Global Regional Consistent Population/Urbanization Projections for Developing Socioeconomic Scenarios

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Abstract

Urbanization projections and population projections are the two basic elements included in the new socioeconomic scenarios for climate change researches - the Shared Socioeconomic Pathways (SSPs). While the two projections signify the plausible trends in urbanization levels and national population compositions respectively and separately, there is no projection of changes in age and gender structure of rural and urban population, information important for studying the needs and challenges to socioeconomic development and environmental change. We develop a multiregional population/urbanization model to project the changes of rural and urban population composition of 31 global regions, consistent with the SSPs' urbanization and population scenarios. Based on the projection results, we explore the implied patterns of future urban population change through natural growth vs. rural-urban migration under different scenarios; analyze the impacts of rural-urban population dynamics on population structures and socioeconomic development in the rural and urban areas of different regions.

Extended Abstract

1. Motivation

The new IPCC socioeconomic scenarios for climate change researches – the Shared Socioeconomic Pathways (SSPs) include for the first time a comprehensive set of demographic factors on population, urbanization, and education, along with other aspects of socioeconomic conditions, such as GDP, technology, and governance (Jiang 2014; O'Neill et al., 2013). It presents a major step forward as compared to the earlier IPCC socioeconomic scenarios (e.g. Special Report on Emission Scenarios (SRES, Nakicenovic N. et al. 2000), which only includes projections of total population growth, as a scaling factor for assessing the challenges and options of climate change mitigation. Building on a set of five alternative global socioeconomic scenarios (see Table 1 for the set of assumptions made for the five SSPs), the research community put efforts in quantifying the basic elements of the storylines, including quantitative changes in the trends of population, urbanization, economic growth, technology and governance.

The SSPs urbanization projections by NCAR project the changes in the proportion of population living in the urban area for each country, as a function of the difference between urban and rural population growth rate (Jiang and O'Neill forth coming). It does not provide information on the changes in the population age and gender compositions in the rural and urban areas, information important for studying the needs and challenges to socioeconomic development and environmental changes. On the other hand, the SSPs population projections by IIASA, based on assumptions of fertility, mortality, international migration, and education transition (KC and Lutz 2014), project changes in population size and composition for the country as a whole, but not for rural and urban separately. More importantly, the interactions between population and urbanization are not specifically modeled in either the population or the urbanization projections, although they are all based on the SSPs storylines (Jiang 2014).

Several authors indicate that urbanization transition is closely linked with demographic transition (Becker 2007; Skeldon 2008); and in different phases of urban transition, the impacts of natural growth and migration on urbanization vary significantly (Kelley and Williamson 1984; Ledent 1982;). In the early stage of urban establishment, net rural-to-urban migration is the main source of urbanization growth. In the second stage, when urbanization increases to a certain level, natural growth in the urban areas contributes more to urban growth. After urbanization reaches a high level in the third stage, net rural-to-urban migration may again play a more important role to further urbanization (Zelinsky 1972). Some studies are devoted to quantifying the relative contribution of natural growth and migration to urban growth in the past decades (Chen et al 1996; Ledent 1982; National Research Council 2003; Rogers 1982). According to Chen et al (1996), the rural out-migration rate increased from 0.61 percent in the 1960s to 1.14 percent in the 1980s in the developing regions as a whole. However, this trend varies significantly across regions which had experienced different socioeconomic paths: during the same period, the rural out-migration rate declined steadily in Africa, while it gradually increased in Asia; in Latin America and the Caribbean, the rural out-migration rate increased between the 1960s and 1970s before declined afterwards. Those different trends are consistent with what is known about the socioeconomic situations, demographic dynamics and urbanization processes in these regions.

Therefore, it is important to analyze whether the projected urban growths through implied natural growth and rural-urban migration under the alternative socioeconomic pathways by the SSPs population projections and urbanization projections are consistent with the urban transition theories and the experiences from different regions over time.

It is noteworthy that the estimate of relative contribution of natural vs. migratory growth to urbanization in the past decades are based on the instantaneous contributions and short term flows. It is important to study the trends by considering the "stock effect", induced by the cumulative impacts from the contribution of not only the migrants themselves but also their descendants (National Research Council 2003). Rogers (1982) indicates that "the long run impacts of current patterns of migration and natural increase on urban population growth and urbanization levels can be assessed only by population projection", and the population projection should be based on "a more realistic model that allows the natural increase rate to change over time along with rate of net urban in-migration". What he refers to here is a multistate projection model that is able to project rural and urban population by age. In our previous case studies, we followed Roger's suggestion and constructed a multistate population/urbanization projection model, to assess the net contribution from migration and natural growth to future urbanization in India and China (Jiang and O'Neill 2009, 2011).

