated that rural to urban migration rates are likely to increase in China with the further transition of China economy toward a market economy. At present, it will be difficult to predict the exact level of future migration rates. For simplicity, the rural to urban population migration will be projected with fixed migration rates. Reduced migration rates will be used if the total number of migrations and transitions projected by the demoeconomic model is less than the number of migrations calculated with the fixed migration rates. The rural-urban population transition will be calculated as a residual. There will be no rural to urban transition if the residual is zero. This procedure is similar to that used in some recent studies in which attempts were made to model migration by means of demoeconomic models (Isserman, 1985; 1986; Isserman et al, 1985; Ledent, 1978;1982). In these studies, selected economic variables were used to model or project population migration, and birth and death rates. The level of urbanization is relatively low in China. Ran and Berry (1989) pointed out that China is just a case of systematic underurbanization in planned economy countries. For a long period since the foundation of the People Republic, the Chinese government used a series of measures to control urban growth in order to achieve maximum capital accumulation an industrial growth. However, the situation began to change in 1978 when economic reforms' were introduced. Urbanization is recognized by the government as a positive way of promoting economic development. Those areas eligible for city or town status have been approved for the status more quickly than they were before the introduction of reforms. In 1984 the regulations for the designation of a place as a town were changed so that many areas became eligible for the town status. The number of cities increased rapidly from 191 in 1978 to 450 by 1989. The number of towns increased from 2819 in 1982 to 10609 by 1988.

The dramatic increase in the number of cities and towns partly reflects the rapid economic development in that period. However, this process is inevitably affected by administrative procedures and considerations. More important, there have been changes in the official definition of urban population between censuses. Thus, there has been growing confusion about the exact nature of urban population data for China. Many scholars all over the world have tried to establish a realistic picture of urbanization in China. Previous research is helpful in clarifying this problem (Chan, 1988; Chan and Xu, 1985; Goldstein, 1990; Kirkby, 1985; Ma and Cui, 1987; Pannell, 1990; Veeck, 1991).

In the present research, urban areas refer to town and city areas excluding counties in the administrative areas of cities; rural areas refer to county areas excluding towns in the administrative areas of counties. Not all the population in the administrative areas of cities and towns should be counted as urban population. Figure 1 illustrates the various components used in the different definitions for the urban population of China. It should be mentioned that a person's registration of residence is classified as either nonagricultural or agricultural population. This may not, however, reflect the nature of the actual employment engaged in. As shown in figure 1, the population can be divided either into agricultural or nonagricultural populations or into agricultural or nonagricultural employment-related populations. In the period 1963-81 the most commonly used definition of urban population included only the registered nonagricultural population in the urban areas. In the 1982 census, the urban population was defined as the population in the urban areas described above, and thus included the nonagricultural and agricultural populations. It has been estimated that the urban population may be overenumerated when the 1982 census definition is used, as newly designated cities and towns include a high proportion of agricultural population (Goldstein, 1990). In the 1990 census, the State Statistical Bureau (SSB) of China adopted another variation of the definition of urban population. Cities are divided into two types according to whether they are further divided into city districts or not. All the population, including registered agricultural population and nonagricultural population in the city districts, are counted as urban population. This is in line with the 1982 census definition. Only the registered nonagricultural population in towns and in the cities which do not have city districts are counted as urban population. This is in line with the definition before the 1982 census. It should be remembered that the reason for adopting the 1982 census definition of urban was to include some actual nonagricultural population, who engaged in nonagricultural employment but were still registered as agricultural population. It seems that, if the 1990 census definition is used, the urban population may be underenumerated because a considerable number of the actual nonagricultural population are excluded.

Figure 1. Population components used in the different population definitions in China. The pre-1982 definition consists of the nonagricultural population (NA) in cities and towns., whereas the 1982 census definition consists of the entire population in cities and towns (NA and A, or NAe and Ae). The 1990 census definition includes the entire population in cities with districts (NA and A of city population 1) and nonagricultural population in cities without districts and in towns (NA of city population 2 and NA of town population). The definition used in the present paper consists of

nonagricultural employment-related population (NAe) plus a part of agricultural employment-related population (Ae) in cities and towns.

In this research, the urban population is based on actual urban nonagricultural employment and also includes a small proportion of agricultural population. The range of urban population by this definition lies between the 1982 and 1990 census definitions. In 1987 the urban population was 498 million by the 1982 census definition (DPS, 1988b), 277 million by the 1990 census definition (SSB, 1991), and 329 million by the estimation used in this research. According to our recent estimation, which was based on official sources (DPS, 1988b; SSB, 1989), the urban population proportion was 29.4% in mid-1987. There is no doubt that the urban population proportion will rise with socioeconomic development in China. In this research we have tried to establish a demoeconomic urbanization model linked with an urban-rural population projection model to model urbanization and urban-rural population growth in contemporary China.

The rest of the paper is organized as follows. In section 2, the demoeconomic model of urban and rural sectors will be calibrated. In section 3, an accounts-based urban-rural population projection model will be established. In section4, these models will be used to make urban-rural population projections for China. Finally, some conclusions are presented in section 5.

2 Calibration of the demoeconomic model of urban and rural sectors

In this section we will attempt to calibrate a demoeconomic model of urban and rural sectors in an effort to model the long-term trend of urbanization in terms of rural to urban population migration. For simplicity, the word 'migration' here refers to both migration and transition in this section.

There have been a number of theoretical studies (Artle et al, 1977; Baumol, 1967; Lee, 1984; Simon, 1947; Varaiya et al, 1979; Vislie, 1979) dealing with the economic forces determining differential urban-rural, or more generally, sectoral growth. From these, the direction of labour mobility between sectors can be deduced. A demoeconomic model of urban and rural sectors based on a general equilibrium model (Lee, 1984) has been chosen for this research. The model is presented in the appendix.

It is assumed in the demoeconomic model that the national economy can be divided into an urban sector and a rural sector. In reality, there are no statistics based on such a division. Therefore, the division into an agricultural sector and a nonagricultural sector has to be used to estimate the exogenous variables needed in the model. Generally, urban and rural sectors overlap with agricultural and non-agricultural sectors in China. There are some rural dwellers employed in the nonagricultural sector, although most of the rural population are employed in the agricultural sector. It should be emphasized that most of the registered agricultural population who engaged in nonagricultural employment have been counted in the urban population by the definition used in this research. There is no doubt that the conversion of the labour force from the agricultural to the nonagricultural sector is the main cause of rural to urban population migration and transition. The agricultural and nonagricultural employment data for China in the period 1979-88 will be used to test the performance of the model in the first instance. Then the urban and rural employment data for the period 1979-87 will be used to test further the performance of the model.

The four main parameters in the demoeconomic model are the growth rate of productivity and the income elasticity of consumption of the products in the two sectors. Employment and GNP data are used to calculate these parameters. Agricultural and nonagricultural employment data are available from official Chinese sources (SSB, 1989). The GNP generated by the agricultural sector and the non-agricultural sector at a comparable price are calculated with the GNP data in 1978 and the GNP growth index data in subsequent years (SSB, 1989). The comparable price is assumed to have excluded the effect of inflation on the current price. Table 1 shows the annual growth rates of productivity in the two sectors and the income elasticity of consumption of agricultural and nonagricultural products in the period 1979-88. In most years except 1981 and 1982, the income elasticity of consumption of the agricultural product is less than one, whereas that of the nonagricultural product is more than one, as expected. Generally, the consumption of agricultural products is not income elastic. Therefore, most of the increased income will be used for the consumption of nonagricultural products. There was a slowdown of nonagricultural production in 1981 and 1982 and therefore the growth rate in the nonagricultural sector was less than that of the agricultural sector. Because of this change in the supply condition, the consumption of agricultural products increased faster than that of nonagricultural products in 1981 and 1982. If these annual growth rates of productivity and income elasticity of consumption are used, the demoeconomic model will measure the agricultural and nonagricultural employment and the net migration between the two sectors exactly. Instead, the average growth rates of productivity and the income elasticity of consumption in the period 1979-88 will be used to test if the model can capture the general trend of the net migrations between the two sectors. In long-term population projections, it will not be possible to project the annual figures of these parameters. On the other hand, average parameters of a period will smooth out annual fluctuations resulting from short-term factors. For example, the agricultural to nonagricultural shift peaked in 1984 owing to the expansion of township firms. A peak of the growth rate of agricultural productivity was also recorded in 1984. As shown in table 1, the average increase in the annual rate of productivity is 4.29% for the agricultural sector and 4.09% for the nonagricultural sector for the period 1979-88. The income elasticity of consumption is 0.5239 for the agricultural product and 1.1463 for the nonagricultural product over the same period.

Table 1.
The growth rate of productivity and the income elasticity of consumption of the products in the two sectors.

Year	Growth rate of productivity (%)		Income elasticity of consumption	
	agriculture	nonagriculture	agriculture	nonagriculture
1979	5.21	3.22	0.8061	1.0743
1980	-3.45	4.22	-0.4548	1.5421
1981	4.74	-1.65	1.8339	0.7231
1982	7.87	4.04	1.4233	0.8565
1983	7.50	4.77	0.8035	1.0695
1984	13.97[a]	1.54	0.8772	1.0419
1985	1.86	7.30	0.1370	1.2914
1986	2.63	2.82	0.2338	1.2294
1987	3.16	6.99	0.3192	1.1909
1988	4.12	8.07	0.0898	1.2370
1979-88	4.2918	4.0945	0.5239	1.1463

[a] The productivity in agriculture was greatly increased in 1984, as a large number of labourers were released to the nonagricultural sector in that year.

The model also needs the rates of natural increase of the national population and the work forces in the two sectors. The rates of natural increase of the national population for the period 1979-88 are readily available (SSB, 1989). However, similar rates for the work forces in the two sectors are not available. The annual data of work forces registered as agricultural population and nonagricultural population (SSB, 1989) are used to calculate the rates of natural increase of the work forces in the two sectors. The data for labour migration from registered agricultural population to registered nonagricultural population are available for the years 1978, 1980, and the period 1983-88 (SSB, 1989). The SSB reported the new employment in cities and towns recruited from rural areas. The distinction between the employment in cities and towns and the employment in rural areas generally corresponds to the distinction between registered nonagricultural and agricultural populations under different administrative arrangements in Chinese statistics. The migration data for unreported years are estimated as the average migration of two adjacent years when these data are available. These migration data are used to adjust the annual data of work forces registered as agricultural population and nonagricultural population to calculate the rates of natural increase of the work forces in the two sectors.

