AN ANALYSIS OF POPULATION MIGRATION AND ITS ENVIRONMENTAL IMPLICATIONS IN CHINA: APPLICATION TO DOMESTIC WATER USE

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This paper studies China's population migration and its environmental implications taking domestic water use as an example. Firstly, mechanisms of population migration between provinces and between rural and urban areas are analyzed by regression models. Secondly, future scenarios integrating economic development, population migration and urbanization up until 2020 are developed. Finally, the implication of population migration for domestic water use is examined.

The major findings are as follows: a) income gap, migration stock and distance are main determinants of inter-provincial migration; b) In 2020, population migration will cause domestic water use increase by 7.2% in Eastern Region, and decrease by 5.5% and 4.9% in Middle and Western Regions respectively.

Key Words: *Environmental issues in China, Domestic water use, Population migration, Urbanization*

1. INTRODUCTION

Since the start of economic reform in 1978, China has been experiencing a dramatic transition from a planned economy to a market economy. Uneven regional economic development has created a massive population migration in the past two decades. As a result, urbanization in China is taking place rapidly because of the large flow of rural to urban migration. From 1978 to 2000, China's urbanization level in terms of the ratio of urban population to the total one grew from 18% to 36%, while the total urban population increased from about 170 million to 460 million people. During the period of 1995 to 2000, the total migration amounted to 128 million people[1)]. What do this timing and magnitude of urbanization imply? What is the mechanism of population migration? And more importantly, what the regional environment change will take place due to the population migration and urbanization in China? Although the environmental implications caused by population migration cover many aspects, such as water use, energy consumption, land use change and environmental pollution, this paper just emphasizes on domestic water use as an example, because among the total water use, domestic water use is always given the top priority in water supply and planning, it is directly linked to the public health and regarded as one of the important premises for urban and economic development.

Regarding China's population migration issue, many studies have been conducted in the last decade. As a macro-level study, Wu *et al.* (1996) surveyed the literature on China's rural-to-urban labor migration[2)]. Wang *et al.* (1999) pointed out that huge urban-rural income gap and massive rural surplus labor were the main drivers of the rapid

increase of immigrants in cities[3]. Seeborg *et al.* (2000) adopted sociological theories to supplement the neoclassical explanation of rural-urban migration in China[4]. Wu *et al.* (2003) established an economic model to explain rural-urban migration theoretically and tested it with empirical data[5]. Yan (2004a) used national census data and examined the driving forces of inter-provincial migration by using a regression model[1]. IIASA (2003a, b) summarized the historical characteristics of China's demographic changes and projected their future development[6], [7]. In the micro-level studies, Zhao (1999) used questionnaires on migrants from rural to urban areas to analyze the motivation of individual migrants[8]. Liang (2004) analyzed the patterns and social characteristics of temporary migrants[9]. Yan (2004b) modeled the choice and schedule of individual migrant with different age and living condition[10]. These studies provide a useful insight into the actual situation. However, most of them focused on the whole China, and the regional disparities of population migration and environmental implications caused by migration have not yet been analyzed.

Water resource issues in China have been paid much attention nationally and internationally. Chinese Academy of Engineering (2001) evaluated the current water resource issues and analyzed the future trend of water supply and demand[11]. World Bank (2001) focused on water resource and demand management issue in north China[12]. Japan Bank for International Cooperation (2004) studied the water supply and demand balance in China's Yellow River Basin[13]. All of these studies analyzed water resource in China comprehensively. However, while evaluating the socio-economic development, especially the population growth, most of the studies just extrapolate the historical trend, neglecting population migration under specific socio-economic development.

In order to overcome the shortcomings of previous studies, this paper uses the works of previous studies as a baseline, and explores particular socio-economic scenarios to consider population migration (as shown in Fig. 1). It attempts to a) characterize the population migration and urbanization phenomena in China; b) analyze the mechanism of population migration by using both nationwide time-series data and 2000 census data; c) formulate scenarios of economic development, population migration and urbanization in China toward the year 2020 by considering possible socio-economic development in the future; d) evaluate the implication of population migration for domestic water use.

