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Supplementary Materials for

Forty years of reform and opening up: China's progress toward a sustainable path

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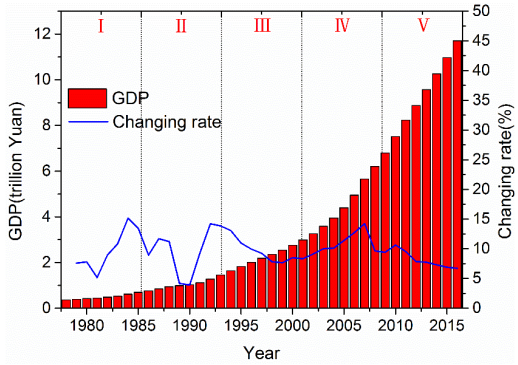
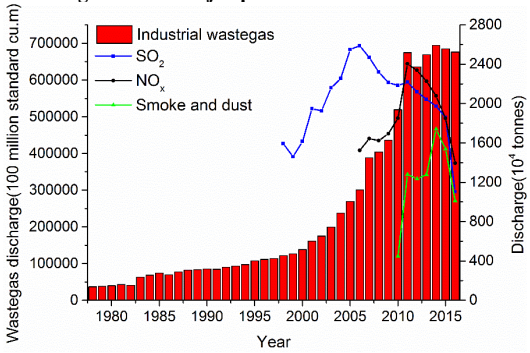
Figures:

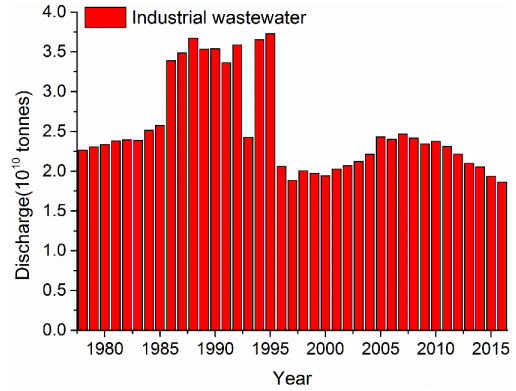
A Economic growth in China



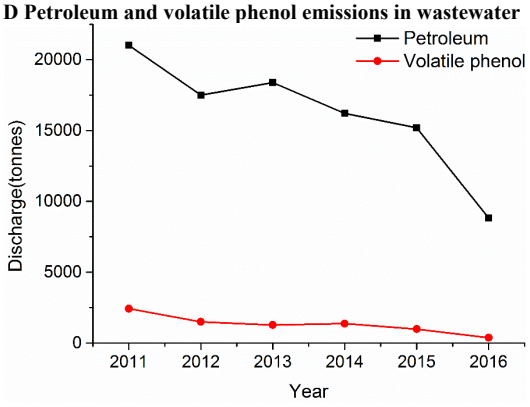
B waste gas and its major pollutants emission



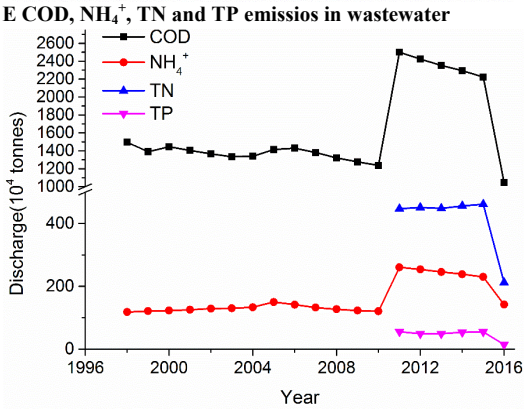
C Wastewater emission



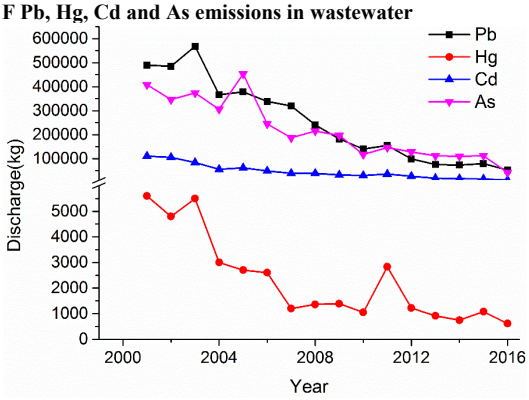
D Petroleum and volatile phenol emissions in wastewater



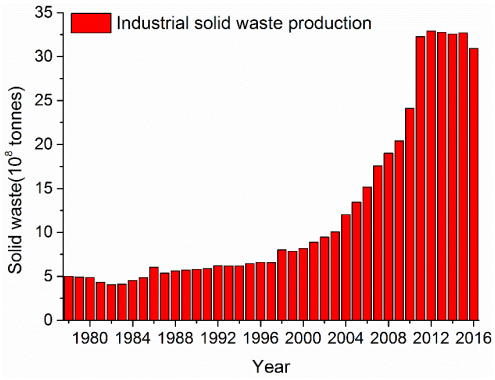
E COD, NH_4^+, TN and TP emissios in wastewater



F Pb, Hg, Cd and As emissions in wastewater



G Solid waste production



H CO_2 emission

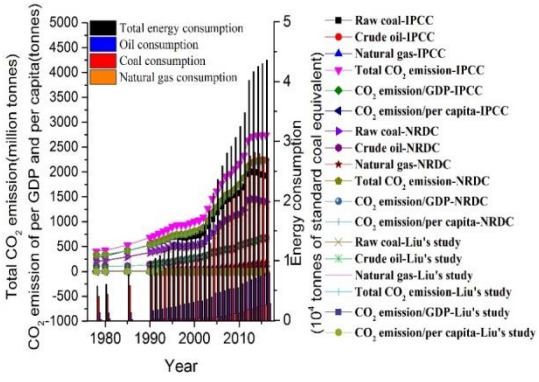
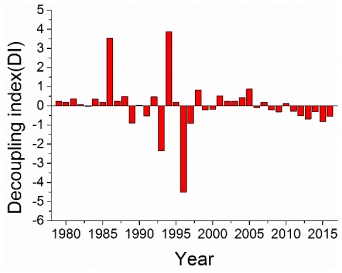
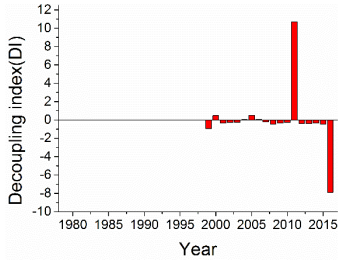


Fig. S1. Economic growth, total emissions of waste gas, wastewater, solid waste and CO_2, and the major pollutant emission in waste gas, wastewater, and solid waste in China from 1978 to 2016. With economic growth, environmental emissions including waste water, gas and solid are rapidly increasing as well. Industrial wastewater discharge presented an increasing trend from 1978 to 1995, then decreasing from 2005 to 2016. Chemical Oxygen Demand (COD) and Ammonium Nitrogen (NH_4^+) discharge stabilized from 1998 to 2010, and increased by 1.01 and 1.17 times in 2011 respectively, then declined steadily. The discharge level of COD might top the world in 2011. The other pollutants in wastewater showed a decreasing trend from 2002 or 2011, such as total nitrogen (TN), total phosphorus (TP), petroleum, volatile phenol and major heavy metals. Industrial waste gas and solid waste discharge have been increasing rapidly from 1978 to 2011, and keep stable and downward slightly in recent years. Sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emitted from coal-fired power plants, and industry is a major source contributing to China's air pollution. SO_2 emissions increased by 55% from 1998 to 2007 and reached the peak and topped the world in 2007. Energy consumption amount increased by 6 times from 1978 to 2016. Carbon dioxide (CO_2) emissions and CO_2 emission per capita showed a clear relationship with the growing economy from 1978 to 2012. Data source: China Statistical Yearbook (1979-2017) and China Statistical Compendium 1949-2014 (http://www.stats.gov.cn/english/). CO_2 emission calculation is described in Supplementary Methods.