The labour force in the nonagricultural sector consists of two parts: those registered as nonagricultural population and those as agricultural population. This is also true for urban population. Therefore, the real net labour migration between the agricultural sector and the nonagricultural sector in China consists of two parts. The first part is the labour migration from registered agricultural population to registered nonagricultural population. The data on this component are available from the sources mentioned above and are shown in table 2. The second part is the net labour migration between the two sectors by the registered agricultural population. This part is estimated from the rate of natural increase of the work force in the agricultural sector and the nonagricultural employment in the registered agricultural population, and is also shown in table 2.

Table 2.
Net labour migration' between the agricultural and nonagricultural sectors (in millions)[source :SSB(1989) for year 1980, 1983 -1988 of column 2].

Year	Estimation 1			Estimation 2 [d]	Model Result
	migration [a]	net migration [b]	total migration [c]		
1979	1.379	-0.140	1.239	1.670	2.39
1980	1.270	2.155	3.429	3.789	4.06
1981	0.978	0.873	1.851	2.009	3.84
1982	0.978	-0.331	0.647	0.996	6.66
1983	0.682	4.349	5.031	5.214	5.32
1984	1.230	13.727 [f]	14.957 [f]	15.425 [f]	7.19
1985	1.502	6.218	7.720	8.126	6.14
1986	1.665	6.103	7.768	7.945	6.02
1987	1.668	3.750	5.418	5.610	6.49
1988	1.599	2.252	3.851	4.099	6.90
Total			513911	54.883	55.01

a Labour migration between the registered agricultural population and the urban nonagricultural population
b Estimated net labour migration between the two sectors by the registered agricultural population.
c Estimation of total net labour migration between the two sectors (column 2 plus column 3)
d Estimation of net labour migration by using the rate of natural increase data.
e Net labour migration projected by the model.
f A great shift of labour from the agricultural to the nonagricultural sector occurred as a result of the expansion of township firms in 1984.

A second estimation of the real net labour migration between the two sectors can be obtained by using the data for the agricultural employment and the rate of natural increase of the work force in the agricultural sector. This second estimation is also shown in table 2. These two estimations of the real net labour migration between the two sectors are similar.

The demoeconomic model is next used to project the net labour migration and the agricultural and nonagricultural employment in the period 1979-88; the base year is 1978. Table 2 presents the resulting projected net labour migration between the two sectors. The relative error is especially susceptible to small net real labour migration as found in 1982. If the data for 1982 are excluded, the RMSE (root mean square relative error) of the projected net labour migration are 58.53% and 46 15% for estimation 1 and estimation 2 of the real net labour migration, respectively. The total net labour migration projected by the model in the period 1979-88 is 55.01 million, which is similar to estimation 2 of the real net labour migration. It seems that the general trend of the net labour migration is captured by the model, as only the average parameters of the period have been used.

Table 3 presents the real employment and the projected employment in the agricultural and nonagricultural sectors in the period 1979-88. The relative errors of the projected employment are small. The maximum relative error of the projected agricultural employment is -2.88% in 1983. Overall, the RMSE of the projected agricultural employment is 1.37%. The maximum relative error of the projected nonagricultural employment is 6.45% in 1982. Overall, the RMSE of the projected nonagricultural employment is 3.09%.

Table 3.
Comparison of real employment and projected employment by the model in the agricultural and nonagricultural sectors (in millions).

Year	Real employment		Projected employment	
	agriculture	nonagriculture	agriculture	nonagriculture
1979	286.92	123.32	286.20	124.48
1980	291.81	131.80	290.79	133.51
1981	298.36	138.89	295.48	142.81
1982	309.17	143.78	300.52	153.05
1983	312.09	152.27	303.11	161.71
1984	309.27	172.70	308.16	173.85
1985	311.87	186.86	312.70	186.09
1986	313.11	199.71	315.89	196.73
1987	317.20	210.63	319.19	208.01
1988	323.08	220.26	322.33	219.71

The model is next tested against the urban-rural employment data in the period 1979-87 with the same parameters as were used in the test against the real agricultural and non-agricultural employment data discussed above. Because urban-rural labour population will be used in the demoeconomic model for the rural to urban migration projection, it is sensible to test the model performance with urban-rural employment data instead of the real agricultural and nonagricultural employment data.

However, the urban-rural employment data are in fact not available. The rural employment data are estimated from the rural population data and the participation rate data of thc registered agricultural population. This participation rate is defined as the total labour force divided by the total population in the registered agricultural population. The participation rate data are calculated from the total employment data of the registered agricultural population (SSB, 1989) and the registered agricultural population data (DPS, 1988b). The urban employment data are estimated as the difference between the total employment of China (SSB, 1989) and the estimated rural employment. The rates of natural increase of the work forces in the urban and rural sectors are estimated by the rates of natural increase of the work forces registered as nonagricultural population and agricultural population.

The real rural to urban net labour migration is calculated with the estimated rural employment data and the rate of natural increase data of the rural work force. The demoeconomic model is used to project the rural to urban net labour migration between the urban and rural sectors. Table 4 presents the estimated real urban and rural employment, rural to urban net labour migration, and the projections of the model. Except for 1980 and 1983 when the real net labour migration is relatively small and the relative projection error is large, the RMSE of the projected net labour migration is 37.89%. The total net labour migration in the period 1979-87 projected by the model is 46.64 million, which is close to the estimated 40.74 million real net migrations. The relative errors of the projected employment are small. The maximum relative error of the projected rural employment is -3.19% in 1983. Overall, the RMSE of the projected rural employment is 1.83%. The maximum relative error of the projected urban employment is 8.07% in 1983. Overall, the RMSE of the projected urban employment is 4.24%. It should be remembered that only the average parameters for the period 1979 - 87, rather than the annual parameters, have been used in this calibration.

Table 4
Comparison of estimated net urban-rural labour migration, urban and rural real employment, and model projections (in millions).

Year	Labour migration		Real employment		Projected employment	
	real	projection	rural	urban	rural	urban
1979	2.44	2.27	301.44	108.80	301.61	108.78
1980	1.30	3.87	309.26	114.35	306.86	116.99
1981	2.51	3.68	315.82	121.43	312.18	125.45
1982	3.65	6.40	324.67	128.28	318.13	135.00
1983	1.25	5.14	331.96	132.40	321.36	143.09
1984	12.24 [a]	6.98	333.13	148.84	327.36	154.46
1985	6.20	6.00	338.48	160.25	332.71	165.88
1986	5.08	5.91	343.36	169.46	336.60	175.90
1987	6.07	6.39	347.93	179.90	340.64	186.58
Total	40.74	46.64				

Notes: Simulations S1 is based on the assumption that the growth rates of productivity in both the agricultural and the nonagricultural sectors will decline gradually by 50% in the period 1988-2087. In simulation S2, the growth rates of productivity in both agricultural and the nonagricultural sectors will decline gradually to zero by 2087. In simulations S3 it is assumed that the annual growth rate of agricultural productivity in the projection period will be 50% of that achieved in the period 1979-88, and that of the nonagricultural productivity will be the same as that achieved in the same period. The growth rates of productivity will remain unchanged in both the sectors in the whole projection period.

It seems that the performance of the model is relatively satisfactory in projecting the general trends of rural to urban net labour migration and employment growth. It will therefore be most useful in projecting long-term trends in rural-urban migration and transition, thus effectively linking long-term economic performance with the urbanization process and urban-rural population growth. It may well be that short-term fluctuations will occur, possibly because of specific government policy stances, which the model cannot account for. It must be emphasized that the model focuses on long-term trends and does not deal with short-term fluctuations.

The average annual growth rates of productivity and income elasticity of consumption in the period 1979-88 will be used in three population projections (A, B, and C) for the whole projection period (see section 4). It will be useful to make alternative simulations of urbanization in China, assuming different trends of the growth rates of productivity in agricultural and nonagricultural sectors. The results will be compared with those of projection B (see section 4).

As China is a developing country, the annual growth rate of productivity is relatively high. It is possible that the growth rates of productivity may decline in the long term. Simulation S_1, assumes that the growth rates of productivity will decline gradually by 50% in the period 1988-2087. Simulation S_2 assumes that the growth rates of productivity will decline gradually to 0 by 2087. Table 5 shows the major results of simulations S_1, S_2, and projection B in selected years.

Table 5
Comparison of the total population and the proportion of urban population in projection B and simulations S_1, S_2, S_3.

	Year				
	2000	2020	2040	2060	2087
Total Population (in millions)					
projection B	1296	1466	1516	1469	1415
simulation S_1	1297	1467	1519	1473	1419
simulation S_2	1297	1469	1521	1477	1423
simulation S_3	1303	1497	1570	1542	1494
Proportion of urban population (%)					
projection B	40.5	58.1	71.3	80.9	89.3
simulation S_1	40.2	56.0	67.2	74.9	81.6
simulation S_2	39.8	53.9	62.5	67.3	69.3
simulation S_3	31.1	34.8	36.8	39.1	41.1

It is clear that the proportion of urban population will be lower if lower growth rates of productivity are assumed in the agricultural and nonagricultural sectors. According to projection B, the proportion of urban population in China will be 40.5% in 2000, 71.3% in 2040, and 89.3% in 2087. If the growth rates in productivity are reduced gradually by 50% in the period 1988-2087, as is done in simulation S_1, the proportion of urban population in China will be 40.2% in 2000, 67.2% in 2040, and only 81.6% by 2087. If the growth rates in productivity are reduced gradually to 0 in 2087, as is done in simulation S_2, the proportion of urban population in China will be 39.8% in 2000, 62.5% in 2040, and only 69.3% by 2087. It is assumed that the urban population will have a lower total fertility rate than the rural population before 2030, and that both the urban and rural populations will have the same total fertility rate after 2030. Hence, a lower proportion of urban population means greater total population. But the differences in total population between projection B and simulations S_1 and S_2 are small. The total population of China in 2087 will be 1415 million, 1419 million, and 1423 million according to projection B, simulation S_1, and simulation S_2, respectively.