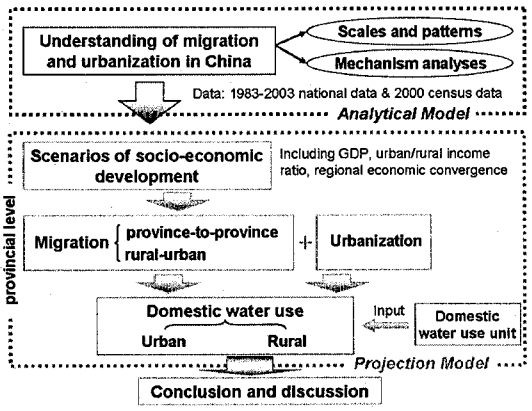


Figure 1 Flow chart of this study

2. CHARACTERISTICS OF POPULATION MIGRATION AND URBANIZATION IN CHINA

(1) Scales and contribution of rural-to-urban migration to urbanization 1983-2003

The rise of urbanization level is caused either by rural-to-urban migration or by natural growth of urban population. In this paper, in order to see how much the migration contributes to urbanization from 1983 to 2003, the annual urban population growth is decomposed into two parts: one is natural growth; the other is net migration. As shown in Table 1, the net migration shares 80% of total urban population growth. The contribution of rural-to-urban migration to urban population growth was 77% in 1983-1989, 67% in 1990-1995 and 86% in 1996-2003. The annual average number of city ward migrants amounted to about 12 million. It is obvious that the rural-to-urban migration turns out to be the dominant source of China's urban growth.

Table 1 Contribution of rural-to-urban migration to urban population growth 1983-2003

Period	Annual growth of total urban pop. (million)	Annual natural growth of pop.		Annual net migration	
		Number (million)	Share (%)	Number (million)	Share (%)
1983-1989	11.52	2.69	23.3	8.83	76.7
1990-1995	9.39	3.08	32.8	6.31	67.2
1996-2003	21.50	2.96	13.8	18.54	86.2
1983-2003	14.71	2.90	19.7	11.81	80.3

Source: China Statistical Yearbook (National Bureau of Statistics, 2000, 2004) and China Population Statistics Yearbook (National Bureau of Statistics, 2004)

(2) Spatial patterns of population migration

Since 1978, the economic disparity among

regions has been increasing. Economic development level, as shown in Fig. 2, lowers sharply from Eastern Region to Middle and Western Regions. As a result, special conditions for massive population migration were created in the last decade.

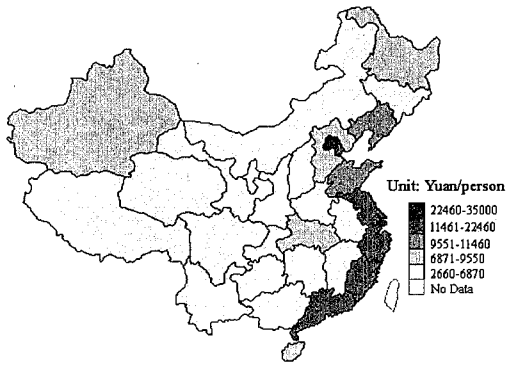


Figure 2 China's disparity of per capita GDP in 2000

a) Intra-provincial migration

According to the 2000 census data, a total of 128 million migrants crossing county boundaries were recorded in 1995-2000. About 73% or 94 million people were identified as the intra-provincial migrants, while 27% or 34 million people were inter-provincial migration.

b) Inter-provincial migration

Table 2 shows the distribution of population migration among three regions. In Eastern Region, 75% inter-provincial migrants still remained in the same region. While 84% and 66% of migrants from Middle and Western Regions moved to Eastern Region. Eastern Region has become the dominant attractor of migrants, while Middle and Western Regions have become the major suppliers of migrants.

Table 2 Distribution of inter-regional migration in China 1995-2000 (unit: %)

Destination regions	Original regions		
	Eastern	Middle	Western
Eastern	74.7	84.1	66.2
Middle	17.1	9.7	8.1
Western	8.2	6.2	24.5

Notes: Eastern Region includes: Beijing, Tianjing, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, Hainan. Middle Region includes: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Shaanxi. The rest belong to Western Region.
Data source: calculated from the 2000 census data.

