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# Internal migration and urbanization in China: Impacts on population exposure to household air pollution (2000–2010)

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## HIGHLIGHTS

- We identify changes in household fuel use in China from 2000 to 2010.
- We estimate how the population exposure to $PM_{2.5}$ changed over the decade.
- ~60% of the total exposure reduction of about 50 μg/m$^3$ can be linked to migration.
- Annual mean $PM_{2.5}$ exposure of rural–urban migrants was reduced by about 215 μg/m$^3$.
- The annual health benefit from the energy transition is about 30 billion USD.

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## ABSTRACT

Exposure to fine particles ≤2.5 μm in aerodynamic diameter ($PM_{2.5}$) from incomplete combustion of solid fuels in household stoves, denoted household air pollution (HAP), is a major contributor to ill health in China and globally. Chinese households are, however, undergoing a massive transition to cleaner household fuels. The objective of the present study is to establish the importance of internal migration when it comes to the changing household fuel use pattern and the associated exposure to $PM_{2.5}$ for the period 2000 to 2010. We also estimate health benefits of the fuel transition in terms of avoided premature deaths. Using China Census data on population, migration, and household fuel use for 2000 and 2010 we identify the size, place of residence, and main cooking fuel of sub-populations in 2000 and 2010, respectively. We combine these data with estimated exposure levels for the sub-populations and estimate changes in population exposure over the decade. We find that the population weighted exposure (PWE) for the Chinese population as a whole was reduced by 52 (36–70) μg/m$^3$ $PM_{2.5}$ over the decade, and that about 60% of the reduction can be linked to internal migration. During the same period the migrant population, in total 261 million people, was subject to a reduced population weighted exposure (ΔPWE) of 123 (87–165) μg/m$^3$ $PM_{2.5}$. The corresponding figure for non-migrants is 34 (23–47) μg/m$^3$. The largest ΔPWE was estimated for rural-to-urban migrants (138 million people), 214 (154–283) μg/m$^3$. The estimated annual health benefit associated with the reduced exposure in the total population is 31 (26–37) billion USD, corresponding to 0.4% of the Chinese GDP.



## 1. Introduction

Photos and news stories from today's Chinese cities often tell a story of extreme urban air pollution. According to the comparative risk assessment of the Global Burden of Disease Study 2010 (Lim et al., 2012; IHME, 2013), ambient urban particulate air pollution (fine particles ≤2.5 μm in aerodynamic diameter ($PM_{2.5}$)) causes 1.2 million premature deaths annually in the country, making it the fourth most important risk factor for premature death. One may presume that migrating from rural to urban areas in China entails an increased exposure burden for the individual migrant. In actual fact it entails an increased exposure to *urban ambient* $PM_{2.5}$ pollution. Whether it entails an increased *overall* exposure to $PM_{2.5}$ depends on the migrant's previous exposure to $PM_{2.5}$. As the majority of the rural population in China still uses traditional fuels and inefficient stoves, rural–urban migrants often come from a setting of high exposures to smoke particles ($PM_{2.5}$) from household stoves, so-called household air pollution (HAP).

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On an annual basis HAP is estimated to cause about 1 million premature deaths in China, making it the fifth most important risk factor in 2010, down from number one in 1990 (Lim et al., 2012).

The reduced role of HAP as a contributor to ill health in China is a result of the transition to cleaner fuels that is taking place in Chinese households. In the decade from 2000 to 2010, the number of households reporting to have solid fuel (firewood or coal) as their main cooking fuel fell substantially, from 900 million to 650 million. In 2010, 80% of urban and 23% of rural households reported to have clean fuels (gas or electricity) as their main cooking fuel (AMCR, 2004; NBS, 2012).

Several factors have contributed to household fuel switch in China. Income and education level have been identified as robust determinants of household energy choices. In addition, accessibility of energy resources has been identified as a key determinant (Jiang and O'Neill, 2004; O'Neill et al., 2012a; Papineau et al., 2009; Peng et al., 2010). Since access to modern fuels depends on infrastructure for their distribution, urbanization as such plays a key role in energy transition (Krey et al., 2012; Leach, 1992; O'Neill et al., 2012a, b). Moving from a rural to an urban area is likely to enhance access to cleaner household fuels. Thus, the massive migration from rural to urban areas taking place in China likely played an important role for the household energy transition happening during the last decade.