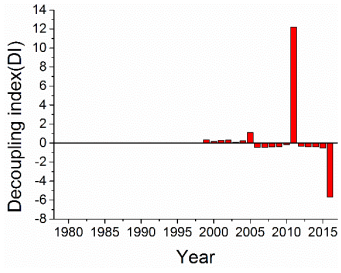
A wastewater



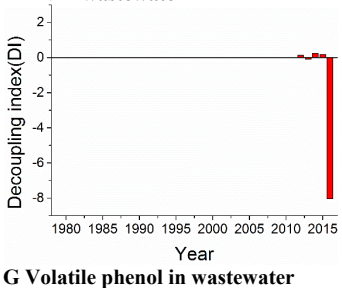
B COD in wastewater



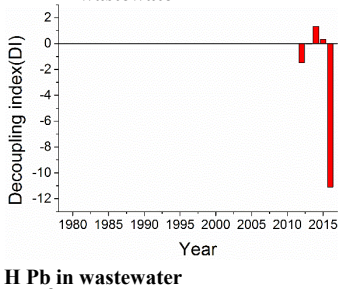
C NH_4^+ in wastewater



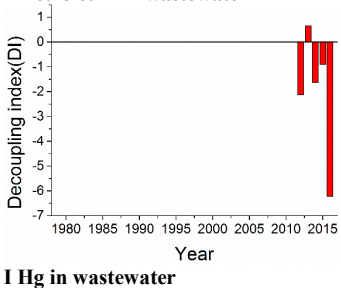
D TN in wastewater



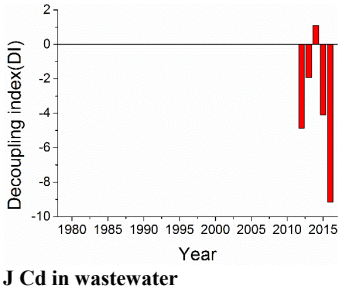
E TP in wastewater



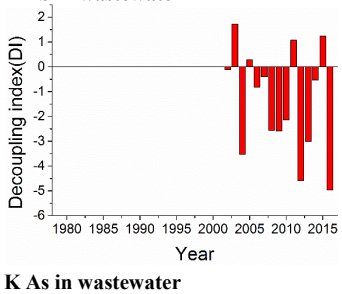
F Petroleum in wastewater



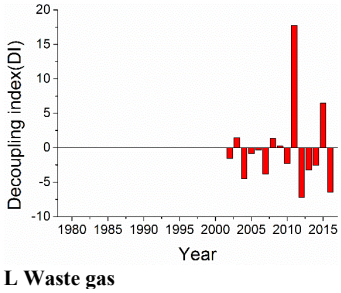
G Volatile phenol in wastewater



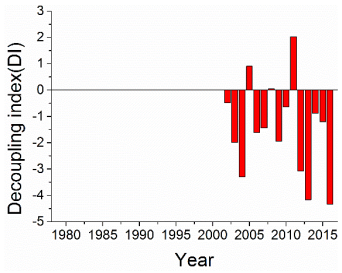
H Pb in wastewater



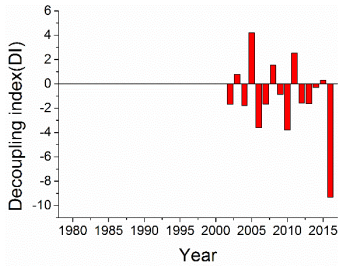
I Hg in wastewater



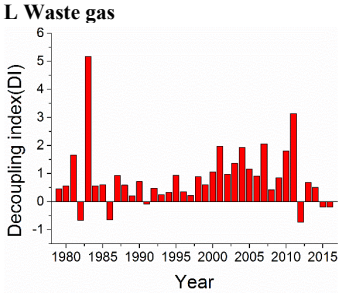
J Cd in wastewater



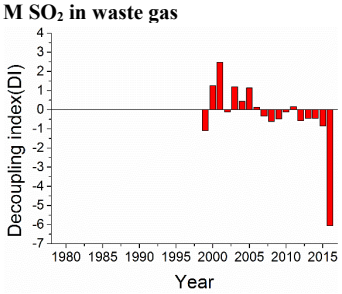
K As in wastewater



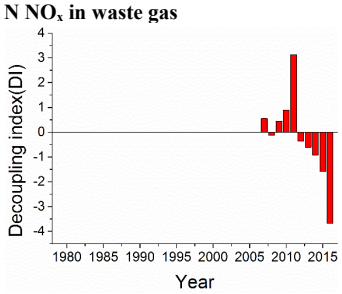
L Waste gas



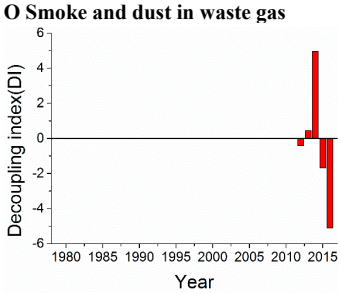
M SO_2 in waste gas



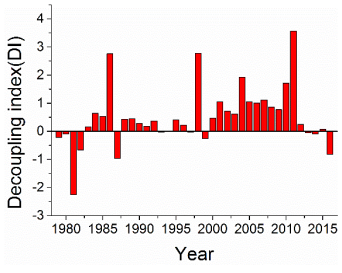
N NO_x in waste gas



O Smoke and dust in waste gas



P Solid waste



Q CO_2 emission

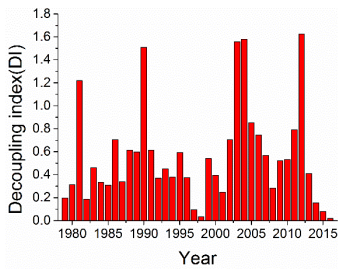


Fig. S2. DI of wastewater, waste gas, solid waste, smoke and dust, SO_2 emission, and CO_2 emission to GDP growth. Chemical oxygen demand (COD), ammonia nitrogen (NH_4^+), total nitrogen (TN), total phosphorus (TP), petroleum and volatile phenol have shown a decreasing trend since 2002 and major heavy metals in wastewater have shown a similar decreasing trend since 2011, with DI less than 0 and even -1, indicating decoupling with economic growth. The major pollutants in industrial waste gas such as sulfur dioxide (SO_2), nitrogen oxide (NO_x) and smoke dust presented a clear transformation from coupling to decoupling with economic growth, with the turning point in 2007, 2011 and 2014, respectively. The turning point for CO_2 has not yet been reached. Data source: China Statistical Yearbook (1979-2017) and China Statistical Compendium 1949-2014 (http://www.stats.gov.cn/english/). Decoupling index is described in Supplementary Methods.