Fig. 3 shows net inflow and outflow population migration of each province. Guangdong, Shanghai, Zhejiang and Beijing, etc. were the provinces with the largest net immigration. Guangdong alone accommodated 11.7 million migrants from other provinces, which accounted for about 35% of total inter-provincial migrants. Sichuan, Hunan, Anhui, and Jiangxi, etc. were the largest senders of emigrants. Sichuan supplied 4 million emigrants or 12% of total.

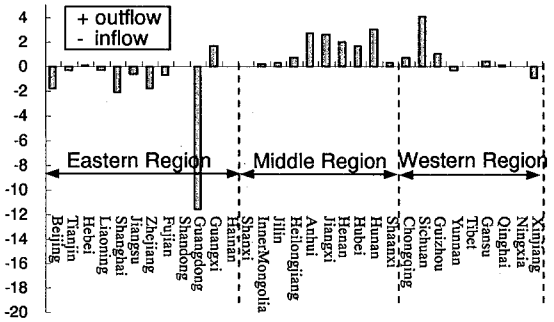


Figure 3 Provincial-level net in and out flow of population migration 1995-2000 (Unit: million)

In order to know the flow of population migration among provinces, the 31 largest inter-provincial migrations are mapped in Fig. 4, based on the 2000 census. It shows that the migration flows take place primarily from provinces in Middle and Western Regions toward provinces in Eastern Region. Guangdong, Shanghai, Zhejiang and Beijing are central attracters of population migration. Here, a large inflow of migration into Xinjiang may due to China's policy that organizing people designedly to move to Xinjiang in support of local construction.

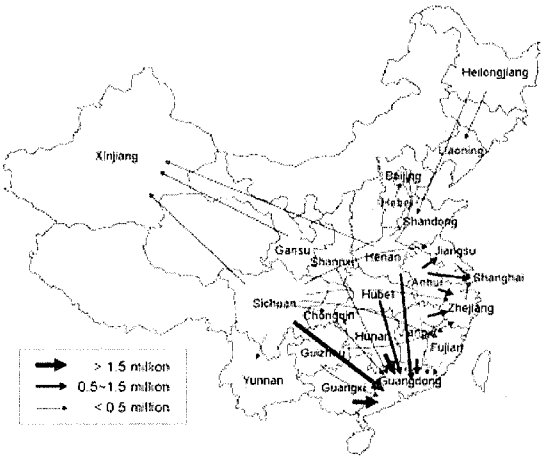


Figure 4 The 31 largest inter-provincial migration flow in 1995-2000 in China

c) Migration between rural and urban areas

The total population migration can be divided into 4 categories in terms of origin and destination of migration: "rural-to-urban", "rural-to-rural", "urban-to-rural" and "urban-to-urban". Among

them, "rural-to-urban" is the largest, which shares 40.7% of the total migration. The second is "urban-to-urban", which shared 37.2% of the total. "urban-to-rural" is the smallest or merely 3.9% of the total migration[14]. In short, the primary population migration in China is the flow from rural areas to cities.

3. ANALYSIS OF THE MECHANISM OF POPULATION MIGRATION

(1) Analysis of rural-to-urban migration data 1983-2003 (national level)

As discussed in the theories of development economy, rural-to-urban migration is an answer to the economic development[15]. Economic development entails a massive shift of labor from rural sector to urban sector. Assuming a positive impact of economic development on rural-to-urban migration, the following model with national rural-to-urban migration data in 1983-2003 is used to validate this assumption for China.

$$\ln M_t = C + a_1 \ln Y_t + a_2 \ln G_t + a_3 \ln \mathrm{UE}_t + a_4 \ln R_t + a_5 \ln T \quad (1)$$

Here, subscript t denotes year; M is net rural-to-urban migration (the same source as Table 1); Y is urban/rural per capita income ratio; G is per capita GDP; UE is unemployment rate in cities; R is rural population per arable land; T is time dummy; C is constant.

Stepwise estimation method is adopted to eliminate the multicollinearity among variables. Table 3 shows the results, from which the following main points are identified.

Table 3 Determinants of rural-to-urban migration 1983-2003

Variables	Full model		Model with stepwise estimation	
	coefficients	*t* statistic	coefficients	*t* statistic
C	-16.44	-1.43	-21.74***	-4.87
Y	-1.63	-1.59		
G	4.32***	4.39	4.72***	6.12
UE	-1.42*	-1.93	-1.82**	-2.66
R	-1.32	-0.38		
T	-2.61**	-2.41	-3.38***	-5.24
Adjusted R^2	0.76		0.75	
F statistic	13.64***		21.18***	

*Level of significance: 10%; **Level of significance: 5%; ***Level of significance: 1%.