In this paper, we construct a global multiregional population/urbanization model to project the changes of population by age and gender for rural and urban areas of 31 global regions/countries, consistent with the SSPs urbanization projections and SSPs population projections. Using this model, we can also validate the SSPs urbanization scenarios and test whether or not the assumed urban growth at aggregate level is demographically plausible – e.g. whether the urbanization scenario implies total exhaust of rural population in certain age groups or an unrealistic surge of rural out-migration that differ dramatically from the recent experiences (O'Neill and Scherbov 2008). Moreover, based on the multiregional population/urbanization projections we explore the regional patterns of change in migratory vs. natural growth at different stages of urban transitions, and examine the plausibility of urban growth under different socioeconomic pathways, by comparing to the empirical evidences and urban transition theories.

2. Method and Data

Adopting multistate demography methodologies (Rogers 1996), we develop the multiregional population/urbanization projection model as a component of NCAR Community Demographic Model (CDM) (Figure 1) and project the changes of rural and urban population by age and gender for 31 global regions.

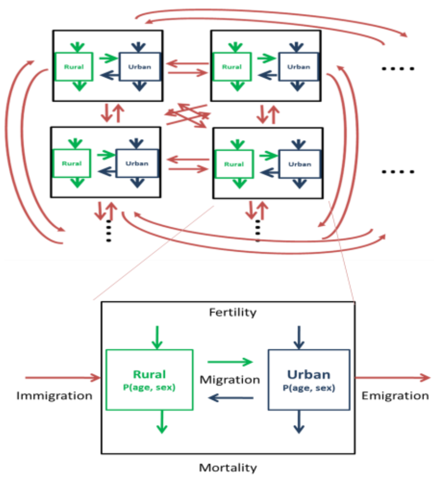

Figure 1 NCAR-CDM Multiregional population/urbanization projection model

Figure 2 Definition of 31 global regions of NCAR-CDM model

In each region, population $p_{s,g}^{x,t}$ is defined by sex g, aged x, residence s (either urban u or rural r) in time t. People of different states enter or leave the population by demographic events (fertility, mortality and migration), which is represented in the large transition matrix below

$$\begin{bmatrix} S_f + B_f & 0 \\ B_m & S_m \end{bmatrix} = \begin{bmatrix} 0 & 0 & \cdots & B_f^{15} & B_f^{16} & \cdots & 0 & 0 & 0 & & 0 & 0 & & 0 \\ S_f^0 & 0 & \cdots & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & S_f^1 & \cdots & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & 0 & 0 & \vdots & 0 & 0 & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & B_m^{15} & B_m^{16} & \cdots & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & & 0 & 0 & 0 & 0 & S_m^0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & S_m^1 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & \vdots & 0 & 0 & \vdots & 0 \\ 0 & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \cdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & & 0 & 0 & & 0 \end{bmatrix}$$

where , S_m and S_f are the matrix of transition due to mortality and rural-urban migration for male and female population, while B_m and B_f are the matrix of birth rate to baby boys and girls. The transition matrix is used to determines the sizes, age and gender compositions of rural and urban population of each region, using the accounting strategy as follows

$$\begin{bmatrix} \begin{pmatrix} P_{u,f}^{0,t+1} \\ P_{r,f}^{0,t+1} \\ P_{u,f}^{1,t+1} \\ P_{r,f}^{1,t+1} \end{pmatrix} \\ \vdots \\ \begin{pmatrix} P_{u,m}^{0,t+1} \\ P_{r,m}^{0,t+1} \\ P_{u,m}^{1,t+1} \\ P_{r,m}^{1,t+1} \end{pmatrix} \\ \vdots \end{bmatrix} = \begin{bmatrix} S_f + B_f & 0 \\ B_m & S_m \end{bmatrix} \begin{bmatrix} \begin{pmatrix} P_{u,f}^{0,t} \\ P_{r,f}^{0,t} \\ P_{u,f}^{1,t} \\ P_{r,f}^{1,t} \end{pmatrix} \\ \vdots \\ \begin{pmatrix} P_{u,m}^{0,t} \\ P_{r,m}^{0,t} \\ P_{u,m}^{1,t} \\ P_{r,m}^{1,t} \end{pmatrix} \\ \vdots \end{bmatrix}$$

