

## Inter-regional Population Migration in China under Climate Change and Its Impacts: Postprint

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### Abstract

Climate change-induced population migration in China is not only a scientific issue, but also a significant policy concern that warrants focused attention. This article estimates the scale of climate change-induced population migration by analyzing changes in agricultural production potential. The study finds that under conditions of altered agricultural production potential due to climate change, China's Bohai Rim region, mature industrialized areas, and newly industrialized areas become the primary population outflow regions and will face severe labor shortages. Using a dynamic multi-regional CGE model, we analyze the impacts of changes in population distribution patterns on regional growth, regional disparities, and resident welfare. The results indicate that economic growth accelerates in population inflow destinations while decelerating in outflow origins, with larger migration scales producing greater economic impacts; population migration widens intra-regional disparities, narrows inter-regional disparities, and reduces overall regional inequality. Future regional policies in China must account for these effects.

### Full Text

#### Preamble

#### Climate Change-Induced Interregional Population Migration in China and Its Impacts

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## Abstract

Climate change-induced population migration in China represents not only a scientific issue but also a critical policy concern requiring urgent attention. This study estimates the scale of climate-driven migration by analyzing changes in agricultural production potential. The findings reveal that under altered agricultural production potential due to climate change, the Circum-Bohai-Sea region, mature industrialized regions, and newly industrializing regions will become primary sources of out-migration and face severe labor shortages. Using a dynamic multi-regional Computable General Equilibrium (CGE) model, we analyze how shifts in population distribution affect regional growth, regional disparities, and resident welfare. The results indicate that population in-migration accelerates economic growth in destination regions while out-migration reduces growth in source regions, with larger migration scales producing greater economic impacts. Population migration expands intra-regional gaps while narrowing inter-regional gaps, leading to an overall reduction in total regional disparity. Future Chinese regional policies must account for these effects.

**Keywords:** climate change, population migration, agricultural production potential, regional gap, household welfare

## Introduction

As global climate change intensifies, climate has become a key factor influencing population migration. Throughout human history, large-scale migrations—however complex or dramatic their manifestations—have essentially represented resource reallocation processes driven by changes in climate and agricultural conditions. While industrialization and informatization have somewhat diminished the importance of climate and agricultural factors in human settlement decisions, food security remains fundamental to human survival. The response of agriculture (or agricultural production potential) to climate change undoubtedly remains one of the decisive factors in migration decisions. Estimates suggest that climate change-related increases in tropical cyclone intensity and heavy rainfall frequency, soil drought causing agricultural productivity declines, and sea-level rise from ice melt could displace millions globally [1,2], with some projections indicating 200 million people may migrate due to climate and environmental factors by 2050 [3].

Regarding the socioeconomic impacts of population migration, while leaving environmentally degraded and agriculturally unsustainable areas represents an adaptive measure to reduce environmental pressure, it inevitably causes labor and capital loss that hinders economic development in source regions. Simultaneously, migrants increase pressure on natural resources and the environment in destination regions while posing serious challenges to local economic growth patterns, infrastructure, and healthcare, thereby affecting resident income levels and welfare [4,5]. More critically, large-scale national migration may significantly alter regional ecological conditions and economic disparity levels, disrupt

regional equilibrium, and trigger new social problems.

One research direction on climate change-induced migration in China examines the climate-agriculture-food-population nexus to analyze migration and its socioeconomic impacts. Following this logic, this paper establishes a population distribution model based on agricultural production potential to calculate climate change impacts on agricultural output and estimate future population distribution patterns. We then employ a dynamic multi-regional Computable General Equilibrium (CGE) model as a policy simulation tool to further analyze how migration affects economic growth, household welfare, and regional disparities.

## 1. Climate Change Impacts on Population Distribution

Climate change primarily affects agricultural ecological conditions and production potential through alterations in temperature, precipitation, and sunlight, thereby influencing agricultural output. Calculating agricultural production potential allows estimation of a region's expected agricultural output and, consequently, its population carrying capacity. By comparing regional population carrying capacities before and after climate change, we can derive interregional population distribution patterns and migration scales.

### 1.1 Climate Change Population Distribution Model

**1.1.1 Regional Division** Given China's vast territory and varying regional climate change impacts, this study divides 30 provinces, municipalities, and autonomous regions (Tibet, Hong Kong, Macau, and Taiwan are excluded due to data limitations) into eight regions based on industrial development characteristics.

**1.1.2 Agricultural Production Potential** Building on long-term research at the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Huang Bingwei [6] proposed that agricultural production potential satisfies the following relationship:

$$P = F(Q)$$

where  $P$  represents agricultural production potential,  $F(Q)$  represents photosynthetic production potential expressed in dry matter (kg/ha), and  $Q$  represents total solar radiation (KJ/(cm<sup>2</sup> · a)).  $T$  represents temperature,  $W$  represents water availability, and  $S$  represents soil conditions.