- Economic development level (G) has a positive effect on rural-to-urban migration.
- Urban unemployment (UE) has a negative effect on rural-to-urban migration.
- The variables of urban/rural income ratio (Y) and rural population per arable land (R) are supposed to have positive effects on rural-to-urban migration. But during the period 1983-2003, the ranges of urban/rural income ratio (1.9-3.2) and rural population per arable land (8.0-9.1) changed little, causing the migration did not respond significantly to these two variables.
- The negative coefficient of T indicates a downward time trend in the level of migration. It may result from the administrative controls on the rural-to-urban migration.

(2) Analysis of 2000 census data (provincial level)

The estimation of Eq. (1) is useful for understanding China's rural-to-urban migration, but the specification with time-series data is not enough to describe the mechanism of population migration. Therefore, an analytical model is established based on the provincial level data of 2000 census.

$$\ln M_{ij} = C + \alpha_1 \ln(Y_j / Y_i) + \alpha_2 \ln(\mathrm{GDPR}_j / \mathrm{GDPR}_i) + \alpha_3 \ln(\mathrm{MSK}_{ij}) + \alpha_4 \ln(D_{ij}) + \alpha_5 \ln(\mathrm{UE}_j / \mathrm{UE}_i) + \alpha_6 \ln(S_j / S_i) \quad (2)$$

Here, M_{ij} is migration from province i to j; Y provincial per capita income; GDPR annual growth rate of provincial GDP; MSK_{ij} migration stock (measured by $M_{ij}/\sum M_{ij}$, the proportion of emigrants from province i to j to the total emigrants from province i); D_{ij} distance between province i and j (measured by the shortest railway length between capital cities of two provinces); UE urban unemployment rate; And S share of employment in the second and third industrial sectors. C is a constant.

According to the existing studies focus on population migration and urbanization[1)-10)], it is assumed that regional difference of income, GDP growth rate, and share of employment in the second and third industrial sectors will encourage migrants move to higher income places. Migration stock, which implies the influence of old immigrants on new emigrants who plan to move, will encourage migration. Large distance, which to some extent represents the cost and psychological barriers of migration, will discourage migration. Urban unemployment also will discourage migration. Based on provincial-level census data, Eq. (2) is applied to three regions and whole China respectively. Table 4 shows the results, and its major findings are as follows.

Table 4 Determinants of inter-provincial migration in China (with stepwise estimation)

Independent variables	Eastern Region		Middle Region		Western Region		Whole China	
	Coefficients	*t* statistic	Coefficients	*t* statistic	Coefficients	*t* statistic	Coefficients	*t* statistic
Y	0.84***	10.58			0.43**	2.39	0.62***	9.53
GDPR					2.90***	7.17		
MSK	0.77***	20.84	0.72***	21.52	0.66***	12.55	0.64***	23.89
D	-0.28***	-3.42	-0.42***	-5.00	-1.13***	-7.96	-0.83***	-13.17
UE								
S			0.92***	6.59				
C	5.25***	9.98	6.69***	11.81	10.50***	11.63	8.74***	20.56
Adjusted R^2	0.77		0.82		0.61		0.65	
F statistic	385.06***		433.87***		107.40***		567.27***	

*Level of significance: 10%; **Level of significance: 5%; ***Level of significance: 1%.

Data source: population migration data are from the 5th Census in 2000. Others use the average value in 1995-2000, which are taken from China Statistical Yearbook (National Bureau of Statistics, 1996-2001).

- In Eastern Region, income gap (*Y*) and migration stock (MSK) encourage inter-provincial migration, while distance (*D*) discourages it. The most important reason of population migration is that people want to seek a better income.
- In Middle Region, migration stock (MSK) and share of employment in the second and third industrial sectors (*S*) have positive effects on inter-provincial migration, while distance (*D*) has a negative effect. The share of employment in the second and third industrial sectors (*S*) is the most important determinant affecting migration.
- In Western Region, income gap (*Y*), GDP growth rate (GDPR) and migration stock (MSK) encourage inter-provincial migration, while distance (*D*) discourages it. The most important driving force is that people want to move to a more developed province, where GDP growth rate (GDPR) is higher.
- In the whole China, distance (*D*) is the most important and negative determinant affecting migration.