The regional rural-urban population projections for each of the 31 regions are integrated through international migration - the bilateral net international migration rates $em_{ij,g}^{x}$ from region *i* to *j* by age *x* and gender *g* for each region as origin. For each region, the number of emigrants EM to and immigrants IM from all other 30 regions are derived using the following equations,

$$EM_{i,s,g}^{x,t} = \sum_{j=1}^{30} EM_{ij,s,g}^{x,t} = \sum_{j=1}^{30} em_{ij,g}^{x} \times P_{i,s,g}^{x,t} \quad (i \neq j)$$

$$IM_{i,s,g}^{x,t} = \sum_{j=1}^{30} EM_{ji,g}^{x,t} \quad (i \neq j)$$

Input data of the multiregional population/urbanization projection for each region include:

- *Baseline Population* by age, gender and rural/urban residents for year 2000, based on the age gender structures derived from IPUMS data and UN demographic yearbooks, and scaled to match the regional population size of year 2000 in the UN Population Prospects 2012 Revision (UN 2013).
- *Patterns of Demographic Changes (Age and Gender Profiles)* of fertility rates, mortality rates, rural-to-urban migration rates, urban-to-rural migration rates, (mainly derived

from IPUMS data analysis, Human Mortality Database, Human Fertility Database, DHS survey data and other data sources), and international migration rates (from CDM-International Migration Dataset, derived from the UN Global Migration Database);

- *Volumes of Demographic Changes*: assumptions on life expectancy at birth, total fertility rate (TFR), sex ratio at birth, urbanization level, and trends in international migration (based the SSPs assumption can be obtained from IIASA SSP Database at https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about) .

To ensure the multiregional population/urbanization projections to be consistent with the SSPs population projections and SSPs urbanization projections, the model adjusts the rural-to-urban and urban-to-rural migration rates in each projection step and iterate the process so that the projected urbanization levels match the urbanization level in the SSPs urbanization projections.

3. Primary Results

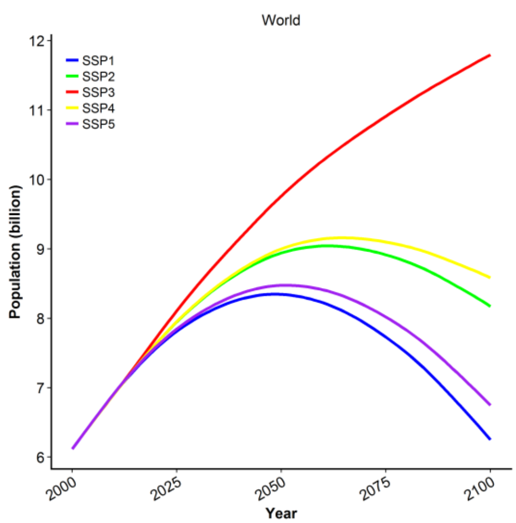

Figure 3 Global population growth under different SSPs

The projection results by using the multiregional population/urbanization model shows that the projected changes in total population size for the whole world (Figure 3) and for each region under different SSP scenarios are very close to the IIASA SSPs population projections. It shows that the world population grows above 12 billion by the end of the century under SSP3 (the fastest growth scenario), but will never go beyond 8.5 billion and move down to about 6 billion by the end of century under SSP1 (the slowest growth scenario). The projected urbanization level is also consistent with the NCAR SSPs urbanization projection, by the design of the model (not shown here).

The projected changes in age and gender structure of the rural and urban population, which does exist in the SSPs projections, are shown in Figure 4. It displays that urban population growth under SSP1 (the fast urbanization scenario) is much faster than under

SSP3 (the slow urbanization scenario). Population aging is also much faster under SSP1 than under SSP3. Moreover, a more careful analysis of population age structure between rural and urban areas reveals that in most of the developed and many developing regions, population aging in the rural areas is far more severe, mainly due to the age selectivity of the migrants. Figure 5 shows that under the slow urbanization and population growth scenario SSP3, the rural population in the US aged much faster than the urban population.