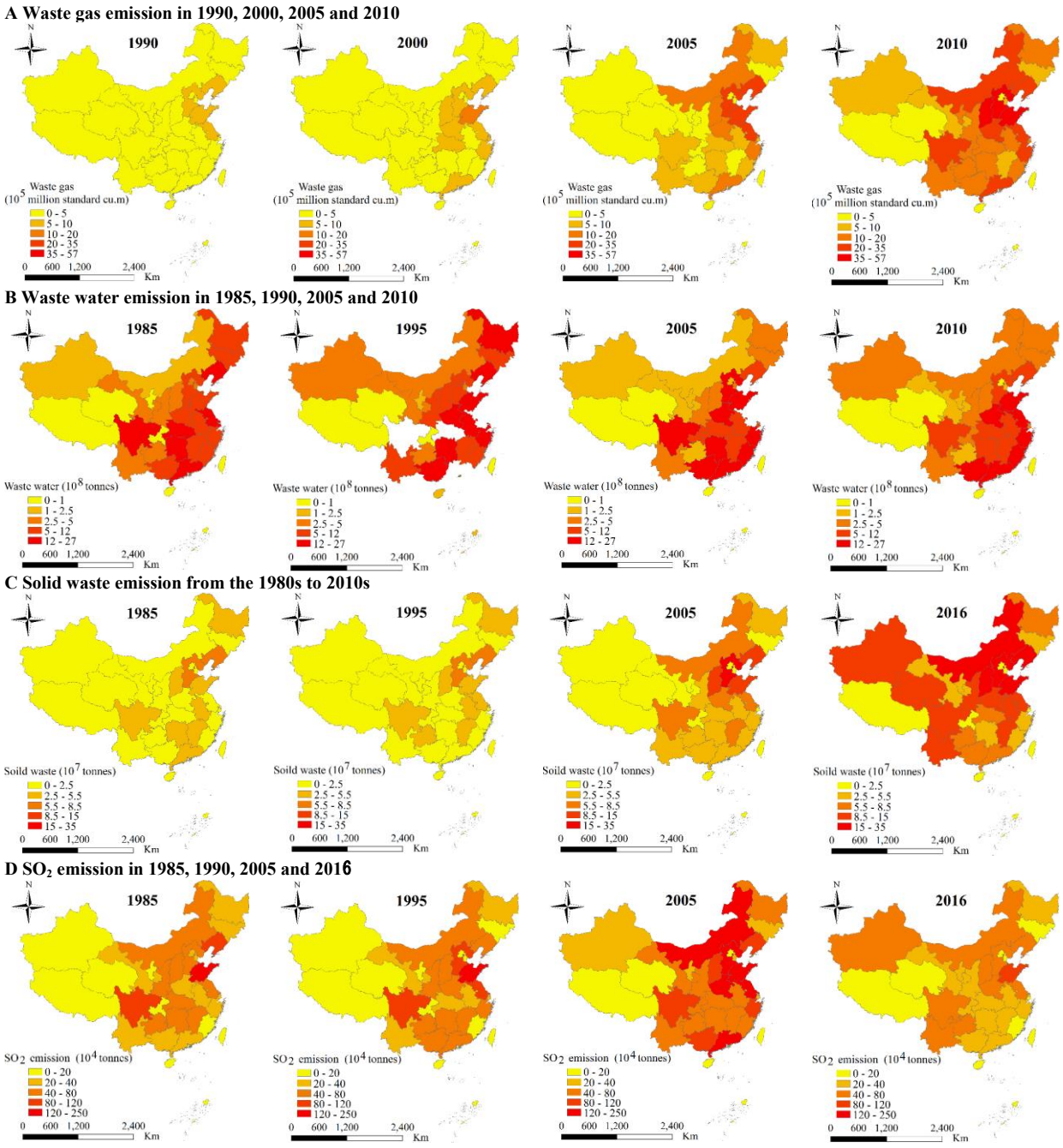
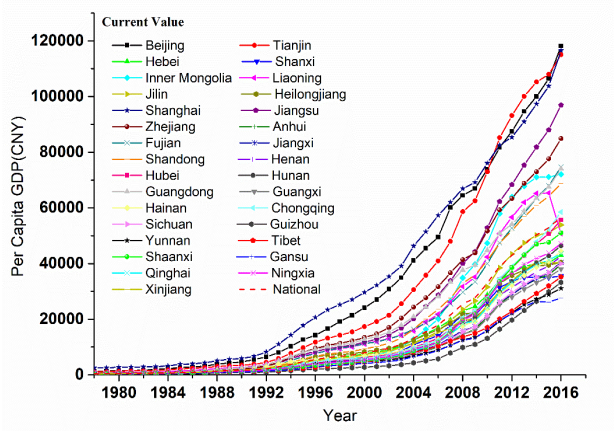


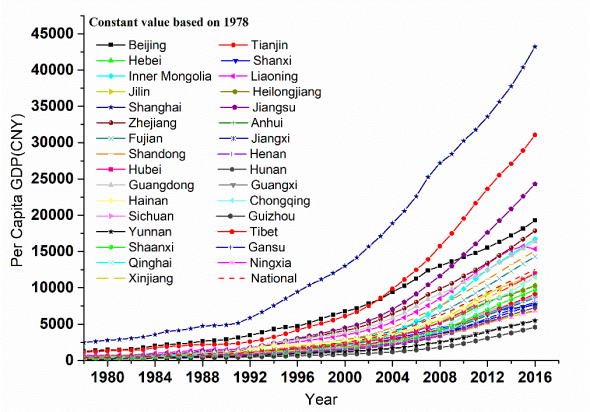
Fig. S3. Spatiotemporal variations of waste gas, wastewater, and SO_2 emission in China.

Excessive emissions of wastewater, waste gas, solid waste and sulfur dioxide extended from the developed east region to the undeveloped west region. SO_2 emission presented a downward variation trend from 2005 to 2016 in most regions of China. However, for solid waste, both the emission and regional coverage showed significant increasing trends. Data source: China Statistical Yearbook (1986, 1991, 1996, 2001, 2006 and 2017)(http://www.stats.gov.cn/english/).