In sum, the most important determinants of inter-provincial migration are income gap (*Y*), migration stock (MSK) and distance (*D*). The first two factors encourage migration while the third one discourages it.

4. SCENARIOS OF POPULATION MIGRATION AND ITS IMPLICATION FOR DOMESTIC WATER USE

In order to further evaluate the features of population migration and its influence on domestic water use in the future China, scenarios of socio-economic development and domestic water use are developed. The base year of projection is 2000, for which a large amount of provincial data including population migration is available. While 2020 is set as the target year by taking into account the reliability of projection results.

(1) Projection of population migration

We follow the works of IIASA for projection[6), 7)]. Since they observed the historical patterns of demographic process in China and extrapolated into the future by assuming continuing trends without significant disruptions, we use their results at provincial level as a baseline scenario, and then add some variant scenarios by assuming possible socio-economic changes. In this paper, we use a gravity model-inspired approach to model marginal changes in population distribution due to the relative income changes between provinces, and between urban and rural areas. The projection of population migration is carried out in two steps: firstly, inter-provincial migration; secondly, rural-urban migration.

a) Inter-provincial migration

Population growth in each province can be decomposed into two parts. One is natural growth, and the other is net inter-provincial migration. Thus, population in province *i* can be calculated by,

$$P_{i,t} = P_{i,t-1} \cdot (1 + \phi_{i,t}) + \mathrm{NETM}_{i,t} \qquad (3)$$

where, subscript *i* and *t* denote province *i* and year *t*; *P* is population; ϕ is the natural growth rate of population; NETM is the amount of net inflow of migrants to province *i*.

The natural growth rate (ϕ) is computed as the difference between natural birth and death rates,

which are calculated by the Logistic Model.

$$f_{i,t} = \frac{c_i}{1 - a_i e^{-b_i t}} \tag{4}$$

Here, f_i denotes natural birth or death rate; a_i, b_i, c_i the parameters of province i estimated from historical data[6], and t year.

The estimation of migration is based on Lowry's model[16].

$$M_{ij} = k \frac{\mathrm{UE}_i}{\mathrm{UE}_j} \times \frac{W_j}{W_i} \times \frac{L_i L_j}{D_{ij}} \tag{5}$$

Here, M_{ij} is migration from province i to j; UE the unemployment rate; W the wage of manufacturing sector; L the labor force; D_{ij} the distance between province i and j, and k a constant. Eq. (5) takes into important determinants of inter-provincial migration in China such as income gap, migration stock and distance.

Eq. (5) is modified by substituting some variables by more readily available data, yielding

$$M_{ij} = k \frac{\mathrm{UE}_i}{\mathrm{UE}_j} \times \frac{y_j}{y_i} \times \frac{P_i P_j}{D_{ij}} \tag{6}$$

Here, y expresses average provincial per capita income, and P provincial population.

In the first order approximation, we obtain

$$\Delta\left(\frac{y_j}{y_i}\right) \approx \left(\frac{y_j}{y_i}\right)_{t-1} \left(\frac{\Delta y_j}{y_{j,t-1}} - \frac{\Delta y_i}{y_{i,t-1}}\right) \tag{7}$$

Ignoring the second-order effect of changes in population due to migration and changes in unemployment associated with income change, we obtain

$$\Delta M_{ij} \approx M_{ij,t-1} \left(\frac{\Delta y_j}{y_{j,t-1}} - \frac{\Delta y_i}{y_{i,t-1}}\right) \tag{8}$$

In this exercise, the relative unemployment $\mathrm{UE}_i/\mathrm{UE}_j$ is neglected, because the unemployment rate in provinces are quite similar according to the published statistical data in China. Using Eq. (8), the net inflow migrants to province i is

$$\begin{aligned} \mathrm{NETM}_{i,t} &= \sum_{j \neq i} (M_{ji} - M_{ij})_t \\ &= \mathrm{NETM}_{i,t-1} + \sum_{j \neq i} (M_{ji} + M_{ij})_{t-1} \left(\frac{\Delta y_i}{y_{i,t-1}} - \frac{\Delta y_j}{y_{j,t-1}}\right) \end{aligned} \tag{9}$$