Production potential baseline data are derived from Zhong Zhangqi et al. [7], whose research shows that climate change increases agricultural production potential across nearly all regions to varying degrees. Since this data uses prefecture-level cities as units, this paper calculates China's agricultural production potential using area-weighted aggregation. Furthermore, because climate

change operates on time series rather than time points, we select 2001–2012 as the baseline period and 2041–2060 as the target period to estimate future changes in China’s agricultural production potential.

**1.1.3 Agricultural Production Potential and Grain Output** Although climate change can increase agricultural production potential nationwide, the magnitude of improvement varies by region. In regions with rapid population growth, if grain output growth cannot meet rapidly increasing demand, a substantial gap between production and demand will emerge, creating supply–demand imbalances. Without considering interregional grain transfers, population migration becomes inevitable. This paper assumes population distribution aligns with food supply capacity, enabling prediction of regional grain changes through agricultural production potential, which further allows forecasting of China’s future population distribution patterns.

Since agricultural production potential is determined by temperature, precipitation, evaporation, and soil coefficients—where temperature, precipitation, and evaporation are significantly affected by climate change—production potential is highly climate-sensitive. Agricultural production potential can be understood as theoretical grain yield per unit area. While this value deviates from actual yields, it exhibits strong correlation with actual grain yield per unit cultivated land. Using data from 2001–2012 and 1990–2000, this paper calculates the correlation between national agricultural production potential and average grain yield per unit cultivated land, revealing a strong correlation with a coefficient exceeding 0.8. Therefore, future grain yields can be predicted through production potential. Regressing grain yield per unit cultivated land against agricultural production potential for 2001–2012 yields the following relationship:

$$UCG = 0.228 \times APP$$

where *UCG* represents grain yield per unit cultivated land and *APP* represents agricultural production potential.

**1.1.4 Grain Output and Regional Carrying Capacity** Based on grain yield projections and assuming constant per capita grain supply structure across regions—that is, the ratio of per capita grain output across regions in the target period equals that in the baseline period—we derive future population distribution. It should be noted that this paper discusses population migration based on the maximum sustainable population capacity of agriculture.

Baseline population data are obtained from the *China Statistical Yearbook 2013*. Target period initial total population data come from the medium-growth scenario of the *UN Population Prospects: 2010 Revision*. Natural growth rates are calculated using 2001–2012 Chinese population data combined with UN projections for 2041–2060. Regional grain yield and cultivated land area data

for 2001-2012 are sourced from the *China Statistical Yearbook 2002-2013*. Regional population data are extrapolated based on baseline regional population proportions.

The model is specified as:

$$P_{2,j}^{(1)} = P_{1,j} \cdot \mu$$

where  $P_{1,j}$  represents population in region  $j$  during 2001-2012,  $\mu$  represents the natural growth rate, and  $P_{2,j}^{(1)}$  represents the natural population in region  $j$  during 2041-2060.

$$P_{2,j} = P_{2,j}^{(1)} + P_{2,j}^{(2)}$$

where  $P_{2,j}$  represents total population in region  $j$  during 2041-2060, and  $P_{2,j}^{(2)}$  represents net migration population in region  $j$  during 2041-2060.

$$\frac{TG_{1,j}}{P_{1,j}} = tg_{1,j}$$

$$\frac{TG_{2,j}}{P_{2,j}} = tg_{2,j}$$

In equations (5) and (6),  $TG_{1,j}$  represents total grain output in region  $j$  during 2001-2012,  $TG_{2,j}$  represents total grain output in region  $j$  during 2041-2060,  $tg_{1,j}$  represents per capita grain output in region  $j$  during 2001-2012, and  $tg_{2,j}$  represents per capita grain output in region  $j$  during 2041-2060, with the constraint:

$$tg_{1,1} : tg_{1,2} : \dots : tg_{1,8} = tg_{2,1} : tg_{2,2} : \dots : tg_{2,8}$$

Equation (7) indicates that the model assumes the ratio of per capita grain output across regions in the target period equals that in the baseline period due to population migration. This assumption primarily considers ecological factors: the structural level of population support capacity remains constant across regions, with humanity advancing or retreating together in agricultural ecological conditions.