There is no doubt that urban-rural differences in the growth rate of productivity have significant effects on the urbanization process. The average annual growth rate of productivity of the agricultural sector was slightly greater than that of the nonagricultural sector in China in the period 1979-88. This high growth rate of productivity in the agricultural sector resulted mainly from the release of the surplus agricultural work force to nonagricultural sectors and the change in the agricultural production system, namely, the introduction of the production responsibility system. Productivity increases in the agricultural sector in this period resulted mainly from organizational and managerial changes. Further increases in agricultural productivity will depend mainly on the technical progress of agricultural production, which will need great capital investment. In simulation S_3, it is assumed that the annual growth rate of agricultural productivity in the projection period will be 50% of that achieved in the period 1979-88. The growth rates of productivity in both sectors will remain unchanged in the whole projection period. The major result of simulation S_3 is also shown in table 5. The proportion of urban population in simulation S_3 will be much lower than in the other simulations. According to simulation S_3, the proportion of urban population in China will increase slowly to

31.1% in 2000, 36.8% in 2040, and reach only 41.1% by 2087. The total population in simulation S_3 will be much greater than in any of the other simulations and will be 1303 million in 2000, 1570 million in 2040, and 1494 million by 2087. It is clear that great efforts are needed to increase agricultural productivity to speed up urbanization in China.

3 The urban-rural population projection model

Multiregional population models have been developed since the mid-1960s originally by Rogers and his collaborators (Rogers, 1966; 1973; 1975). Multiregional population accounts and accounts-based multiregional population models have also been developed (Rees and Wilson, 1975; 1977; Rees, 1989).

An accounts-based urban - rural population projection model for China was established in earlier research (Shen, 1991). In this section, this model will be linked with the demoeconomic model. One major feature of the urban-rural population projection model used in this research is that the components of rural to urban population migration and transition are driven by a demoeconomic model.

Labour population variables will be used in this section to replace the labour force variables used in the demoeconomic model, though the same notations are used. The labour population includes all the population of working age. Some people of working age such as students may not be in the labour force. Some people above the working age such as some senior officials and professionals may remain in the labour force. This replacement is based on the assumption that the ratio of labour force to labour population is constant and that it will not affect population projection as long as this assumption is valid. In fact, the rate of participation of the population has been stable in China, as almost every person who is able to work is in the labour force.

The variables are defined as follows:

u_{ag}^{k} is the mortality rate of period-cohort *a* in gender *g* in region *k*: *k* = u (urban), r (rural); *g* = m (male), f (female).

f_{a}^{nk} is the normal fertility rate of the female population of period-cohort *a* in region *k*.

$m_{ag}^{k}(t)$ is the out-migration rate of period-cohort *a* and gender *g* in the period *t*-1 to *t*.

$s_{ag}^{kh}(t)$ is the survival rate of the population of period-cohort *a* and gender *g* in the region *k* at time *t*-1 who survive in region *h* at time *t*: *k* = u, r; *h* = u, r; $k \neq h$.

R_{g}^{k} is the ratio of gender *g* in births in region *k*.

$f^{tk}(t)$ is the total fertility rate in region *k* in the period *t*-1 to *t*.

$P_{g}^{b(k)*}(t)$ are the births of gender *g* in region *k* in the period *t*-1 to *t*[1].

$P_{0g}^{b(*)k}(t)$ is the population of infants-cohort of gender *g* in region *k* at the end of the period *t*-1 to *t*.

$P_{ag}^{k*}(t-1)$ is the population of period-cohort *a* and gender *g* in region *k* at the

[1] The asterix (*) denotes a summation over the regions *h* and *k*. For example,

$$P_{g}^{b(k)*}(t) = P_{g}^{b(k)k}(t) + P_{g}^{b(k)h}(t)$$

beginning of the period t-1 to t.

$P^{*k}_{ag}(t)$ is the population of period-cohort a and gender g in region k at the end of period t-1 to t.

$P^{'*k}_{ag}(t)$ is the population of period-cohort a and gender g in region k at the end of period t-1 to t.

$P^{*d(k)}_{g}(t)$ are the deaths of gender g in region k in the period t-1 to t.

$M^{p1k}(t)$ is the pure labour out-migration from region k in the period t-1 to t estimated with fixed out-migration rates.

$M^{ppk}_{g}(t)$ is the pure population out-migration of gender g from region k in the period t-1 to t.

$M^{gpk}(t)$ is the gross population out-migration and transition from region k in the period t-1 to t.

$R^{gp}(t)$ is the ratio of gross rural out-migration and transition to the pure rural out-migration estimated with fixed rural out-migration rates.

$R^{rp}(t)$ is the rural population transition ratio.

$R^{rug}(t)$ is the ratio of rural-urban transition to the gross rural out-migration and transition.

As mentioned before, fixed urban out-migration rates will be used in the model. Total net rural to urban labour population migration and transition will be projected by the demoeconomic model. Then the gross rural labour out-migration and transition will be calculated by adding together the urban labour out-migration and the net rural to urban labour migration and transition. It is proposed that, if the gross rural labour out-migration and transition is less than the rural labour out-migration projected by using fixed rural out-migration rates, then the rural out-migration rates will be scaled down. Otherwise, fixed rural out-migration rates will be used to project the pure rural out-migration. The rural-urban labour transition will be projected as the difference between the gross rural labour out-migration and transition, and the pure rural labour out-migration. At the end of each projection year, some rural population will transit to urban population in proportion to the projected rural-urban labour transition. According to the projection results described in the next part of this research, the ratio of rural-urban transition to the gross rural out-migration and transition will increase gradually from about 60% in the year 1988 to about 80% in 2087. Some assumptions could be made to propose alternative trends for this ratio but they are not introduced into the model at this stage. The equations in the urban-rural population projection model will be discussed next according to the sequence of calculations.

The rates of natural increase of the urban and rural labour populations, $n^{1k}(t)$, are calculated assuming that there was no rural to urban migration:

$$n^{1k}(t) = \frac{1}{P^{1k}(t-1)}\left[\sum_{a=18}^{59} P^{k*}_{af}(t-1)(1-u^{k}_{af}) + \sum_{a=18}^{64} P^{k*}_{am}(t-1)(1-u^{k}_{am})\right] - 1, \qquad (1)$$

$$k = u, r,$$

where

$$P^{1k}(t-1) = \sum_{a=18}^{59} P_{af}^{'*k}(t-1) + \sum_{a=18}^{64} P_{am}^{'*k}(t-1)$$
$$= \sum_{a=19}^{60} P_{af}^{k*}(t-1) + \sum_{a=19}^{65} P_{am}^{k*}(t-1), \qquad k = u, r. \tag{2}$$

The labour population, $P^{1k}(t)$, consists of females in period-cohorts 18-59 or aged 18-59 years, and males in period-cohorts 18-64 or aged 18-64 years at the end of one-year periods (Song et al, 1981). The rate of natural increase of the population, $n^p(t)$, can be estimated by disregarding migration for the moment, as follows:

$$n^p(t) = \frac{1}{P(t-1)}\Big[\sum_k f^{tk}(t)\sum_{a=15}^{50} P_{af}^{k*}(t-1) f_a^{nk} \sum_g R_g^k (1-u_{0g}^k)$$
$$+ \sum_{k,g}\sum_{a=1}^{A} P_{ag}^{k*}(t-1)(1-u_{ag}^k)\Big] - 1, \tag{3}$$
$$P(t-1) = \sum_{k,g,a} P_{ag}^{'*k}(t-1) = \sum_{k,g,a} P_{ag}^{k*}(t-1). \tag{4}$$

Here $P(t)$ is the total population and A is the maximum age (A = 101 years). The rates of natural increase obtained from equations (1) and (3) are used in equation (A14) of the demoeconomic model (see appendix) to project the total net rural to urban labour migration and transition $M^{nl}(t)$. The pure labour out-migration from region k can be calculated with fixed out-migration rates as follows. Only survival migrants are counted because the demoeconomic model is concerned only with the balance of the work force at the end of the period t-1 to t:

$$M^{p1k}(t) = \sum_{a=18}^{59} P_{af}^{k*}(t-1) m_{af}^k(t_0) + \sum_{a=18}^{64} P_{am}^{k*}(t-1) m_{am}^k(t_0), \qquad k = u, r. \tag{5}$$

The ratio of the gross rural labour out-migration and transition tot he pure rural labour out-migration can be calculated with fixed rural out-migration rates as follows:

$$R^{gp}(t) = \frac{M^{n1}(t) + M^{p1r}(t)}{M^{p1r} j(t)}. \tag{6}$$

The rural out-migration rates are adjusted as follows:

$$m_{ag}^r(t) = \begin{cases} m_{ag}^r(t_0) & \text{if } R^{gp}(t) \geq 1 \\ R^{gp}(t) m_{ag}^r(t_0) & \text{if } R^{gp}(t) < 1, \end{cases} \qquad a = 0, 1, \dots, A. \tag{7}$$

New rural survival rates are calculated with the following equations:

$$S_{ag}^{ru}(t) = m_{ag}^r(t), \qquad a = 0, 1, \dots, A, \tag{8}$$
$$s_{ag}^{rr}(t) = \left[1 - \frac{m_{ag}^r(t)}{1 - 0.5u_{ag}^u - 0.5u_{ag}^r}\right](1 - u_{ag}^r), \qquad a = 0, 1, \dots, A. \tag{9}$$

The births in period t-1 to t can be calculated with the following equation. The initial populations corresponding to survival migrants and survival nonmigrants are calculated first, as forward fertility rates are used in the equation:

$$P_g^{b[k]*}(t) = R_g^k f^{tk}(t)\sum_{a=15}^{50} f_a^{nk}\left\{P_{af}^{k*}(t-1)\frac{s_{af}^{kk}(t)}{1-u_{af}^k}\right.$$
$$\left.+\frac{0.5\left[P_{af}^{k*}(t-1)s_{af}^{kh}(t)+P_{af}^{h*}(t-1)s_{af}^{hk}(t)\right]}{1-0.5u_{af}^k-0.5u_{af}^h}\right\} \qquad (10)$$
$$k=u,r, \qquad h=u,r, \qquad k\neq h,$$

The final population of the infant-cohorts of gender g in region k in period t-1 to t can be calculated as follows:

$$P_{0g}^{b(*)k}(t) = P_g^{b(k)*}(t)s_{0g}^{kk}(t)+P_g^{b(h)*}(t)s_{0g}^{hk}(t), \qquad k=u,r, \qquad h=u,r, \qquad k\neq h. (11)$$

The final population of the period-cohort a of gender g in region k in period t-1 to t is produced from:

$$P_{ag}^{*k}(t) = P_{ag}^{k*}(t-1)s_{ag}^{kk}(t)+P_{ag}^{h*}(t-1)s_{ag}^{hk}(t),$$
$$a=1,2,\ldots,A, \qquad k=u,r, \qquad h=u,r, \qquad k\neq h. \qquad (12)$$