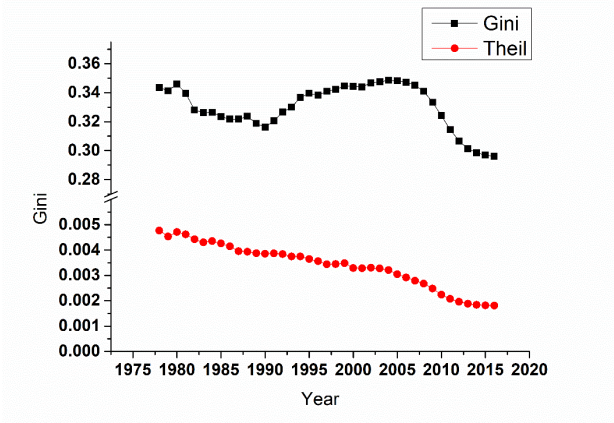
A Per capita GDP of 31 provinces in current value



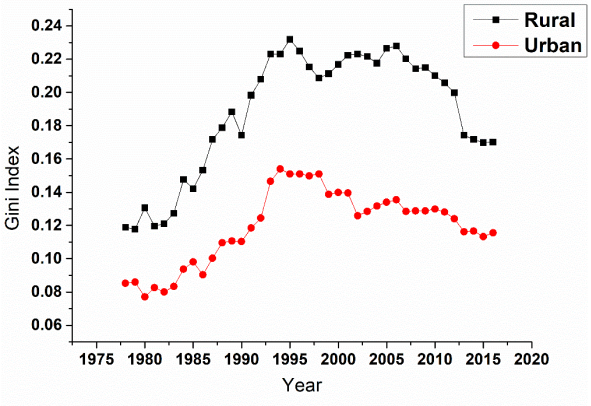
B Per capita GDP of 31 provinces in constant value



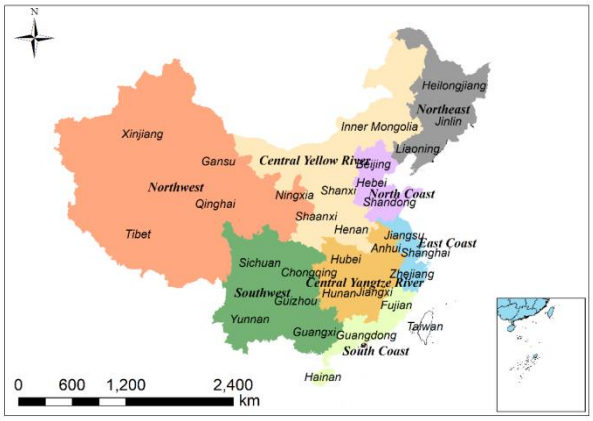
C Gini and Theil Index of per capita GDP



D Gini coefficient of per capita disposable income



E Division of 31 provinces into eight regions



F Coefficient of variation of per capita GDP within and between regions

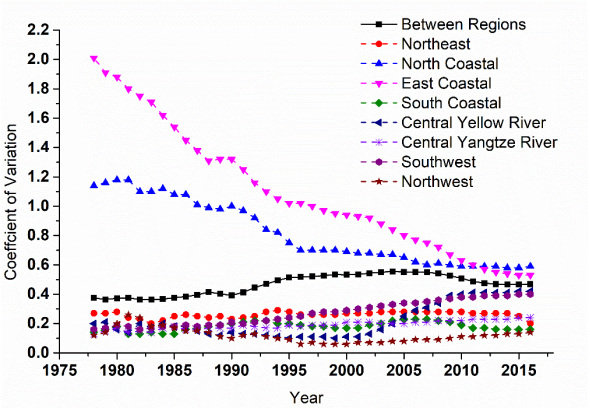
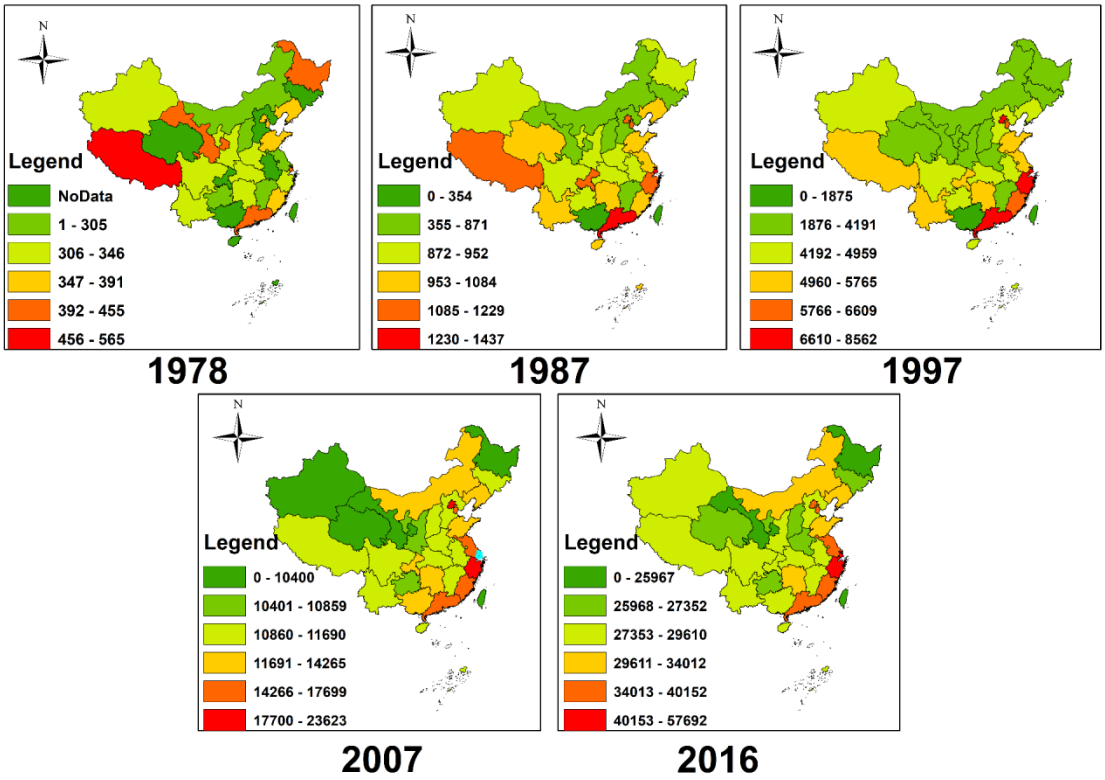


Fig. S4. Regional divide in per capita GDP and disposable income. Regional divide in provincial GDP reached peak during the 2000s and decreased with fluctuation. The variation of GDP within some regions (e.g. North Coastal and East coastal) decreased while increased among all regions. In the 1980s, the opening up in coastal regions and the national reform policy drove the nation-wide development leading to decreases of regional divide. Since then, the rapid coastal economic growth has resulted in a sharp increase in the regional gap, but with a continuous decrease among the coastal regions. Data sources: China Statistical Yearbook (1979-2017) and China Statistical Compendium 1949-2014 (http://www.stats.gov.cn/english/). Higher value of Gini coefficient, Theil Index and Coefficient of Variation (CV) indicates larger differences or inequalities between regions. The calculation of each index is described above.