## 1.2 Climate Change Population Distribution and Migration

Based on the population distribution model in Section 1.1, we calculate climate change impacts on regional population distribution. The results show that

total migration due to climate change shocks in the target period will reach approximately 190 million people, accounting for about 14% of the national population. Four regions experience out-migration: the Circum-Bohai-Sea region, Yangtze River Delta region, mature industrialized region, and newly industrializing region. Among these, the Circum-Bohai-Sea region, mature industrialized region, and newly industrializing region are the primary sources, contributing 99% of total out-migrants. The remaining four regions are destinations, with the Southeast coastal region, energy base region, and environmentally fragile region being the main recipients, accounting for 97% of total in-migrants. In terms of migration relative to regional population size, the Southeast coastal region's in-migration exceeds 30% of its local population, while the Yangtze River Delta and classic industrial base regions experience minimal migration (both under 3%). The Yangtze River Delta shows the lowest proportion, with out-migrants comprising only 0.37% of its population.

It should be noted that some argue grain transfers should take priority over population migration, which is technically convenient to implement. However, such research logic is based on assumptions of general stability, short time scales, absence of climate catastrophes, no major changes in international and domestic trade environments, and exclusion of extreme social changes, focusing on short-term realistic scenarios. This study temporarily abandons the grain transfer mechanism primarily because food security is the nation's lifeline. Even under medium-to-long-term climate change shocks, each region must maintain certain self-sufficiency capacity as a basic national security requirement. This study thus provides a baseline for long-term climate change-induced migration, meaning that even during severe natural and social crises, regions can still guarantee basic food supply, upon which population migration then occurs. As forward-looking scientific and policy research, this red-line design is reasonable. While we fully agree that grain transfers are important in population migration, given the conflict between its short-term realism and this study's long-term early warning purpose, we prefer to leave exploration of such mechanisms to other work.

## 2. Impacts of Climate Change-Induced Migration

Large-scale climate change-induced migration inevitably significantly impacts economic growth, household welfare, and regional disparities—issues crucial for future regional policy regulation that can be simulated through dynamic multi-regional CGE modeling.

This multi-regional CGE model employs a hierarchical social accounting matrix equilibrium approach, using SAM-expressed equilibrium relationships as the starting point to establish general economic equilibrium, then describing economic processes from this equilibrium. The model builds on references [8] and [9] with substantial algorithmic improvements. Model solving employs an improved Johansen-Euler algorithm oriented toward Euclidean norms and Moore-Penrose generalized inverse matrices, with system operation based on a multi-regional

policy simulation platform for climate change economic analysis. Model data primarily come from the “China 2007 Interregional Input-Output Table for 30 Provinces and Municipalities” compiled by Liu Weidong’s research group [10] and multi-regional SAM tables compiled by our research group. As this paper focuses on policy research, the model itself is not discussed further.

## 2.1 Policy Scenarios

Population migration comprises labor and non-labor migration, but current Chinese migration is primarily labor migration represented by migrant workers. Following general patterns, this paper assumes labor accounts for 90% of migrants, enabling inference of labor migration volumes from total migration figures. We then use the dynamic multi-regional CGE model to analyze how population distribution changes affect regional economic development and disparities.

This paper designs the following migration scenarios:

**Baseline Scenario (A0):** Population and economy grow naturally according to development inertia.

**Migration Scenario (A1):** Regional labor forces in each sector grow (or decline) linearly during the study period according to the migration scenario described in Section 1.2; regional migration populations remain consistent annually (i.e., annual new migrants are constant); out-migrants leave according to the proportion of labor in each industry in source regions, while in-migrants are allocated to industries in destination regions according to local labor proportions. Population growth follows the medium-growth scenario of the *UN Population Prospects: 2010 Revision*, with labor proportions calculated based on labor force participation rates and allocated according to previous-year regional industry labor proportions.

**2.1.1 Regional Economic Growth Impacts** National GDP annual growth rates in the baseline scenario show continuous decline, dropping to approximately 5.7% by 2025 and 2.73% by 2040, with annual growth rate reductions of 0.1%-0.3%. Under migration scenario A1, population migration further reduces overall economic growth, though the impact is not particularly strong. Further observation reveals that climate change-induced migration has the greatest economic impact in the early simulation period, with GDP growth rates 0.3 percentage points lower than the baseline scenario, while by the end period, the GDP growth rate is 2.7%, only 0.03 percentage points below baseline. Thus, migration’s negative GDP impact gradually diminishes over time.

Examining regional growth under both scenarios reveals several commonalities: compared to national average growth rates, the Southeast coastal region and newly industrializing region show GDP growth above the national average, while the Circum-Bohai-Sea region, Yangtze River Delta region, energy base region, classic industrial base region, and mature industrialized region fall below the

national average. The environmentally fragile region's GDP growth roughly matches the national average.