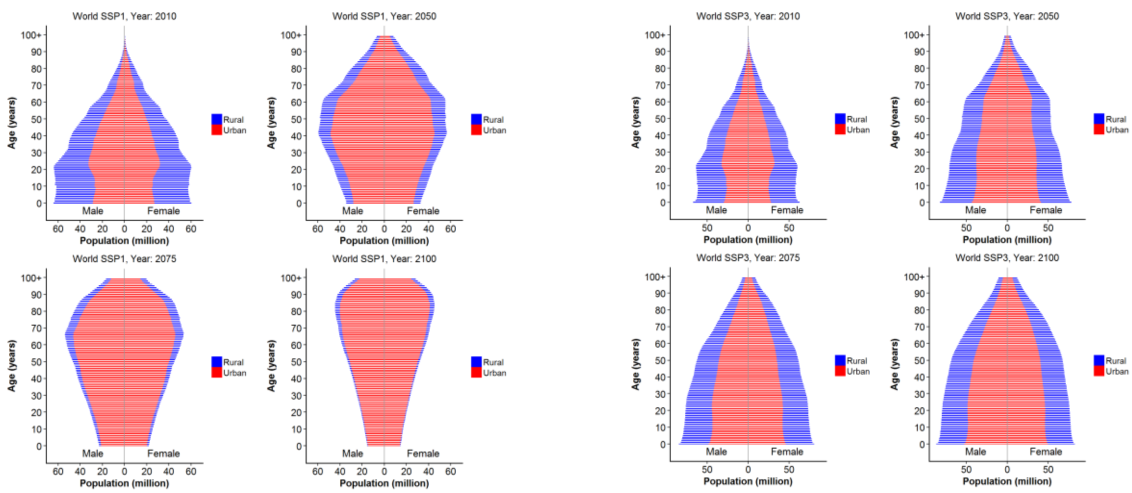

Figure 4 Global population pyramids by urban and rural under SSP1 and SSP3

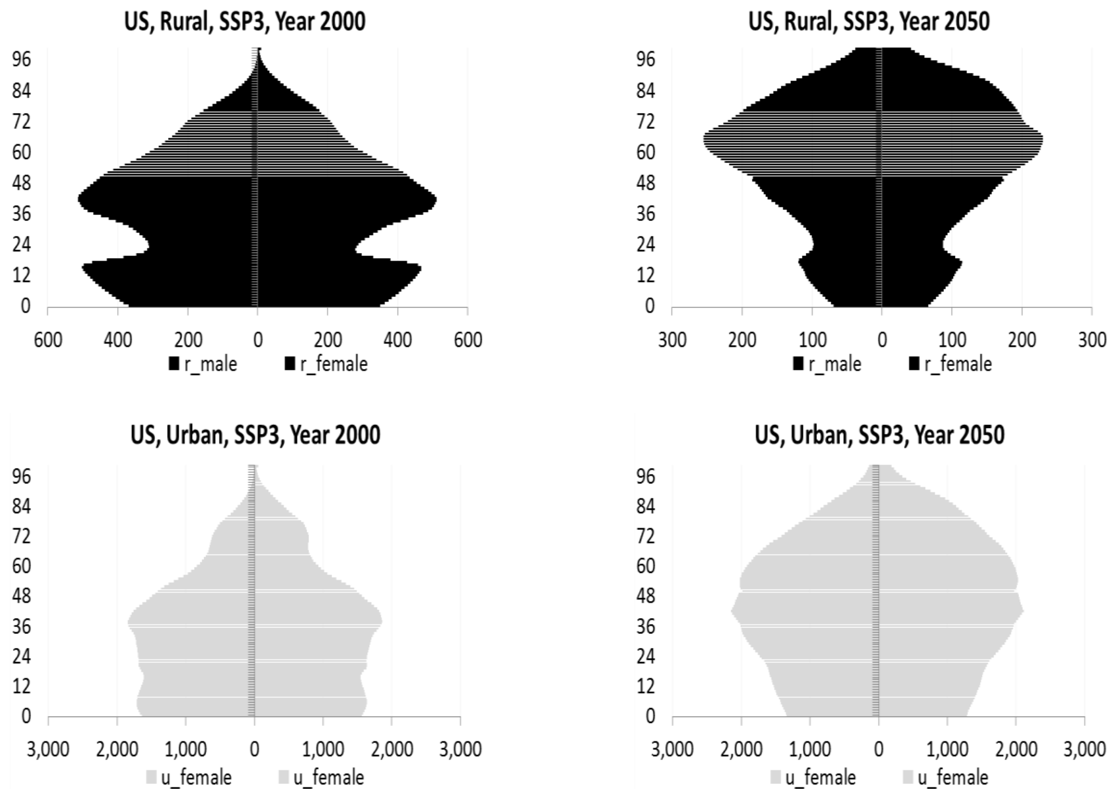

Figure 5 USA rural and urban population composition changes between 2000-2050 under SSP3

The analysis of India population/urbanization projection indicates that future urban population change is largely driven by migratory growth, particularly under the fast urbanization but slow population growth scenario SSP1. However, the sources of urban growth vary in different stages of urban transition.