A Urban per capita disposable income of 31 provinces



B Per capita water deficits of different regions in China

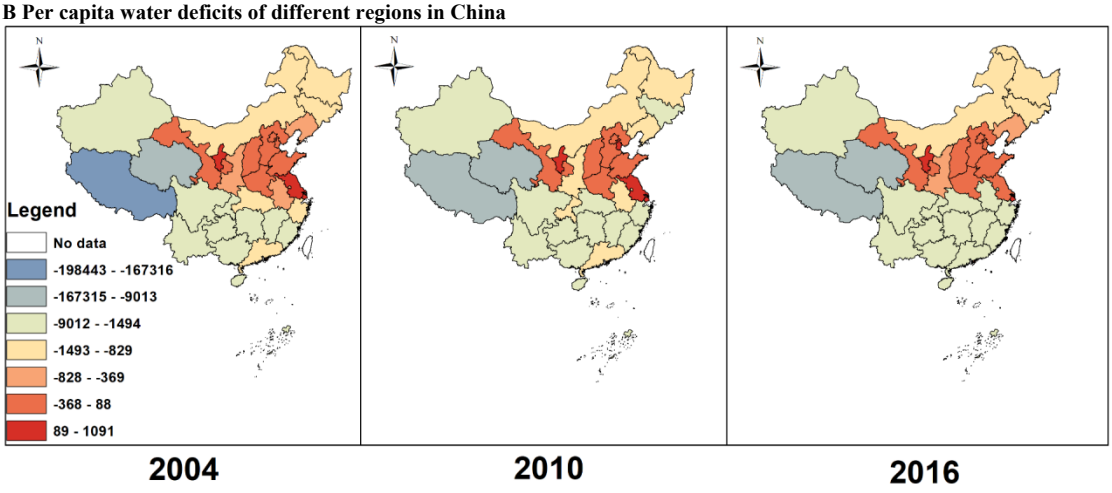


Fig. S5. Spatiotemporal variation of per capita disposable income and water deficit of 31 provinces. The spatial pattern of per capita disposable income has shifted from uneven distribution which was concentrated in coastal regions. At the early stage of the reform and opening up, the rapid development in coastal regions led to huge differences in urban disposable income between coastal and inland areas. From 2007 to 2016, the urban disposable income of western regions significantly increased. The water deficits in central and northern China have been mitigated recently. Data source: Statistical Yearbook of China (http://www.stats.gov.cn/english/). Water deficit is calculated by using per capita water consumption minus available per capita water resource. Water Consumption refers to gross water used by various water users (including domestic, agricultural and industrial sectors), and Water Resource refers to gross water of various sources supplied to consumers, including losses during distribution.

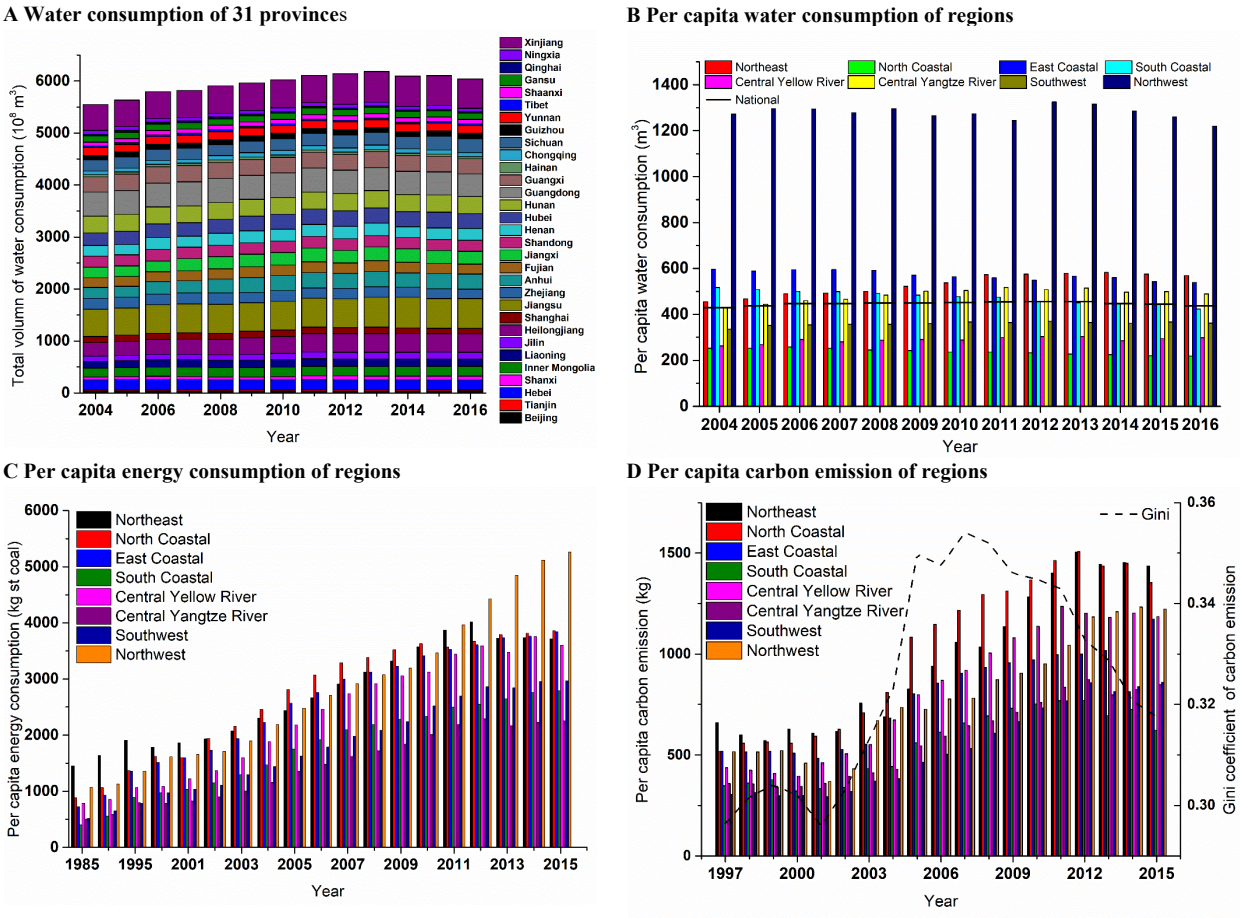
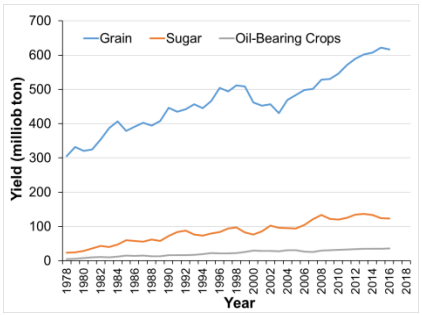
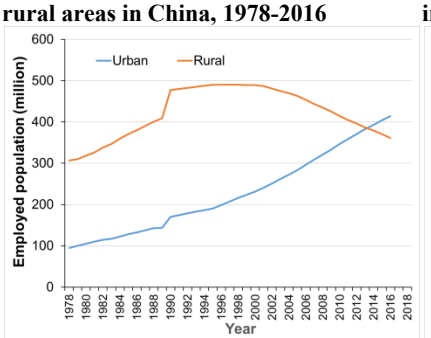


Fig. S6. Regional per capita water and energy consumption. Water consumption shows a decoupling trend from economic growth with the decreasing regional divide since 2013. Energy consumption among regions showed a divergence while the carbon emission showed a convergence since 2011. The Gini index of carbon emission among regions increased significantly from 2002 and reached peak in 2007. Data sources: China Statistical Yearbook (1979-2017) and China Statistical Compendium 1949-2014 (http://www.stats.gov.cn/english/). China Energy Statistical Yearbook (2000-2017). The energy consumption and carbon emission were calculated based on published statistical data and academic literature, which is shown in Materials and Method section. In S6D, the Gini coefficient measures the inequality of carbon emission of 31 provinces in China.