The total out-migration of gender g from region k in period t-1 to t can be calculated as follows. Nonsurvival migrants are also counted:

$$M_g^{ppk}(t) = \frac{P_{0g}^{b(k)*}(t)s_{0g}^{kh}(t)}{1-0.5u_{ag}^h}+\sum_{a=1}^{A}\frac{P_{ag}^{k*}(t-1)s_{ag}^{kh}(t)}{1-0.5u_{ag}^h}, \qquad g=m,f. \qquad (13)$$

The total number of deaths of gender g in the region k in period t-1 to t can be estimated by:

$$P_s^{*d(k)}(t) = \left\{P_g^{b(k)*}(t)\frac{s_{0g}^{kk}(t)}{1-u_{0g}^k}+0.5\frac{\left[\sum_{h,k=u,r,h\neq k}P_g^{b(h)*}(t)s_{0g}^{hk}(t)\right]}{1-0.5r_{0g}^u-0.5u_{0g}^r}\right\}u_{0g}^k$$
$$+\sum_{a=1}^{A}\left\{P_{ag}^{k*}(t-1)\frac{s_{ag}^{kk}(t)}{1-u_{ag}^k}+0.5\frac{\left[\sum_{h,k=u,r,h\neq k}P_{ag}^{h*}(t-1)s_{ag}^{hk}(t)\right]}{1-0.5u_{ag}^r-0.5u_{ag}^r}\right\}u_{ag}^k, \quad k=u,r. \qquad (14)$$

The rural labour population transition ratio $R^{rp}(t)$ is calculated as follows when $R^{gp}(t)$>1 [otherwise $R^{rp}(t)$ equals zero]:

$$R^{rp}(t) = \frac{M^{n1}(t)+M^{p1u}(t)-M^{p1r}(t)}{\sum_{a=18}^{59}P_{af}^{*r}(t)+\sum_{a=18}^{64}P_{am}^{*r}(t)}. \qquad (15)$$

The gross population out-migration and transition from region k in period t-1 to t is derived from:

$$M^{gpu}(t) = \sum_g M_g^{ppu}(t), \qquad (16)$$

$$M^{gpr}(t) = \sum_g M_g^{pppr}(t)+R^{rp}(t)\sum_{a=0}^{A}P_{ag}^{*r}(t). \qquad (17)$$

The ratio of rural-urban transition to the gross rural out-migration and transition, $R^T(t)$, is given by:

$$R^{rug}(t) = 1 - \sum_g \frac{M_g^{ppr}(t)}{M^{gpr}(t)}. \qquad (18)$$

The projection results from equations (11) and (12) are modified by the population transition, with the rural labour population transition ratio being applied to the whole rural population:

$$P_{0g}^{'*u}(t) = P_{0g}^{b(*)u}(t) + P_{0g}^{b(*)r}(t) R^{rp}(t), \qquad g = m, f; \qquad (19)$$

$$P_{ag}^{'*u}(t) = P_{ag}^{*u}(t) + P_{ag}^{*r}(t) R^{rp}(t), \qquad a = 1,2,\ldots,A, \qquad g = m, f, \qquad (20)$$

$$P_{0g}^{'*r}(t) = P_{0g}^{b(*)r}(t) - P_{0g}^{b(*)r}(t) R^{rp}(t), \qquad g = m, f, \qquad (21)$$

$$P_{ag}^{'*r}(t) = P_{ag}^{*r}(t) - P_{ag}^{*r}(t) R^{rp}(t), \qquad a = 1,2,\ldots,A; \qquad g = m, f. \qquad (22)$$

It is assumed that the population transition takes place at the end of period *t*-1 to *t*. $P_{ag}^{'*k}(t)$ is the projected population of the period-cohort *a* of gender *g* at the end of period *t*-1 to *t*. Various population indexes can be calculated from these basic projections. The starting populations for the next period *t* to *t*+1 are as follows:

$$P_{ag}^{k*}(t) = P_{(a-1)g}^{'*k}(t); \qquad a = 1,2,\ldots,A-1; \qquad k = u,r; \qquad (23)$$

$$P_{Ag}^{k*}(t) = P_{(A-1)g}^{'*k}(t) + P_{Ag}^{'*k}(t), \qquad k = u,r. \qquad (24)$$

Equations (1) - (24) constitute the urban-rural population projection model In this model, the rural to urban population migration and transition is driven by the demoeconomic model described in the appendix.

4. Urban-rural population projections

Basic demographic rates estimated in earlier research (Shen, 1991) will be used in this paper. However, three points need to be emphasized. First, as mentioned before, a series of urban population data for the period 1983-87 has been estimated recently by the authors based on official sources (DPS, 1988b; SSB, 1989). It is deemed preferable to use the estimated total urban population in 1987 as the basis for urban-rural population projections in this research. Total fertility rates of the estimated urban and rural populations can be calculated and were found to be 1.741 and 2.638, respectively.

Second, the armed forces are not included in the 1% sampling data of 1987 (DPS, 1988a). The 3.14 million male and 0.10 million female members of the armed forces were allocated to each of the period-cohorts 19-27 so that these period-cohorts have the same male to female ratio.

Third, the total fertility rate in China has declined significantly in the past two decades. This decline is associated with the overall level of socioeconomic development and a series of government birth control campaigns. It seems that both of these have contributed to the dramatic decline of the fertility rate in the past two decades in China (Birdsail and Jamison, 1983). The rigorous birth control policy has been somewhat relaxed since 1984, in that most rural couples are now allowed to have two children (Greenhalgh, 1986; Peng, 1991). Although generally the government is still strongly encouraging couples to have only one child. Most urban couples are still required to have only one child. The recent economic reforms and the introduction of the family production responsibility system in rural areas may decrease the effect of government birth control efforts. The overall implication is that socioeconomic development and modernization may play a much greater role in the future trend of the fertility rate in China. In fact, the total fertility rate of China has been further decreased from 2.6r8 in 1982 to 2.374 by 1987.

For the purpose of urban-rural population projections, three sets of total fertility rate trends in China are assumed. In set A it is assumed that the total fertility rates of urban and rural populations will remain unchanged from the base year 1987. The projection A based on this assumption shows the consequence of continuing population growth if fertility rates are not reduced in future.

Total fertility rates of urban and rural populations are, however, likely to decline in future because of population control policy and changes in social, economic, and psychological factors. According to previous population projection practices in China, it is recognized that a U-shape total fertility rate trend is probably both desirable and feasible (Jiang and Lan, 1987). A realistic long-term target for the population control policy may be a zero population growth rate (Hu and Zhang, 1984; Song et al, 1981).

In set B it is assumed that the total fertility rate of the urban population will decline gradually to 1.5 in year 2000, remain unchanged until 2010, gradually increase to the replacement level of 2.2 in 2030, and then remain unchanged until 2087. A total fertility rate of 1.5 is assumed to be the lowest value for the urban population, and with this rate about half of all urban couples will have only one child. The total fertility rate of the rural population is assumed to decline gradually to 2.2 in 2020, and then remain unchanged until 2087.

However, there may be concern that, once the total fertility rate of the urban population has declined to a low level, it may be difficult to reverse the trend and increase the total fertility rate unless the earlier decline is a forced one. In set C it is assumed that the total fertility rate of the urban population will decline to 1.5 in year 2000, and then remain unchanged until 2087. However, in projection C the total fertility rate trend of the rural population is assumed to be the same as in set B.

The main results of the urban-rural population projections are presented in tables 6-8. Projection A is based on the assumption that the urban and rural total fertility rates will remain unchanged, thought the total fertility rate of China will decline because of he increasing urban population component. This projection can be regarded as approximating the upper bound of the likely future population of China. Table 6 presents the result of projection A. It shows hat the total population of China will continue to grow until 2040 (figure 2). It will increase from 1101 million in 1988 to 1312 million in 2000 and to 1604 million in 2040.

Figure 2. The urban, rural, and total populations of China in projection A.

Figure 3. Percentage of urban population (projections A, B, and C).

Figure 4. Urban-rural migration (including transition)(projection A)

It will decline slowly after 2040 to 1370 million in 2087. The urban population will increase from 334 million in 1988 to 531 million in 2000 and reach 1199 million by 2050. The urban population will be almost stable around 1220 million after 2050. The rural population will increase slightly from 766 million in 1988 to 781 million in 2000. Then it will decline gradually and dramatically to 481 million in 2040 and 151 million in 2087. The percentage of urban population will increase steadily from 30% in 1988 to 40% in 2000, to 70% in 2040 and reach almost 89% by 2087 (figure 3). Urban out-migration will increase from 0.25 million in 1988 to 0.79 million in 2050, and will then be stable around 0.80 million (figure 4). Rural out-migration (including rural-urban transition) will increase from 12.18 million in 1988 to 15.43 million in 2010, decrease to 12.68 million in 2030, increase slightly to 13.27 million in 2035 and will then decrease gradually to 5.71 million in 2087. The trend of the net rural to urban migration is similar to that of the rural out-migration, as the urban out-migration is relatively small.

Table 6
Urban-rural population projection A (in millions).