Here, Eq. (9) is used for the projection of inter-provincial migration.

b) Rural-urban migration

In the second step, urban or rural populations are adjusted within province, to read

$$\begin{aligned} P_{u,t} &= P_{i,t} \cdot \mathrm{UBASE}_{i,t} + \mathrm{NETM}_{u,t} \\ P_{r,t} &= P_{i,t} - P_{u,t} \end{aligned} \tag{10}$$

Here, P_u and P_r are urban and rural population in province i; P_i the population in province i; NETM_u the net inflow of migrants to urban areas; UBASE_i the projected urbanization level in province i in baseline scenario. It is estimated by S-curve regression model.

$$\mathrm{UBASE}_{i,t} = \frac{1}{1 + \alpha_i e^{-\beta_i (t - t_0)}} \tag{11}$$

Here, a_i and β_i are parameters of province i, estimated by historical trend[7]; t is year and t_0 is the base year which is set to 1979.

Similar to Eq. (9), the net inflow of migrants to urban is

$$\begin{aligned} \mathrm{NETM}_{u,t} &= -\mathrm{NETM}_{r,t} = (M_{ru} - M_{ur})_t \\ &= \mathrm{NETM}_{u,t-1} + (M_{ru} + M_{ur})_{t-1} \left(\frac{\Delta y_u}{y_{u,t-1}} - \frac{\Delta y_r}{y_{r,t-1}}\right) \end{aligned} \tag{12}$$

Eq. (12) is used for the projection of rural-urban migration.

Accordingly, the urbanization level in province i (U_i) after the rural-urban migration is,

$$U_{i,t} = P_{u,t} / P_{i,t} \times 100\% \tag{13}$$

(2) Projection of economic development

In order to achieve sustainable development, China is making a great effort to reduce the disparities between regions and urban-rural areas. The implementation of "Develop-the-West Strategy" is a well known policy in the 21st century. And according to the "Proposals for Establishing National 11th Five-Year Plan", promotion of harmonious regional development is emphasized as one of the targets in future development[17]. Therefore, when estimating the economic development, regional convergence must be taken into account as an important consideration in the model.

According to theories of conditional economic convergence, the model is based on the following two hypotheses. If other things being equal, per capita GDP growth rate is higher in regions with lower per capita GDP. Then, per capita income is a constant proportion of per capita GDP. For the whole scenario, they have the same growth rate. The national GDP growth rate is given as an exogenous variable: 7% in 2001-2010, and 6.5% in 2011-2020[18]. Following the work of Barro *et al.* [19], we assume that the growth rate of per capita income

in each province converges as:

$$r_i = r^* - \chi_i \lambda \ln(y_i / y^*) \qquad (14)$$

Here, r_i is the growth rate of per capita income y_i in province i; r^* is the growth rate of per capita income y^* in the reference province. The growth rate for the reference province is set so that the national GDP growth rate matches the rate given exogenously. The choice of reference province can be arbitrary, and any choice of reference province will give the same result. The coefficient λ is set at 2.5% (from Barro and Martin, 2003). χ_i is the economic convergence parameter of province i, which varies from -1(divergence) to +1 (convergence). The same value of χ_i is assumed for all provinces which belong to the same region (For Eastern Region, χ_i=1.0; Middle Region, χ_i=0.7; Western Region, χ_i=0.6)[18].

As a result, GDP of province i in year t is

$$GDP_{i,t} = P_{i,t} \cdot GDPP_{i,t-1} \cdot (1 + r_{i,t}) \qquad (15)$$

where, P is provincial population, GDPP is the per capita GDP; r is the growth rate of per capita GDP, which shares same value with the growth rate of per capita income.

Next, we discuss the share of urban and rural income within each province. At national level, the changing rate of urban/rural income ratio during 1978-2003 varies in the range between -5% and 5% per year. And according to the "Proposals for Establishing National 11th Five-Year Plan", to decrease the disparity between rural and urban areas has been emphasized by China's government as an important target. We assume that the urban/rural income ratio of each province will decrease at the rate of 1% per year.