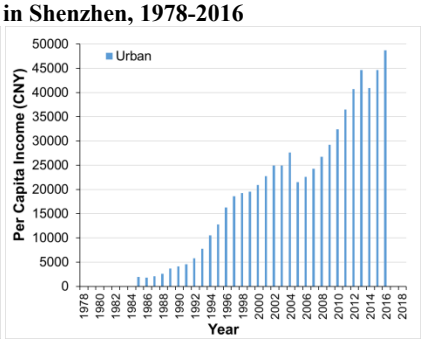
A Agricultural productivity of China, 1978-2016



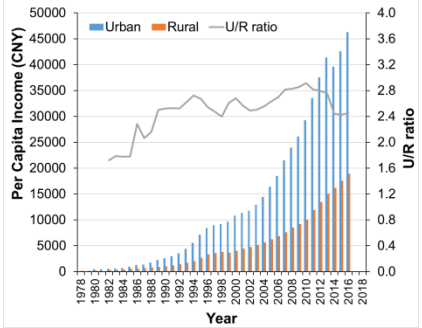
B Employed population in urban and rural areas in China, 1978-2016



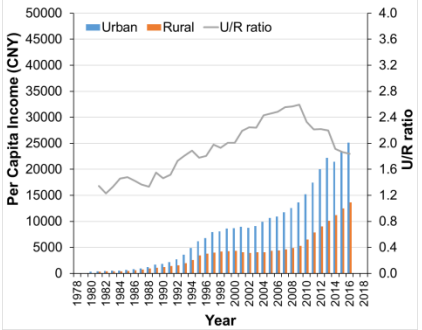
C Per capita income of urban population in Shenzhen, 1978-2016



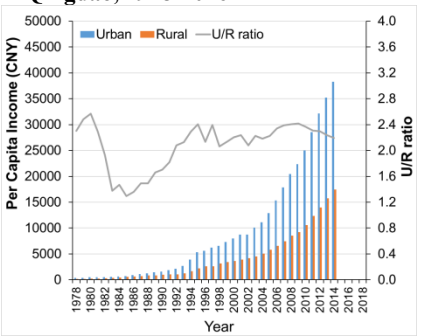
D Per capita income of rural and urban population in Xiamen, 1978-2016



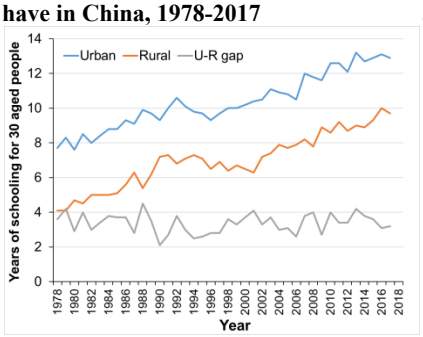
E Per capita income of rural and urban population in Shantou, 1978-2016



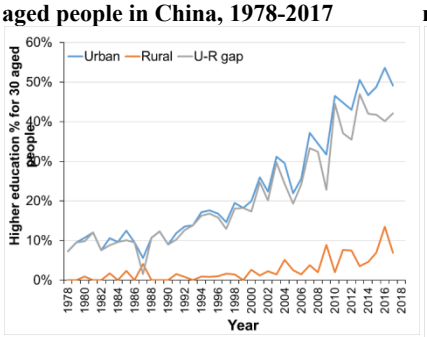
F Per capita income of urban population in Qingdao, 1978-2016



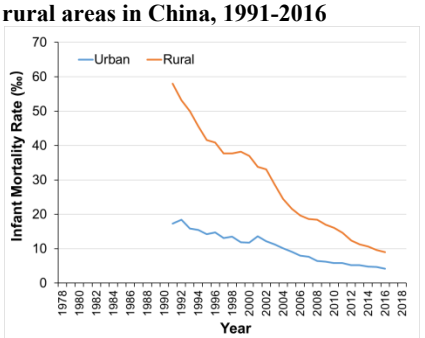
G Years of schooling that 30 aged people have in China, 1978-2017



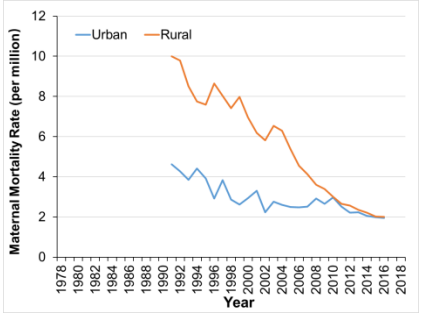
H Higher education percentage for 30 aged people in China, 1978-2017



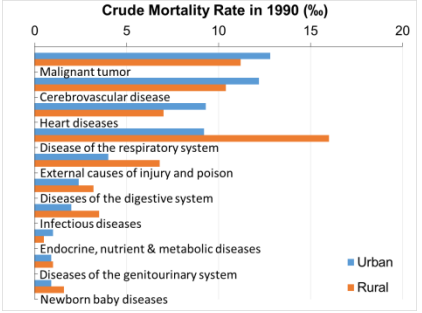
I Infant mortality rate in urban and rural areas in China, 1991-2016



J Maternal mortality rate in urban and rural areas in China, 1991-2016



K Major diseases and their crude mortality rates in China, 1990 (earliest record)



L Major diseases and their crude mortality rates in China, 2016 (latest record)

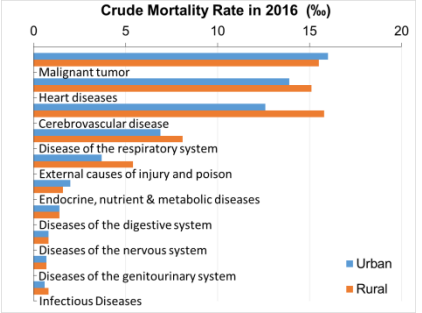
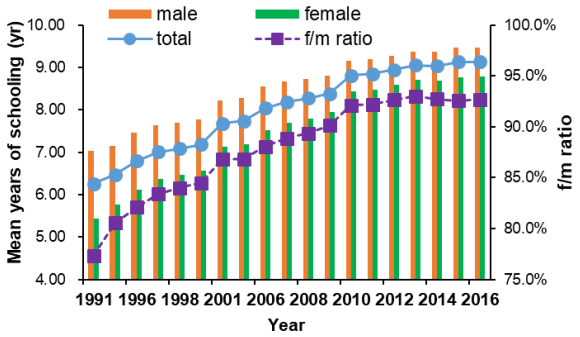
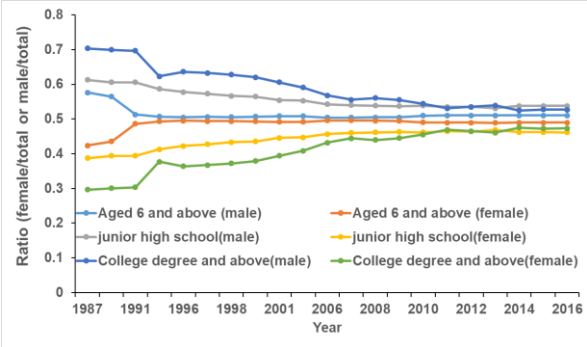