Year	Population	Births	Deaths	Out-mig.	Labour pop.	Labour (%)	Elderly (%)	Mean age (years)	Urban (%)
Urban China									
1988	334.4	5.70	1.94	0.25	206.74	61.83	6.99	29.17	
1990	367.4	6.51	2.20	0.28	231.72	63.07	7.25	29.52	
1995	450.04	8.14	2.91	0.33	286.21	63.60	7.87	30.30	
2000	530.51	8.08	3.62	0.35	335.70	63.28	8.43	31.26	
2010	702.50	8.70	5.51	0.45	456.01	64.91	9.34	33.78	
2020	875.66	11.48	8.08	0.60	570.11	65.11	12.12	35.85	
2090	1015.66	11.22	11.32	0.65	624.99	61.54	16.10	37.69	
2040	1122.59	12.37	15.08	0.73	675.69	60.19	19.04	39.10	
2060	1233.56	12.68	19.03	0.80	732.54	59.38	20.23	40.06	
2087	1218.53	12.29	20.40	0.79	716.95	58.84	21.58	40.95	
Rural China									
1988	766.44	17.88	4.84	12.18	425.69	55.54	7.16	27.54	
1990	768.51	18.51	5.07	12.36	435.80	56.71	7.48	27.89	
1995	778.57	18.91	5.55	11.00	446.21	57.31	8.09	28.54	
2000	781.49	16.39	5.87	13.11	442.83	56.66	8.48	29.31	
2010	725.12	12.94	6.10	15.43	422.91	58.32	9.36	31.51	
2020	654.56	12.66	6.24	13.82	385.31	58.87	11.55	33.03	
2030	578.95	9.72	6.30	12.68	325.13	56.16	14.12	34.30	
2040	481.01	8.42	6.03	13.24	267.46	55.60	16.18	35.19	
2060	306.86	5.23	4.09	9.55	170.00	55.40	16.04	35.32	
2087	151.02	2.68	2.04	5.71	83.86	55.53	15.94	35.28	
China total				Net. mig.					
1988	1100.84	23.58	6.78	11.93	632.43	57.45	7.10	28.03	30.38
1990	1135.91	25.03	7.27	12.08	667.52	58.77	7.40	28.42	32.34
1995	1228.61	27.05	8.46	10.67	732.42	59.61	8.01	29.19	36.63
2000	1312.00	24.48	9.49	12.76	778.53	59.34	8.46	30.10	40.44
2010	1427.61	21.64	11.61	14.98	878.93	61.57	9.35	32.63	49.21
2020	1530.22	24.14	14.31	13.22	955.42	62.44	11.87	34.64	57.22
2030	1594.61	20.94	17.62	12.03	950.13	59.58	15.38	36.46	63.69
2040	1603.60	20.79	21.10	12.51	943.15	58.81	18.18	37.93	70.00
2060	1540.42	17.91	23.12	8.75	902.54	58.59	19.40	39.12	80.08
2087	1369.55	14.98	22.44	4.92	800.82	58.47	20.96	40.32	88.97

Note: In projection A it is assumed that the total fertility rates of the urban and rural populations will remain unchanged, as in 1987, in the whole projection period.
Out-mig., out-migration; Labour pop., labour population; Net mig., net rural-urban migration.

The labour population of China will increase from 632 million in 1988 to 779 million in 2000, to 963 million in 2025, then decrease slowly to 801 million in 2087. Its percentage will be relatively stable at around 59% in the projection period 1988-2087 (figure 5). The urban population has a slightly higher percentage of labour population than the rural population. The percentage of elderly population in China will increase slowly from around 7% in 1988 to over 9% in 2010, then increase rapidly to 18% in 2040, and increase slowly to over 20% in 2087 (figure 5). The percentages of elderly population in the urban and rural populations show similar increasing trends as those for the whole population before 2040. There will be almost no urban-rural difference in the percentage of elderly population before 2020. But the difference begins to widen after 2020. This percentage for the rural population will be less than that for the urban population, and will be stable at around 16% after 2040. In the case of the urban population, it will increase slowly from around 19% in 2050 to somewhat less than 22% in 2087, which is similar to that of the whole population of China.

Figure 5. Percentage of labour and elderly population (projection A).

Projection B is based on the assumption that the total fertility rates of the urban and rural populations will decline in future, but that the total fertility rate of the urban population will have a U-shaped trend, which means that the urban and rural populations will have the same total fertility rate of 2.2 after 2030. Table 7 presents the results of projection B. In this case, the total population of China will also continue to grow until 2035. It will increase to 1296 million in 2000 and to 1519 million in 2035. It will decline slowly after 2035 to 1415 million in 2087. The urban population will increase to 525 million in 2000, 1151 million in 2050, then increase slowly to 1263 million in 2087. The rural population will increase slowly to 774 million in 1995, then decrease gradually to 435 million in 2040, and will be only 152 million in 2087. The trend of the percentage of urban population in projection B is similar to, if slightly higher than, that in projection A (figure 3). Urban out-migration will increase gradually from 0.25 million in 1988 to 0.83 million in 2087. Rural out-migration will increase from 12.21 million in 1988 to 15.36 million in 2010, then decrease gradually to 10.21 million in 2040 and to 4.10 million in 2087. Net rural to urban migration shows a similar trend as that of the rural out-migrations.

Table 7.
Urban-rural population projection B (in millions).

Year	Population	Births	Deaths	Out-mig.	Labour pop.	Labour (%)	Elderly (%)	Mean age (years)	Urban (%)
Urban China									
1988	334.36	5.63	1.94	0.25	206.76	61.84	6.99	29.18	
1990	367.16	6.30	2.20	0.28	231.81	63.14	7.26	29.56	
1995	448.22	7.44	2.90	0.33	286.88	64.00	7.93	30.48	
2000	525.33	6.97	3.60	0.35	337.41	64.23	8.56	31.68	
2010	687.51	7.51	5.51	0.45	458.66	66.71	9.64	34.57	
2020	851.26	11.55	8.12	0.58	561.84	66.00	12.58	36.61	
2090	986.09	12.62	11.37	0.62	596.87	60.53	16.65	38.02	
2040	1080.95	13.94	14.95	0.69	625.42	57.86	19.62	38.95	
2060	1188.35	15.61	18.19	0.77	668.84	56.28	19.85	38.45	
2087	1262.76	17.17	18.16	0.83	727.94	57.65	18.05	37.70	
Rural China									
1988	766.33	17.79	4.84	12.21	425.67	55.55	7.16	27.54	
1990	767.82	18.24	5.06	12.44	435.70	56.75	7.48	27.91	
1995	774.28	18.14	5.52	11.23	445.54	57.54	8.12	28.65	
2000	771.15	15.29	5.81	13.38	441.13	57.20	8.56	29.55	
2010	700.90	11.34	5.99	15.36	417.90	59.62	9.59	32.10	
2020	614.36	10.08	6.04	13.08	374.05	60.88	12.14	34.22	
2030	528.62	7.39	6.12	10.81	309.64	58.58	15.34	36.15	
2040	434.97	6.12	5.98	10.21	250.36	57.56	18.26	37.64	
2060	280.84	3.77	4.40	6.38	158.86	56.56	19.56	38.56	
2087	151.95	2.14	2.44	4.10	85.93	56.55	19.34	38.37	
China total									
1988	1100.69	23.43	6.78	11.96	632.43	57.46	7.11	28.04	30.38
1990	1134.98	24.54	7.26	12.16	667.52	58.81	7.41	28.44	32.35
1995	1222.50	25.59	8.42	10.90	732.42	59.91	8.05	29.32	36.66
2000	1296.49	22.26	9.42	13.04	778.54	60.05	8.56	30.41	40.52
2010	1388.40	18.85	11.50	14.91	876.56	63.13	9.61	33.32	49.52
2020	1465.62	21.63	14.17	12.49	935.89	63.86	12.40	35.61	58.08
2030	1514.71	20.00	17.49	10.19	906.51	59.85	16.19	37.37	65.10
2040	1515.93	20.06	20.93	9.52	875.78	57.77	19.23	38.58	71.31
2060	1469.19	19.38	22.59	5.62	827.69	56.34	19.79	38.47	80.88
2087	1414.70	19.32	20.60	3.27	813.86	57.53	18.19	37.77	89.26

Note: In projection B it is assumed that the total fertility rate of the urban population will decline gradually to 1.5 in 2000, remain unchanged until 2010, increase gradually to 2.2 in 2030, and then remain unchanged until 2087. The total fertility rate of the rural population is assumed to decline gradually to 2.2 in 2020, then remain unchanged until 2087.
Out-mig., out-migration; Labour pop., labour population; Net mig., net rural-urban migration.

Under these projection assumptions, the labour population of China will increase from 632 million in 1988 to 779 million in 2000, to 936 million in 2020, then decline slowly to 814 million in 2087. Its percentage will be relatively stable at around 60% in the period 1988 - 2030, and then reduce to around 58% in the period 2030-87. The proportion of labour population in the urban population will be higher than that in the rural population before 2040. The difference will be about 6 percentage points in the period 1988-2015. But the difference will decrease rapidly in the period 2015-40. The urban and rural populations will have almost the same percentage of labour population after 2040. This is mainly because of the assumption that the total fertility rates of the urban and rural populations are the same after 2030.

The percentage of the elderly population in China will increase slowly from around 7% in 1988 to somewhat under 10% in 2010, increase rapidly to over 19% in 2040, then will be stable at around 19% in the period 2040-87. The urban-rural difference in the percentages of elderly population is small in the period 1988-2087. Thus percentage trends of the elderly population in the case of the urban and rural populations are again similar to that of the whole population of China.

Projection C is based on the assumption that total fertility rates of the urban and rural populations will decline in future, and that the total fertility rate of the urban population will remain at a level lower than the replacement level. Table 8 presents the result of projection C. In this case, the total population of China will continue to grow until 2025. It will increase to 1296 million in 2000 and to 1472 million in 2025. It will decrease rapidly after 2025 to 952 million in 2087. The urban population will increase to 525 million in 2000, 1032 million in 2050, then decrease slowly to 849 million in 2087. The rural population will increase slowly to 774 million in 1995, then decrease gradually to 419 million in 2040 and to 103 million in 2087. The percentage trend of the urban population in projection C is again similar to those in projections A and B (figure 3).

Table 8.
Urban-rural population projection C (in millions).