Urban–rural migration likely reduces the exposure to $PM_{2.5}$ from HAP. At the same time exposure to $PM_{2.5}$ from urban ambient sources may increase. To our knowledge, no previous study has attempted to quantify the impact of migration on the overall population exposure to $PM_{2.5}$ in China or elsewhere. Such knowledge would be important e.g., for formulating migration policies and shaping urban green growth, as reducing the overall exposure to pollutants is important for creating healthy living conditions and enhancing welfare. The objective of the current paper is to estimate how the exposure to $PM_{2.5}$ pollution in the Chinese population has changed over the period 2000 to 2010 as a result of migration on the one hand and general household fuel switch on the other hand. We also estimate health effects in terms of avoided premature deaths from the estimated changes in population exposure and the monetized value of the avoided deaths.

## 2. Materials and methods

### 2.1. Population data

We use China Census data to establish the number of internal migrants in China in 2010 and the population residing in urban and rural areas in China's 31 provinces/autonomous regions/municipalities (denoted provinces below) in 2000 and 2010 (Table 1 and Fig. 1) (ACMR, 2004, 2012; NBS, 2012). To be counted as a migrant in the China Census database a person needs to have stayed away from home, i.e. the place where he or she has the household registration, *hukou* in Chinese, for at least 6 months. There are two types of hukou in China, those born in rural areas generally get agricultural hukou while those born in cities get nonagricultural hukou. The two groups are often referred to as rural and urban hukou, and we use these terms in the following (see Meng, 2012 for a description of the household registration system in China).

In the China Census database migrants' current residence (i.e. location of immigration) is defined by the administrative type of setting, and is divided into three: City, town, or rural. We pool the two first groups into 'urban immigrants', i.e. migrants that live in urban areas. In the data for emigration (i.e. from where migrants originally came and still have their household registration) rural areas are differentiated into two, thus there are four types: City, town, village, or township. The first two groups are urban or semi-urban and refer to those with urban hukou. In the following they are pooled into 'urban emigrants', i.e. migrants that come from urban areas. The last two are rural or semi-rural and refer to those with rural hukou. In the following these are pooled into 'rural emigrants'.

The total number of migrants in China in 2010 was 261 million. Of these, 138 million, i.e. 53%, came from rural areas and settled in urban areas (Table 1). About two thirds (67%) of the migrants are intra-provincial migrants, i.e. they have not left for another province, as opposed to inter-provincial migrants, who have left for another province. Nearly half (48%) of the migrant population are women.

The detailed data on migration pattern per province is available in the so-called Long-form database, covering approximately 10% of the total Chinese population (NBS, 2012). The total number of migrants per province is given in the Short-form database which covers 100% (NBS, 2012). For all of China in total and for the eight provinces hosting the largest number of migrants we extract the home province of the migrant population, and whether migrants come from and settled down in urban or rural areas from the Long-form database (example shown in Fig. S1). We divide the migrants' home and host province into northern and southern, defined by whether the main area is located North or South of the Yangtze river (allocation given in Fig. 1). For each province the data are scaled up to a 100% sample by applying the ratio of migrants in the 10% database to the number of migrants in the 100% database.

### 2.2. Estimating population weighted exposure in 2000 and 2010

We estimate the population weighted exposure to $PM_{2.5}$ (PWE) in the total Chinese population (including sub-groups according to location) and the migrant population (including sub-groups according to location of origin and destination) for 2000 to 2010. The change in PWE (ΔPWE) from 2000 to 2010 for total and migrant populations is calculated as the difference between the PWE of the given population group in 2010 versus 2000.

In the following 'migrants' refers to those who were defined as migrants in 2010 according to the definition given above. 'Non-migrants' denote those who were not migrants in 2010, i.e. those who in 2010 were living in their home settlement according to the Census data. Corresponding figures for the eight largest host provinces were also calculated (Table 2). PWE in the given year (2000 or 2010), for a population group $P$, is calculated as:

$$PWE_P = \frac{1}{P}\sum_{i,j}\left(P_{i,j}\cdot PWE_{i,j}\right) \quad (1)$$

where $i$ refers to location of $P$ (any combination of urban or rural, North or South) and $j$ refers to household fuel categories of $P_i$ (clean, coal, or

**Table 1**
Total population in 2000 and 2010 and number of migrants in China in 2010 (million). NBS (2012) and ACMR (2004).

| Total population | Total | Rural | Urban |
|---|---|---|---|
| Year 2000 | 1241 | 758 | 483 |
| Year 2010 | 1333 | 659 | 674 |
| **Migrant population in 2010** | **Total** | **Migrated from rural areas** | **Migrated from urban areas** |
| Total | 261 | 164 (63%) | 97 (37%) |
| Current residence is urban | 227 | 138 (60%) | 90 (40%) |
| Current residence is rural | 34 | 27 (80%) | 7 (20%) |