Fig. S7. Rural-urban gap in employment, income, education, and health care in China, 1978–2017. Since 1978, China has greatly improved agricultural productivity (**A**), and then surplus labors in the countryside have been attracted by emerging employment opportunities in urban areas (**B**). Shenzhen, one of the most developed cities in China, became the first fully urbanized city in China in 2004, developing from a small fishing village in 1978 (**C**). For Xiamen (**D**), Shantou (**E**) and Qingdao (**F**), the income gap between urban and rural areas is smaller than the national average, with stronger economic performance of their rural neighborhoods. The urban-rural gap for education (**G** and **H**) is not getting smaller. Economic development has significantly improved human health, including childbirth and disease control (**I**, **J**, **K** and **L**). Data source: China Statistical Yearbook 2017(http://www.stats.gov.cn/english/); Shenzhen Statistical Yearbook 2017; Xiamen Statistical Yearbook 2017; Shantou Statistical Yearbook 2017; Qingdao Statistical Yearbook 2017; China General Social Survey 2015; China Health and Family Planning Yearbook 2013.

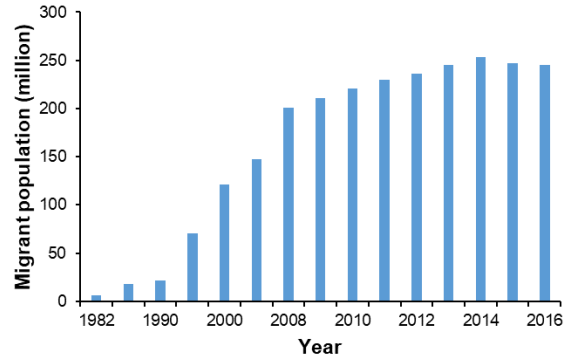
A Mean years of schooling for male and female, 1991-2016 In general, the education level for both genders has greatly increased. Since the early 1990s, the mean years of schooling in China has risen from 6.3 to 9.1.



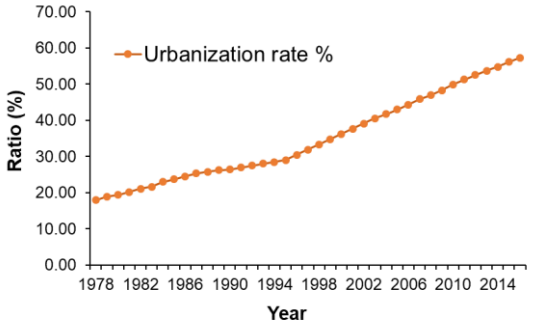
B Comparison of education level between genders, 1987-2016 The gender gaps of mean years of schooling in all education levels have continued to reduce. For example, women accounted for about 30% of the total population of college degree and above in 1987, while now the proportion reach to about 50%.



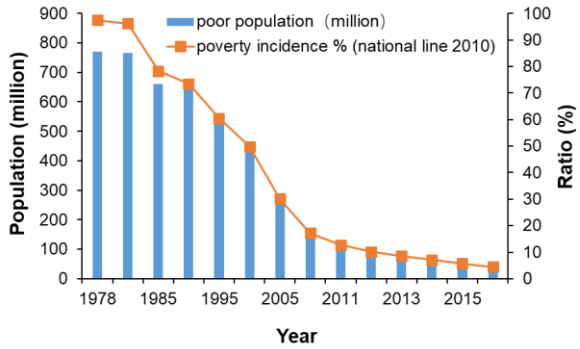
C Number of migrant population in China, 1982-2016 The migrant population in China increased slowly in the 1980s, but had a rapid increase from the early 1990s to 2015, and exceeded 100 million people by 2000 and 200 million people by 2008. The data of 1982, 1990, 2000 and 2010 are from the census of the same year respectively, and the data of the other years are calculated according to the annual population sampling survey.



D Urbanization rate in China since the reform and opening up. With large number of people flowing into cities, the urbanization rate of China rose from 17.92% in 1978 to 57.35% in 2016.



E Poor population and poverty incidence in China under national line 2010 In 1978, more than 700 million people lived under poverty line, but now only 43 million people live on under 2300 CNY (constant 2010) per year. Poverty incidence in rural China has dropped sharply from 97.5% in 1978 to 4.5% in 2016 (national line 2010).



F Poverty headcount ratio at $1.90/day of China According to the World Bank, the poverty headcount ratio at $1.90/day (2011 PPP) of China has dropped sharply from 66.6% in 1990 to 0.7% in 2016, which has resulted in a reduction of those in extreme poverty to about 9.6 million in 2016.

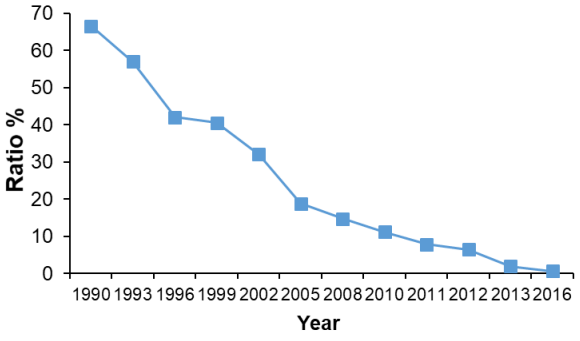


Fig. S8. Indices for gender equity in education, migration for job opportunities, and poverty reduction. Note: Migrant population in fig. S8C refers to the population whose residence is not consistent with the township or street where the registered residence is located and who has left the registered residence for more than half a year, excluding the migration between different towns and streets in the same municipal district. Data source: China Population and Employment Statistics Yearbook (1988-2017). Report on China's Migrant Population Development (2010-2014); China Statistical Yearbook 2017; China's National New Type Urbanization Planning (2014-2020); World Development Indicators, World Bank.

A Migration map of China in 2016 We present the trans-provincial migrant population in 2016. Migrant workers mostly move from the central to east regions of the country. Beijing, Jiangsu, Shanghai, Zhejiang, Fujian and Guangdong are the top 6 provinces for trans-provincial immigration, which account for 87.6% of the total trans-provincial immigration population. While Sichuan, Henan, Hubei, Hunan, Anhui and Jiangxi are the top 6 provinces for trans-provincial emigration, which account for 58% of the total trans-provincial emigration population.

B Spatial variability of poverty incidence in China The west-east gradient of poverty incidence seems significant in China. The spatial distribution of poor population is extremely uneven. The eastern region has less poor population, while the western region has higher poverty incidence.