Year	Population	Births	Deaths	Out-mig.	Labour pop.	Labour (%)	Elderly (%)	Mean age (years)	Urban (%)
Urban China									
1988	334.36	5.63	1.94	0.25	206.76	61.84	6.99	29.18	
1990	367.16	6.30	2.20	0.28	231.81	63.14	7.26	29.56	
1995	448.22	7.44	2.9.00	0.33	286.88	64.00	7.63	30.48	
2000	525.33	6.97	3.60	0.35	337.41	64.23	8.56	31.68	
2005	602.77	6.93	4.45	0.38	393.00	65.20	8.98	33.13	
2010	687.51	7.51	5.51	0.45	458.66	66.71	9.64	34.57	
2020	841.91	9.38	8.08	0.58	563.00	66.87	12.75	37.06	
2090	949.84	8.64	11.31	0.61	600.22	63.19	17.39	39.44	
2040	1010.82	8.99	14.95	0.65	618.39	61.18	21.26	41.36	
2060	1006.51	8.12	18.29	0.64	595.21	59.14	24.10	43.06	
2087	848.63	6.66	17.17	0.54	493.56	58.16	25.84	44.10	
Rural China									
1988	766.33	17.79	4.84	12.21	425.67	55.55	7.16	27.54	
1990	767.82	18.24	5.06	12.44	435.70	56.75	7.48	27.91	
1995	774.28	18.14	5.52	11.23	445.54	57.54	8.12	28.65	
2000	771.15	15.29	5.81	13.38	441.13	57.20	8.56	29.55	
2010	700.90	11.34	5.99	15.36	417.90	59.62	9.59	32.10	
2020	612.44	10.05	6.03	13.41	372.89	60.89	12.14	34.23	
2030	521.87	7.31	6.05	11.42	305.76	58.59	15.34	36.15	
2040	419.38	5.91	5.79	11.22	241.47	57.58	18.27	37.66	
2060	243.96	3.26	3.87	7.20	138.08	56.60	19.73	38.73	
2087	102.98	1.42	1.74	3.77	58.03	56.34	20.14	38.96	
China total									
1988	1100.69	23.43	6.78	11.96	632.43	57.46	7.11	28.04	30.38
1990	1134.98	24.54	7.26	12.16	667.52	58.81	7.41	28.44	32.35
1995	1222.5	25.59	8.42	10.90	732.42	59.91	8.05	29.32	36.66
2000	1296.49	22.26	9.42	13.04	778.54	60.05	8.56	30.41	40.52
2010	1388.40	18.85	11.50	14.91	876.56	63.13	9.61	33.32	49.52
2020	1454.35	19.43	14.11	12.83	935.89	64.35	12.49	35.87	57.89
2030	1471.71	15.95	17.36	10.82	905.98	61.56	16.66	38.28	64.54
2040	1430.20	14.90	20.73	10.57	859.86	60.12	20.38	40.27	70.68
2060	1250.47	11.38	22.16	6.56	733.29	58.64	23.25	42.21	80.49
2087	951.61	8.08	18.90	3.23	551.59	57.96	25.22	43.55	89.18

Note: In projection C it is assumed that the total fertility rate of the urban population will decline to 1.5 in 2000, then remain unchanged until 2087. The total fertility rate trend of the rural population is assumed to be the same as in projection B and to decline gradually to 2.2 in 2020, then remain unchanged until 2087.
Out mig., out migration; Labour pop., labour population; Net mig., net rural-urban migration.

Urban out-migration will increase gradually from 0.25 million in 1988 to 0.68 million in 2050, then decrease slowly to 0.54 million in 2087. Rural out-migration will increase from 12.21 million in 1988 to 15.36 million in 2010, then decrease gradually to 11.22 million in 2040 and to 3.77 million in 2087. Again net rural to urban migration shows a similar trend as that of the rural out-migration.

The labour population of China will increase to 936 million in 2020, as was the case in projection B, then decline rapidly to 552 million by 2087. The percentage of labour population of China will be once again relatively stable at around 59% in the projection period 1988-2087. The urban population has a higher percentage of labour population than the rural population. This difference will decrease gradually from 6.29 percentage points in 1988 to 1.82 percentage points in 2087.

Under these projection assumptions, the percentage of elderly population in China will increase slowly from around 7% in 1988 to somewhat under 10% in 2010, increase rapidly to over 20% in 2040, then increase slowly to over 25% by 2087. The urban and rural populations have similar trends of the percentage of elderly population as that of the whole population. The percentage of elderly persons in the rural population will be relatively stable around 18% of the period 2040-2055 and around 20% after 2055. But the urban population will have an increasingly higher proportion of elderly population than the rural population after 2020. In 2087, this percentage will be almost 26% in the urban population and around 20% in the rural population.

The results of projections A, B, and C can be compared in terms of the whole population of China. Projection A generally projects a greater total population of China than the others (figure 6). In projection B it is assumed that urban and rural total fertility rates will remain at the replacement level after 2030. According to projections A and B, the total population of China will continue to grow until .he late 2030s; then it will decrease slowly. In projection C, a lower urban total fertility rate than that in projection B is assumed. According to projection C, the total population of China will continue to grow until 2025; then it will decline rapidly to 952 million in 2087, which was approximately the actual total population of China at the end of 1977 (SSB, 1991).

Figure 6. The total population in projection A, B, and C.

For the purpose of comparison, table 9 shows the relative projection errors of the total population of China for three years: 1988,1989, and 1990. The real population data are based on the 1990 population census (SSB, 1991). The errors are small: all are much less than 1%, the largest being 0.145% in 1990 for projection A.

Table 9

Relative projection errors of the total population of China, 1988-90 (source: real population data from SSB, 1991).

Year	Real population	Projection A		Projection B and C	
	(million)	Population (million)	error (%)	population (million)	error (%)
1988	1110.26	1109.50	-0.068	1109.19	-0.096
1989	1127.04	1127.03	-0.001	1126.34	-0.062
1990	1143.33	1144.99	0.145	1143.73	0.035

Note: All data are for the end of the year.

In table 10 the results of population projections A, B, and C are compared with medium variant projections of the United Nations (UN, 1991). It seems that the total population projection results of projection B are closest to the UN figures. As mentioned earlier, the proportions of urban population in projections A, B, and C are similar. An urban - rural growth differences method is used to project the proportions of urban population in the UN projections by assuming different growth rates of urban and rural populations for each country (UN, 1989). Despite the different projection methods, the projections of the proportion of urban population in projection B in this research, though a little smaller, are close to and confirm the medium variant projections of the UN.

Table 10
Comparison of projection results (A, B, and C) with the United Nations medium variant projections (source: UN, 1991)

Year	Total population (million)				Urban	
	UN	projection A	projection B	projection C	UN	projection B
1990	1139.06	1144.99	1143.73	1143.73	33.4	32.84
1995	1222.56	1237.7	1230.8	1230.8	40.8	37.02
2000	1299.18	1319.06	1302.47	1302.47	47.3	40.92
2010	1395.33	1432.65	1392.12	1392.03	56.1	50
2020	1476.85	1534.92	1469.2	1456.75	62.8	58.49
2025	1512.59	1574.22	1499.22	1472.59	65.8	62.11

Notes: UN, United Nations; all data are for the end of the year.

3 Conclusion

Urbanization in China evolved rather slowly over the prereform period, 1949-77. This process has speeded up considerably since 1978 owing to the increasingly favorable attitude of the government toward urban development. However there has been growing confusion about urban population data in China because of changes of official definitions between censuses. Generally, urban population data based on the 1982 census definition include many of the agricultural population whereas the urban population data based on the 1990 census definition may exclude some population who were engaged in nonagricultural employment but who still registered as agricultural population. For the purposes of urban-rural population projections in this research, the urban population is based on the actual nonagricultural employment. The range of urban population based on this definition lies between the 1982 and 1990 census definitions. Some additional confusion about China's urban population data also arises from the increasing number of newly designated cities and towns. However, the effects of this type of administrative factor can be reduced to a minimum by defining the urban population on the basis of actual nonagricultural employment rather than on the basis of the administrative areas of cities and towns.

A simplified demoeconomic model of urban-rural sectors is used to model the urbanization mechanism. The four main economic parameters are the annual growth rates of productivity and the income elasticity of consumption of the products in the two sectors. If the annual data of these parameters are used, the model will be capable of revealing the annual fluctuation of rural to urban migration caused by short-term factors. However, it will be difficult to predict these annual parameters for long-term population projections. Only the average parameter of a period may be used and is sufficient for such projections. Thus the demoeconomic model is tested against agricultural and nonagricultural employment data for the period 1979-88, and urban and rural employment data for the period 1979-87. It was found that the general trend of rural to urban migration and transition is captured by the demoeconomic model when the average rates of increase of productivity and income elasticity of consumption in the period are used. The total projected rural to urban net labour migration and transition in the period 1979-87 is similar to the total real net rural to urban labour migration and transition.

However, rural to urban migration is influenced by the effects of short-term political and economic events and policies. This is particularly so in China, where the central government has powerful control over and effect on the society and economy. These factors will of course affect the future process of urbanization and development in the country. At present, China's economy is undergoing a transition toward a market economy, and many powers have been decentralized. The overall implication is that the market mechanism will play a greater role in China's economy and society. The models developed in this research effectively link the urban-rural population change with the long-term economic performance. The urban-rural population projections in this research show the possible future long-term trend.

Some major features of the anticipated urban-rural population growth in the period 1988-2087 are revealed in this research. Three projections have been made assuming different fertility trends. Projections A and B are quite similar in terms of total populations. China's overall fertility will continue to decline, but only slowly, as it moves toward the replacement level. These projections seem most likely to approximate more closely the future population of China. Projection C, which is based on more severe declines in fertility, can be regarded as providing an estimate of the lower bounds of the future population of the country.

According to projection A, which is based on unchanged urban and rural fertility rates, the total population of China will increase to 1604 million in 2040, then decline to 1370 million by 2087. Two major phases of future population growth in China can be identified with a division in the late 2030s. In the first phrase, before the late 2030s, the total population will continue to grow in most years. During this period, China will face three main challenges. The first is the rapid increase of its urban population, which will triple in about 50 years and reach about 1000 million in 2040. The second is the rapid expansion of its total labour force, which will increase rapidly before 2020. China already faces problems of labour force surplus and capital shortage. It seems that these problems will become more severe in the next three decades. The third challenge is the rapid ageing of its population during the period 2010-40. The proportion of elderly population will increase rapidly from 7% in 1988 to over 18% in 2040. It is clear that great efforts are needed to coordinate urbanization and socioeconomic developments to face these challenges.

In the second phase, after the late 2030s, the total population of China may begin to decline. The net rural to urban migration and transition will be relatively small and will continue to decrease. The labour population will begin to decline. The proportion of elderly population will be relatively stable or increase only slowly.

The accounts-based urban-rural population model has thus been linked with the demoeconomic model of urban and rural sectors to forecast urban - rural population in China. The model may be applicable in other countries so long as the model parameters are correctly specified.