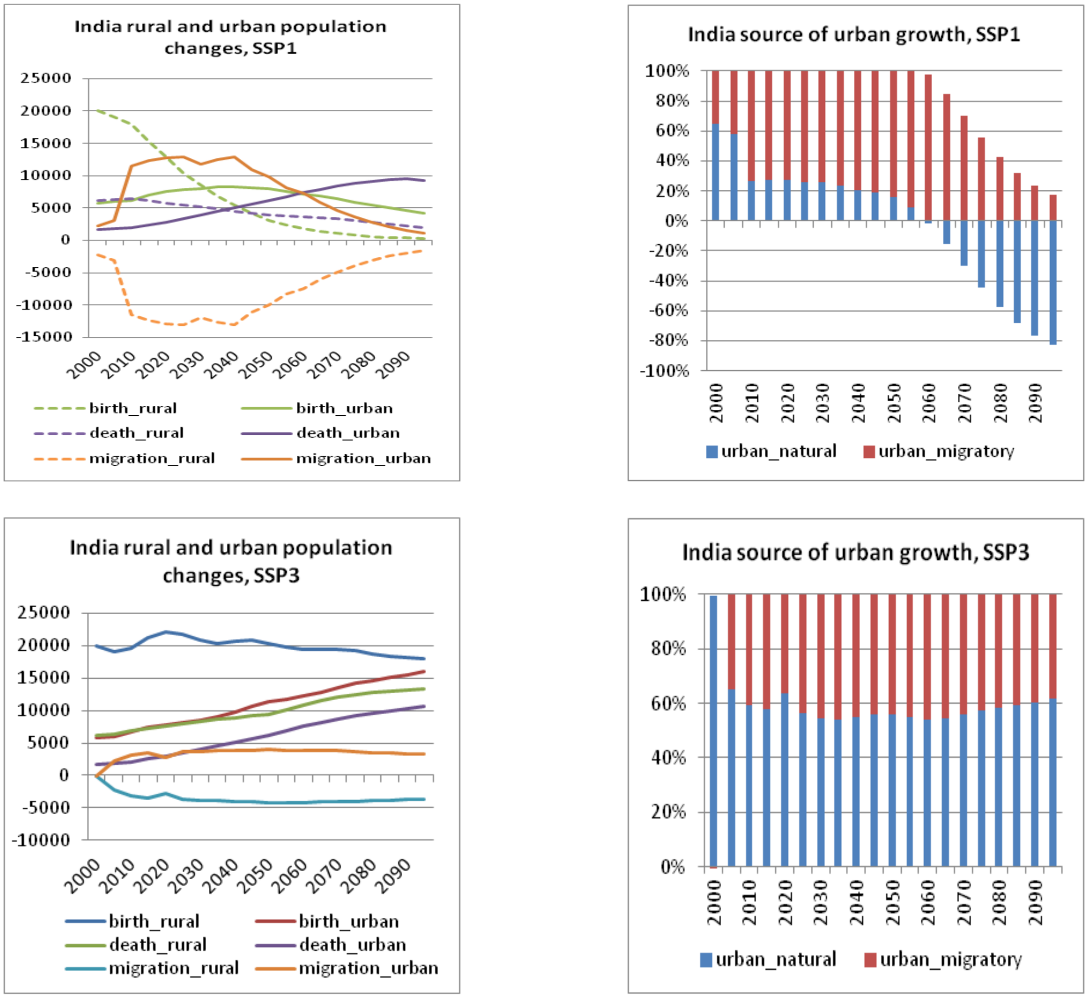

Figure 6. India urban and rural population changes due to natural and migratory growth under SSp1 and SSP5

Table 1 Simplified version of assumptions on key elements of the Shared Socioeconomic Pathways (SSPs)

SSP Element	SSP 1			SSP 2			SSP 3			SSP 4			SSP 5		
	Country Income Groupings														
	Low	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**
Population	Relatively low			Med			High		Low	Relatively high		Low	Relatively low		
Urbanization	Rapid			Central			Slow			Rapid	Rapid	Central	Rapid		
Education	High			Med			Low			V. Low/ unequal	Low/ unequal	Med/ unequal	High		
Economy Growth	High	High	Med	Med, uneven			Slow			Low	Med	Med	High		
Inequality	Reduced across and within countries			Uneven moderate reductions across and within countries			High, especially across countries			High, especially within countries			Strongly reduced, especially across countries		
Policy Orientation	Toward sustainable development			Weak focus on sustainability			Oriented toward security			Toward the benefit of the political and business elite			Toward development, free markets, human capital		
Technology Development	Rapid			Medium, uneven			Slow			Rapid in high-tech economies and sectors; slow in others			Rapid		

Source: Jiang and O'Neill forthcoming.