(3) Projection of domestic water use

We estimate provincial domestic water use (PDW) by:

PDW = urban population × urban domestic water use unit + rural population × rural domestic water use unit (16)

where, domestic water use units (i.e., water consumption per population) in rural and urban areas are estimated according to the study result of Chinese Academy of Engineering[11]. In scenarios, urban domestic water use unit will increase from 189 L/(person·d) in 1997 to 209 L/(person·d) in 2020, while the rural unit will grow from 88 L/(person·d) in 1997 to 105 L/(person·d) in 2020.

(4) Model results

Model results are aggregated to regional level before reporting them. Table 5 shows some major results.

Table 5 Selected outputs from projection models

	Regions	2000	2010	2020
GDP (trillion yuan)	China	9.72	18.44	34.93
	Eastern	5.77	11.36	21.64
	Middle	2.79	4.98	9.29
	Western	1.15	2.11	4.00
Population (million)	China	1242	1319	1394
	Eastern	528	577	628
	Middle	468	483	495
	Western	247	260	271
Urbanization (%)	China	34.24	44.34	54.39
	Eastern	41.47	54.40	66.29
	Middle	31.29	39.58	48.36
	Western	24.36	30.82	37.87

As for inter-provincial migration, Fig. 5 shows the net inflow and outflow in 2010 and 2020. The direction of migration flow is still from Middle and Western Regions to Eastern Region. Guangdong is the largest immigrant attractor with 12.7 million net inflow migrants in 2020. Sichuan is the largest emigrant sender with 4.7 million net outflow migrants in 2020.

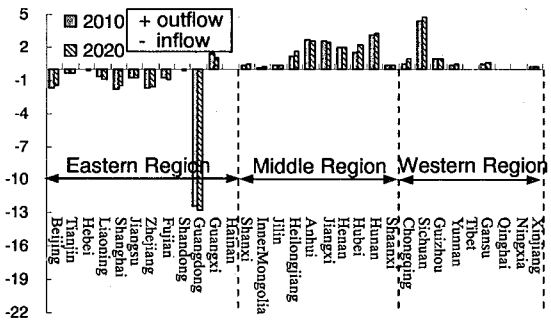


Figure 5 The net inter-provincial migration in 2010 and 2020 (unit: million)

In order to find out the implication of population migration for domestic water use, the amount of domestic water use estimated by two methods are compared at regional level (Table 6).

- **Method A** uses the models presented in this paper. It considers population migration under specific socio-economic development.
- **Method B** is a conventional method used in previous studies (e.g. in IIASA's report)[6), 7)]. It just extrapolates the historical patterns of demographic process neglecting population migration.

Table 6 Regional domestic water use in 2010 and 2020 (unit: billion m^3)

Region	2010			2020		
	Method A	Method B	Growth rate of A to B	Method A	Method B	Growth rate of A to B
Eastern	37.10	35.71	3.9%	47.23	44.06	7.2%
Middle	33.83	34.72	-2.6%	40.29	42.64	-5.5%
Western	14.95	15.30	-2.3%	17.73	18.64	-4.9%
China	85.87	85.74	0.2%	105.26	105.34	-0.1%

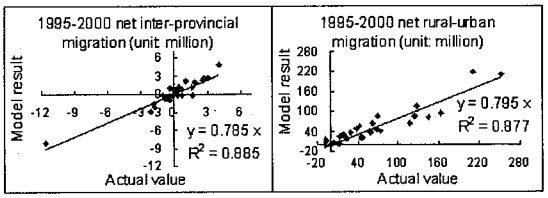
Note: "growth rate of A to B" means growth rate of the value calculated by method A to that calculated by method B. It equals (A-B)/B·100%.

In the whole China, domestic water uses estimated by these two methods are nearly the same. But at regional level, the situation is different. In Eastern Region of 2020, population migration will cause domestic water use increase by 7.2% compared with the amount without considering specific population migration. In Middle and Western Regions of 2020, population migration will cause the domestic water use decreasing by 5.5% and 4.9% respectively, compared with the value without considering specific population migration. When considering the situation at provincial level, we take up Guangdong province as an example, which is located in Eastern Region and absorbing the largest amount of immigrants. Without considering population migration, its domestic water use in 2020 will be 9.2 billion m^3. While considering population migration, its domestic water use will increase by 26%, amounting to 11.6 billion m^3.