References

Artle R, Humes C, Varaiya P, 1977, "Division of labour--Simon revisited" *Regional Science and Urban Economics* **7** 185-196

Baumol W J, 1967, "Macroeconomics of unbalanced growth: the anatomy of urban crisis" *American Economic Review* **57** 415 - 426

Becker C M, Mills E S, Williamson J G, 1986, "Modelling Indian migration and city growth 1960-2000" *Economic Development and Cultural Change* **35** 1-33

Birdsail N, Jamison D T, 1983, "Income and other factors influencing fertility in China" *Population and Development Review* **9** 651-675

Chan K W, 1988, "Rural-urban migration in China, 1950-1982: estimates and analysis "*Urban Geography* **9** 53-84

Chan K W, Xu X Q, 1985, "Urban population growth and urbanization in China since 1949: reconstructing a baseline" *China Quarterly* **104** 583-613
DPS, 1988a *Tabulations of China 1% Population Sample Survey. National Volume* Department of Population Statistics, State Statistical Bureau (China Statistics Press, Beijing)
DPS, 1988b *China Population Statistics Yearbook 1988* Department of Population Statistics, State Statistical Bureau (China Prospect Press, Beijing)
Goldstein S, 1990, "Urbanization in China, 1982-87: effect of migration and reclassification" *Population and Development Review* **16** 673-701
Greenhalgh S, 1986, "Shifts in China's population policy: 1984-86 views from the central, provincial, and local levels" *Population and Development Review* **12** 491-516
Hu H, Zhang S, 1984 *Population Geography of China* (East China Normal University Press, Shanghai)
Isserman A M, 1985, "Economic-demographic modeling with endogenously determined birth and migration rates: theory and prospects" *Environment and Planning A* **17** 25-45
Isserman A M (Ed.), 1986 *Population Change and the Economy* (Kluwer-Nijhoff, Boston, MA)
Isserman A M, Plane D A, Rogerson P A, Beaumont P M, 1985, "Forecasting interstate migration with limited data: a demographic-economic approach" *Journal of the American Statistical Association* **80** 277-285
Jiang Z, Lan S, 1987, "Population development projection of China", in *The Analysis of the Third Population Census Data of China* Population Census Office, State Council of PR China (China Financial and Economic Press, Beijing) pp 323-332
Kirkby R J R, 1985 *Urbanisation in China: Town and Country in a Developing Economy 1949-2000AD* (Croom Helm, London)
Ledent J, 1978, "Regional multiplier analysis: a demometric approach" E*nvironment and Planning A* **10** 537-560
Ledent J, 1982, "Long-range regional population forecasting: specification of a minimal demoeconomic model with a test for Tucson, Arizona" *Papers of the Regional Science Association* **49** 37-67
Lee K S, 1984, "The direction of migration: a dynamic general equilibrium model" *Journal of Regional Science* **4** 509-517
Ma L J C, Cui G, 1987, "Administrative changes and urban population in China" *Annals of the Association of American Geographers* **77** 373 - 395
Pannell C W, 1990, "China's urban geography" *Progress in Human Geography* **14** 373-395
Park H Y, Fullerton H, 1980, "Rural-urban labor migration: the case of Korea" *The Annals of Regional Science* **14** 72 - 89
Peng X, 1991 *Demographic Transition in China: Fertility Trends since the 1950s* (Clarendon Press, Oxford)
Ran M, Berry B J L, 1989, "Underurbanization policies assessed: China, 1949-1986" *Urban Geography* **10** 111 - 120
Rees P H, 1989, "Old model faces new challenges: a review of the state of the art in multistate population modelling", WP-531, School of Geography, University of Leeds, Leeds
Rees P H, Wilson A, 1975, "A comparison of available models of population change" *Regional Studies* **9** 39-61
Rees P H, Wilson A, 1977 *Spatial Population Analysis* (Edward Arnold, London)
Rogers A, 1966, "The multi-regional matrix operator and the stable inter-regional age structure" *Demography* **3** 537-544
Rogers A, 1973, "The mathematics of multiregional demographic growth" *Environment and Planning* A 5 3 - 29
Rogers A, 1975 *Introduction to Multiregional Mathematical Demography (Wiley-lnterscience,* New York)
Shen J, 1991, "Analysis of urban-rural population dynamics for China" *Environment and Planning A* **23** 1797- 1810
Shen J, 1993, "Analysis of urban-rural population dynamics for China: a multiregional life table approach" *Environment and Planning A* **25** 245-253
Simon H A, 1947, "Effects of increased productivity upon the ratio of urban to rural population" *Econometrica* **15** 31-42
Simon H A, 1982, the rural-urban population balance again" *Regional Science and Urban Economics* **12** 599-606
Song J, Tian X, Yu J, Li G, 1981 *Population Projection and Control* (People's Press, Beijing)

SSB, 1989 *China Statistics Yearbook 1989* State Statistical Bureau (China Statistics Press, Beijing)
SSB, 1991 *China Statistics Yearbook 1991* State Statistical Bureau (China Statistics Press, Beijing)
UN, 1989 *Prospects of World Urbanization 1988* Department of International Economic and Social Affairs (United Nations, New York)
UN, 1991 *World Population Prospects 1990* Department of International Economic and Social Affairs (United Nations, New York)
Varaiya P, Artle R, Humes C, 1979, "Division of labor and the distribution of income" *Regional Science and Urban Economics* **9** 71-82
Veeck G (Ed.), 1991 *The Uneven Landscape: Geographic Studies in Post-reform China, Geoscience and Man* series, number 30, Department of Geography and Anthropology Louisiana State University, Baton Rouge, LA
Vislie J, 1979, "Division of Labour-Simon revisited a comment" *Regional Science and Urban Economics* **9** 61-70
Wang W, 1988 *Population Systems Engineering* Shanghai Transportation University Press, Shanghai
Zeng Y, Vaupal J W, 1989, "The impact of urbanization and delayed child bearing population-growth and ageing in China" *Population and Development Review* **15** 425-445
Zhang W, 1987, "Projection of future population development of China", in *The Analysis of the Third Population Census Data of China* Population Census Office, State Council of PR China (China Financial and Economic Press, Beijing) pp 333-340

APPENDIX

The demoeconomic model of urban and rural sectors

For the purpose of projecting a long-term trend of urbanization, a demoeconomic model of urban and rural sectors based on a general equilibrium model (Lee, 1984) has been chosen for this research. Several simplifications are made in the model. First, the production function is simplified by linking output and labour input by means of the labour productivity rate. Second, it is assumed that demands for agricultural and industrial goods are determined by income, and the effect of price on the demand for goods is disregarded. Therefore, the price elasticity of the demand for goods does not appear in the model. In fact, income and price elasticity of the demand for goods are not independent variables, as was shown by Artle et al (1977). Simon (1982) also challenged that the assumption of price elasticity of the demands for goods is not likely to be satisfied in a real economy. This is especially so in underdeveloped countries, where foodstuffs are available at not much above the subsistence level. This assumption means that a decrease in the price of manufactured products will decrease the consumption of agricultural products. There are several advantages in using this model. First, it is relatively simple to implement. It may be of course much more desirable to establish a detailed econometric model of the urban and rural economy of China but this would undoubtedly result in much greater data requirements. In their work on Indian urbanization, Becker et al (1986) recognized the difficulty of estimating large-size models in developing countries, and an alternative estimation method was used. Second, the model has a sound theoretical basis. It is a general equilibrium model and both the supply side and the demand side are incorporated. The economic forces driving the urbanization process are represented simply by the productivity growth rate and the income elasticity of consumption for urban and rural products. Third, exogenous variables are kept to a minimum. In any projection, exogenous variables need to be projected first. The meaning of the projection results is, as a result, much clearer if only a few exogenous variables are involved.

A basic assumption in the demoeconomic model is that an industrial product and an agricultural product are produced in the urban sector and rural sector, respectively, and consumed by the whole population. Thus, the urban sector corresponds to

the
nonagricultural sector, and the rural sector to the agricultural sector.

The variables are defined as follows:

$P(t)$ is the total population at the end of the period *t*-1 to *t*.

$P^{1k}(t)$ is the labour force in sector *k* at the end of the period *t*-1 to *t*; *k* = u (urban, nonagricultural); r (rural, agricultural)

$n^p(t)$ is the rate of natural increase of total population in the period *t*-1 to *t*.

$n^{1k}(t)$ is the rate of natural increase of labour force in sector *k* in the period *t*-1 to *t*; *k* = u, r.

$r^k(t)$ is the labour productivity in sector *k* in the period *t*-1 to *t*; *k* = u,r.

$o^k(t)$ is the growth rate of labour productivity in sector *k* in the period *t*-1 to *t*; *k* = u,r.

$Q^k(t)$ is the output of industrial or agricultural product in sector *k* in the period *t*-1 to *t*; *k* = u,r.

$c^k(t)$ is the consumption per capita of the product produced in sector *k* in the period *t*-1 to *t*; *k* = u,r.

$y(t)$ is the income per capita in the period *t*-1 to *t*.

$e^k(t)$ is the income elasticity of the consumption of the product produced in sector *k* in the period *t*-1 to *t*; *k* = u,r.

$M^{nl}(t)$ is the net urban migration in the period *t*-1 to *t*; *k* = u,r.

The following equations can be obtained. For simplicity, the year-end labour force and population figures are used in the production and consumption equations.

The product equation is

$$Q^k(t) = r^k(t)P^{1k}(t), \qquad k = u,r. \tag{A1}$$

The consumption equation is

$$Q^k(t) = P(t)c^k(t), \qquad k = u,r. \tag{A2}$$

The labour productivity increase equation is

$$r^k(t) = [1 + o^k(t)]r^k(t-1), \qquad k = u,r. \tag{A3}$$

The equation of the income elasticity of consumption is

$$e^k(t) = \frac{d\left[1nc^k(t)\right]}{d\left[1ny(t)\right]} = \frac{\left[c^k(t) - c^k(t-1)\right]/c^k(t-1)}{d\left[1ny(t)\right]}, \qquad k = u,r. \tag{A4}$$

The total population increase equation is

$$P(t) = \left[1 + n^p(t)\right]P(t-1). \tag{A5}$$

The labour force increase equations are

$$P^{1u}(t) = [1 + n^{1u}(t)]P^{1u}(t-1) + M^{n1}(t), \tag{A6}$$

$$P^{1r}(t) = [1 + n^{1r}(t)]P^{1r}(t-1) - M^{n1}(t). \tag{A7}$$

It is assumed that $o^k(t)$ and $e^k(t)$ are exogenous variables representing the supply and demand conditions. The demographic variables $n^p(t)$ and $n^{1k}(t)$ can be calculated endogenously from the urban-rural population model described in the paper. Hence, it is useful to derive the equation for M^{n1}(t) in terms of these exogenous and endogenous variables and the labour force P^{1k}(t-1) in the previous year.