Per capita GDP trends show growth under both scenarios, but labor migration alters growth patterns in source and destination regions compared to baseline. Notably, the four out-migration regions show lower per capita GDP under baseline than under migration scenario, while the four in-migration regions show higher per capita GDP under baseline than under migration scenario. Although migration accelerates destination regions' economic development, this acceleration remains slower than migration itself, resulting in lower per capita GDP. Conversely, while source regions experience slower GDP growth, population decline exceeds the GDP growth slowdown, leading to increased per capita GDP—a phenomenon worth noting regarding resource and environmental pressures.

In summary, climate change-induced migration slows national economic growth. Migration's regional economic effects correlate with migration direction: it increases GDP growth in destination regions while decreasing it in source regions, with larger migration scales producing greater impacts that gradually weaken over time.

**2.1.2 Household Welfare Impacts** Table 5 presents changes in regional per capita income growth rates under climate change. Clearly, source regions show higher income growth rates under baseline than under migration scenario, with growth rates gradually converging over time. Destination regions show lower income growth rates under baseline than under migration scenario, with in-migration reducing the magnitude of income increases. Table 6 reveals that per capita consumption changes follow essentially the same trends and characteristics as income changes.

Thus, climate change-induced population redistribution reduces the magnitude of income and consumption growth to some extent. Migration direction affects these changes: source regions experience reduced consumption and income growth rates, while destination regions experience increased rates, though these effects gradually weaken over time.

**2.1.3 Regional Disparity Impacts** Climate change-induced migration inevitably alters regional disparities—a critical issue in China. This paper employs the Theil coefficient to analyze regional gaps. In equation (8),  $I_0(x)$  represents the overall Theil coefficient reflecting total regional disparity,  $x_i$  is the GDP of region  $i$ ,  $\bar{x}$  is the mean GDP across all regions, and  $n$  is the number of regions.

Overall regional disparity trends [Figure 2: see original paper] show that under baseline scenario, total regional disparity gradually expands from 0.109 in 2012 to 0.145 in 2040, an increase of 0.036. Under migration scenario, regional disparity also increases annually but at a smaller magnitude, growing by only 0.016 from 2012 to 2040. Thus, migration slows the expansion of regional disparity. While the difference in total regional disparity between scenarios gradually

widens, the rate of widening slows.

We further decompose regional disparity into intra-regional and inter-regional components using Shorrocks' method [16,17]. In equation (9), the left side represents total Theil coefficient, the right side's first term represents within-group Theil coefficient, and the second term represents between-group Theil coefficient.  $K$  is the number of regional groups,  $P_k$  is group  $k$ 's population share, and  $V_k$  is group  $k$ 's GDP share.

Intra-regional disparity trends [Figure 3: see original paper] show that under both scenarios, within-region gaps gradually expand over time. However, intra-regional disparity under migration scenario is smaller than under baseline scenario—the opposite of total disparity trends. By 2040, baseline intra-regional disparity expands to 0.0224, while migration scenario intra-regional disparity reaches 0.0226, 0.9 percentage points higher.

Inter-regional disparity trends [Figure 4: see original paper] align with total disparity patterns, gradually expanding over time. Baseline inter-regional disparity exceeds migration scenario values, with the difference between scenarios gradually widening but at a slowing pace. Combining intra- and inter-regional effects, migration narrows inter-regional gaps while expanding intra-regional gaps, with the net result reducing overall regional disparity.

### 3. Summary and Discussion

This paper constructs a climate change economics model to analyze climate change impacts on agricultural production potential and their subsequent effects on population distribution and migration, then uses a dynamic multi-regional CGE model to examine how population redistribution affects regional economies, regional disparities, and household welfare.

Simulation results indicate that under altered agricultural production potential, primary out-migration regions will be the Circum-Bohai-Sea region, mature industrialized regions, newly industrializing regions, and the Yangtze River Delta region. These regions, facing out-migration 叠加 rapid aging, will encounter severe labor shortages affecting economic development. They must remain vigilant and promptly formulate policies to attract talent.

Regarding migration impacts, climate change-induced migration increases GDP growth in destination regions while decreasing it in source regions, with larger migration scales producing greater impacts that gradually weaken over time. Migration reduces the magnitude of income and consumption growth nationally. Notably, migration expands intra-regional gaps while narrowing inter-regional gaps, with the combined effect ultimately reducing total regional disparity.

It should be clarified that this analysis of migration under climate change-induced agricultural production potential shifts is not a prediction of the future but rather an exploration of potential migration scenarios for climate adaptation. In reality, given improved transportation and migration inertia, unless extreme

climate change causes catastrophic shifts in agricultural production potential, interregional grain transfers would generally be prioritized over population migration. However, this does not mean climate change impacts on population distribution can be ignored. If compounded by indirect effects through economic systems, large-scale Chinese population migration will become an unavoidable spatial transformation.

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