Apparently, because of population migration, large amount of people will move to eastern provinces and urban areas, providing plentiful labors to support the economic development in Eastern Region. But from the point of view of environment, population migration will aggravate the burden of domestic water use in Eastern Region, while alleviating the burden of domestic water use in Western and Middle Regions.

(5) Model verification

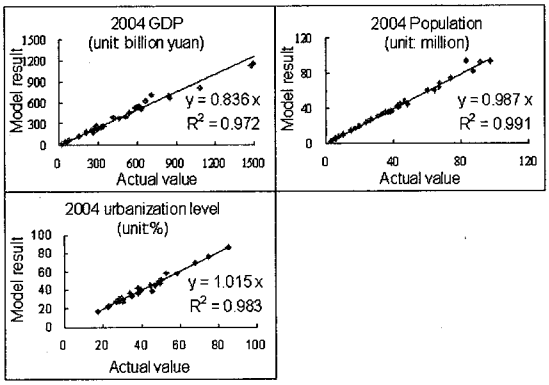
In order to verify the validities of Eq. (9) and (12) in projecting population migration, models are modified to start from 1990 by using the 1990 census data to simulate the net inter-provincial and rural-urban migration till 2000 and results are compared with actual migration data in 2000 census. As shown in Fig.6, R^2 in each case is high, proving that models in this paper are acceptable and reasonable for evaluation.



Data source: the 1990 census (NBS, 1993); the 2000 census (NBS, 2002).

Figure 6 Model verification (1)

As for the verification of Eq. (3), (13) and (15), actual population, urbanization level and GDP of each province in 2004 are compared with model results respectively. As shown in Fig. 7, R^2 in each case is close to 1.0.



Data source: China Statistical Yearbook 2005 (NBS, 2006); China Population Statistical Yearbook 2005 (NBS, 2006).

Figure 7 Model verification (2)

5. CONCLUSION AND DISCUSSION

In China, large flows of population migration, rapid urbanization and their environmental implications have been paid wide attentions in recent years. This paper tries to understand the historical trend and mechanism of population migration, and project its implication for domestic water use. The main findings are as follows.

- The main source of China's urbanization in the past two decades is the rural-to-urban migration, which shares about 80% of total urban population growth.
- The most important determinants of inter-provincial migration in China are income gap, migration stock and distance. Income gap and migration stock encourage migration while the distance discourages migration.
- Due to the uneven regional economic development, large amount of people move from Western and Middle Regions to Eastern Region, particularly from rural to urban areas. This also

results in the disparity of domestic water use among regions. Comparing with the case neglecting population migration, in 2020, population migration will cause the amount of domestic water use increasing by 7.2% in Eastern Region, while decreasing by 5.5% and 4.9% in Middle and Western Regions respectively.

- This paper integrates specific socio-economic development such as regional economic convergence and population migration, etc. with the implication for domestic water use, which are usually neglected in conventional studies. The validities of model results are high and acceptable.

This paper presents a method to evaluate the future population migration between provinces and between rural and urban areas, together with income distribution, urbanization and etc. in China. By using the results, we can apply them for further studies. For example, by taking into account the regional water supply capacity, regional water balance affected by population migration and urbanization can be evaluated. Moreover, by adding assumptions to the projection models, the authors plan to study environmental implications of population migration and urbanization with respect to urban housing issues, energy consumption issues, land use changing issues and environmental pollution issues, etc. in the future.

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中国の人口移動とその環境的意味：生活用水を例として

韓驥[1]，大西暁生[2]，白川博章[3]，井村秀文[4]

本研究では，中国における人口移動が環境に与える意味に関して，家庭用水需要を例として検討した．まず，回帰分析を用いて人口移動のメカニズムを検討した．次に，2020年までの経済成長，人口移動，都市化をシナリオ分析した．最後に，人口移動による家庭用水需要への意味を評価した．

本研究の結果，a）所得格差や移動ストックや移動距離が人口移動に強い影響を与えている．b）人口移動を考慮した場合，これを考慮しない場合と比較し，東部では2020年に家庭用水の消費量が7.2%増加するが，中部および西部地域では逆に5.5%，4.9%それぞれ減少する，という結果を得た．