The following equations can be obtained from equations (A1) and (A2):

$$r^k(t)P^{1k}(t) = P(t)c^k(t), \qquad k = u, r, \tag{A8}$$

$$r^k(t)P^{1k}(t-1) = P(t-1)c^k(t-1), \qquad k = u, r, \tag{A9}$$

It follows that

$$\frac{c^k(t)}{c^k(t-`1)} = \frac{P(t-1)r^k(t)P^{1k}(t)}{P(t)r^k(t-1)P^{1k}(t-1)}, \qquad k = u, r. \tag{A10}$$

If we substitute equations (A3) and (A5) into equation (A10) we get:

$$\frac{c^k(t)}{c^k(t-1)} = \frac{1+o^k(t)}{1+n^p(t)}\frac{P^{1k}(t)}{P^{1k}(t-1)}, \qquad k = u, r. \tag{A11}$$

The following equation can be obtained from equation (A4):

$$\frac{e^u(t)}{e^r(t)} = \frac{c^u(t)/c^u(t-1)-1}{c^r(t)/c^r(t-1)-1} \tag{A12}$$

On substituting equation (A11) into equation (A12) and rearranging, we get:

$$\frac{e^u(t)}{e^r(t)}\frac{1+o^r(t)}{1+n^p(t)}\frac{P^{1r}(t)}{P^{1r}(t-1)} - \frac{e^u(t)}{e^r(t)} = \frac{1+o^u(t)}{1+n^p(t)}\frac{P^{1u}(t)}{P^{1u}(t-1)} - 1. \tag{A13}$$

If equations (A6) and (A7) are used in equation (A13), the following projection equation for $M^{nl}(t)$ can be obtained:

$$M^{n1}(t) = \left\{\frac{e^u(t)}{e^r(t)}\frac{[1+o^r(t)][1+n^{1r}(t)]}{1+n^p(t)} - \frac{[1+o^u(t)][1+n^{1u}(t)]}{1+n^p(t)} - \frac{e^u(t)}{e^r(t)} + 1\right\} \times \left\{\frac{e^u(t)}{e^r(t)}\frac{[1+o^r(t)]/[1+n^p(t)]}{P^{1r}(t-1)} + \frac{[1+o^u(t)]/[1+n^p(t)]}{P^{1u}(t-1)}\right\}^{-1}. \tag{14}$$

Equations (A6), (A7),and (A14) constitute the demoeconomic model of urban and rural sectors.

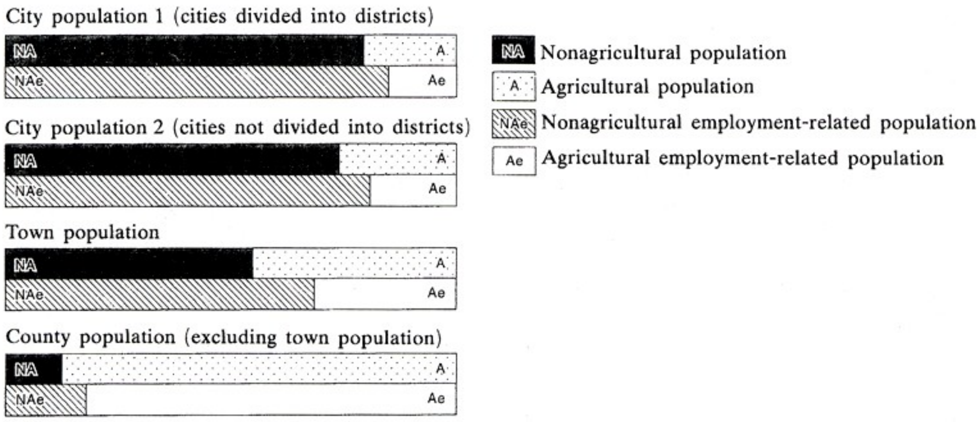

Figure 1. Population components used in the different population definitions in China. The pre-1982 definition consists of the nonagricultural population (NA) in cities and towns, whereas the 1982 census definition consists of the entire population in cities and towns (NA and A, or NAe and Ae). The 1990 census definition includes the entire population in cities with districts (NA and A of city population 1) and nonagricultural population in cities without districts and in towns (NA of city population 2 and NA of town population). The definition used in the present paper consists of nonagricultural employment-related population (NAe) plus a part of agricultural employment-relafed population (Ae) in cities and towns.

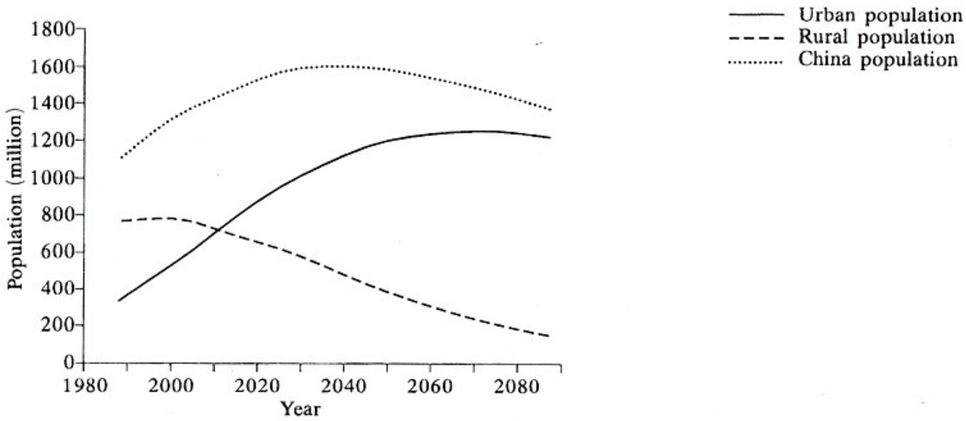

Figure 2. The urban, rural, and total populations of China in projection A.

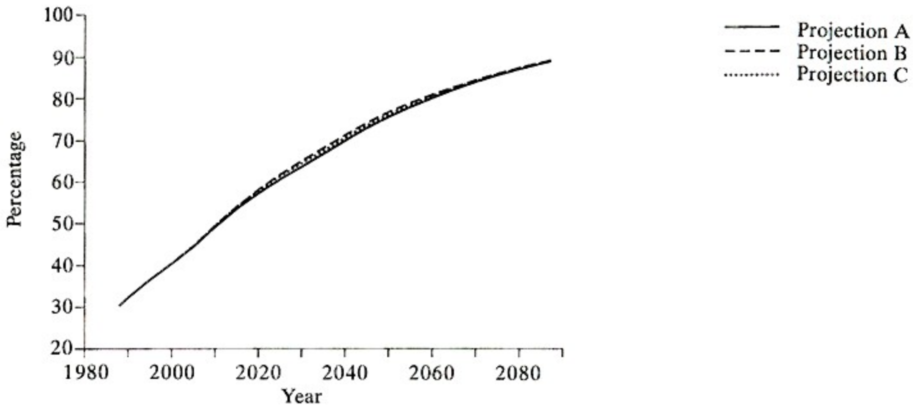

Figure 3. Percentage of urban population (projections A, B, and C).

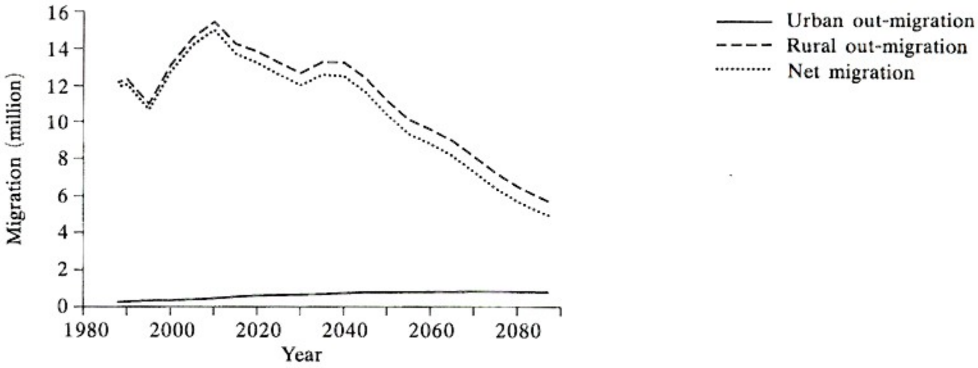

Figure 4. Urban-rural migration (including transition) (projection A).

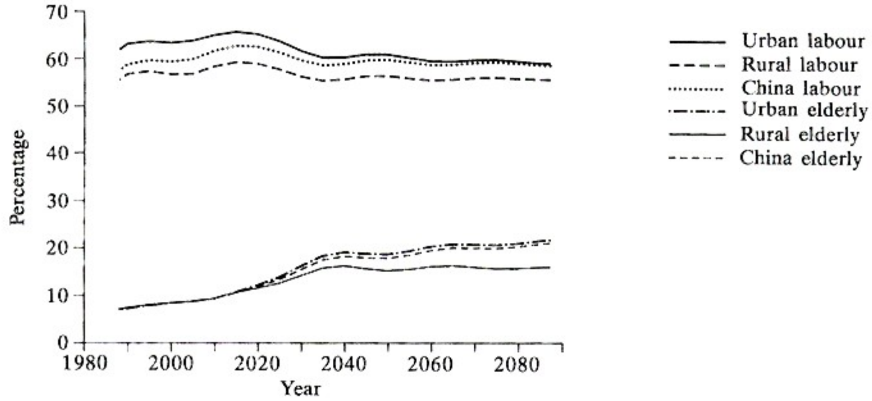

Figure 5. Percentage of labour and elderly population (projection A).

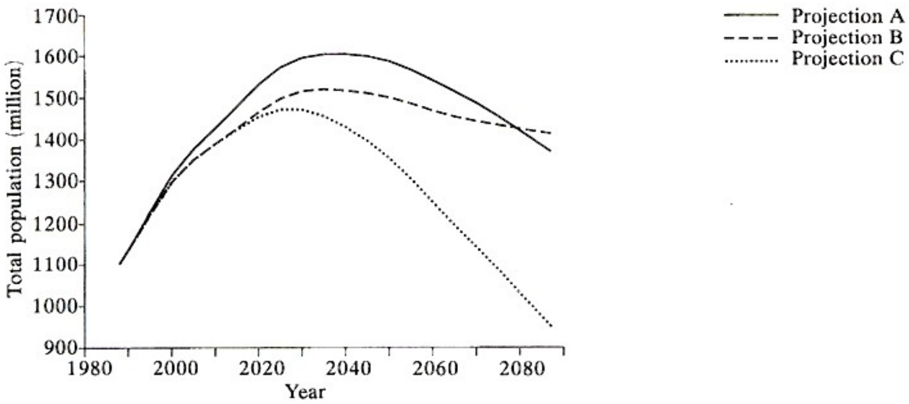

Figure 6. The total population in projections, A, B, and C.