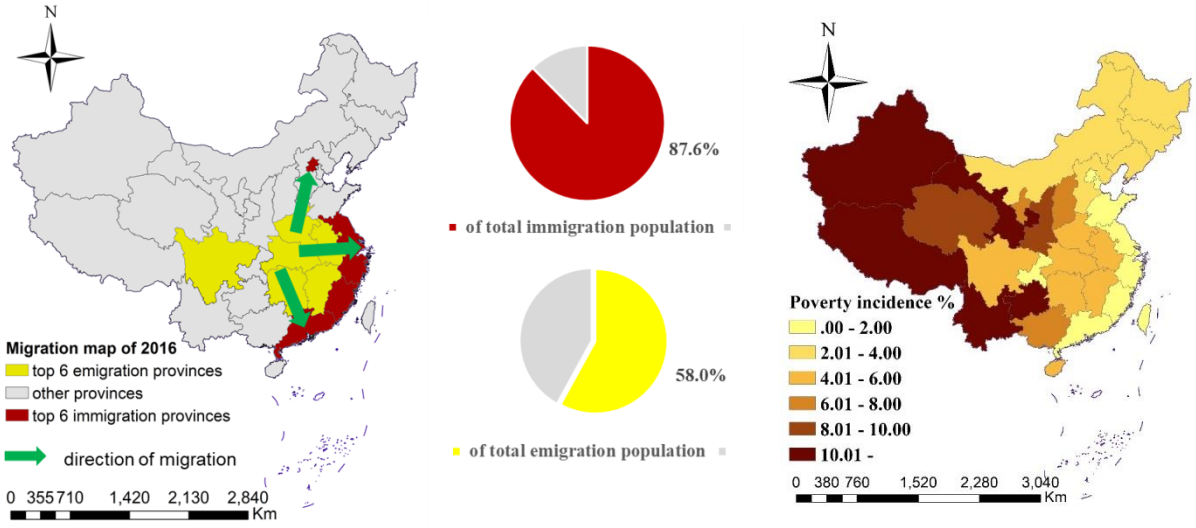
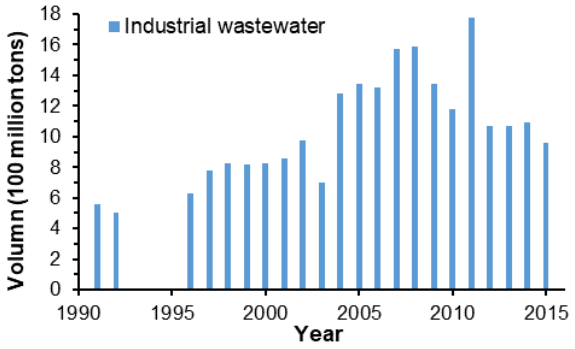
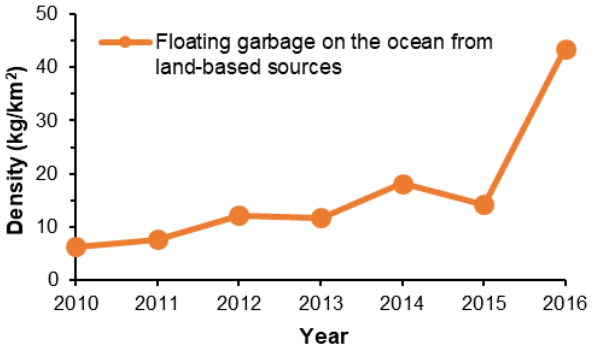


Fig. S9. Spatial analysis for indices of migration for job opportunities and poverty reduction. Data source: Report on China's Migrant Population Development 2017; Poverty Monitoring Report of Rural China 2017; China Statistical Yearbook 2017 (http://www.stats.gov.cn/english/).

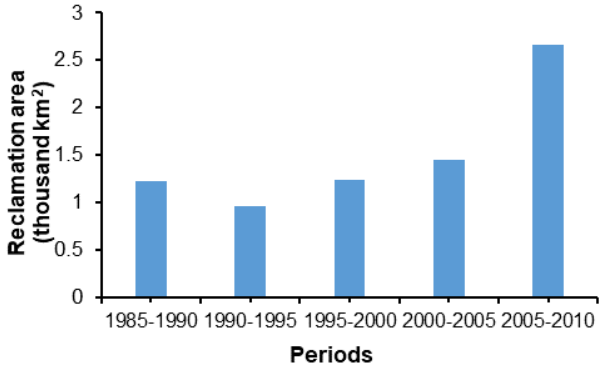
A Volume of industrial wastewater discharged directly into the sea for China, 1991-2015 The amount of industrial wastewater discharged directly into the sea has increased from average 0.7 billion tons every year in the 1990s to average 1.2 billion tons every year in the 2010s.



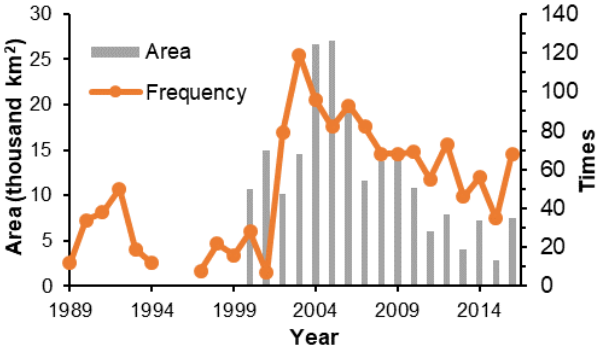
B Floating garbage on the ocean from land-based sources for China, 2010-2016 The density of floating garbage on the ocean recognized as being discharged from land-based sources has also increased from 6.3 kg/km^2 in 2010 to 43.6 kg/km2 in 2016.



C Coastal reclamation area in China, 1985-2010 China's total coastal reclamation area was found to be 7.5 thousand km^2 between 1985 and 2010



D Occurrence of red tide in China's coastal waters, 1989-2016 Due to integrated effects of climate change and pollution, area and frequency of red tide peaked at 27.07 km^2 in 2005 and 119 times in 2003. Although the area and frequency showed declining trends from their peaks, the occurrence of red tide in the 2010s (average 57 times every year) was more than 2 times than that in the 1990s (average 25 times every year).



E Region-based Marine Trophic Index and mean maximum body length of the catch in the waters of China, 1978-2014 Region-based Marine Trophic Index (RMTI), is an index that tracks changes in trophic level of fishery catches in response to fishing pressure. The trophic index and mean maximum body length of the catch decreased sharply since the early 1980s, implying an increasing catch of organisms with low trophic level. Although they increased gradually after the implementation of Fishery Law of the People's Republic of China in 1987, these two indicators were still lower than that in 1978.

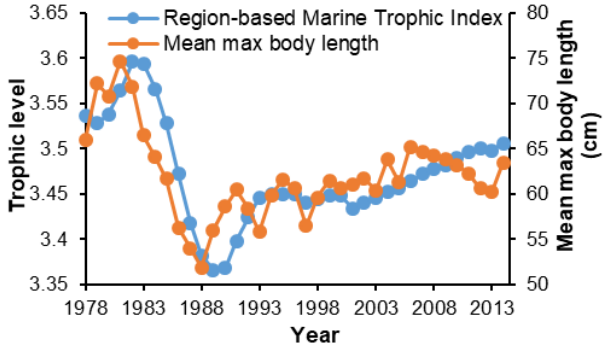


Fig. S10. Marine fish catch and land-ocean interactions. Data source: **A**, China Marine Statistical Yearbook 1993, 1997-2016; **B**, Bulletin of China Marine Environmental Status 2010-2016; **C**, Data collected from reference (*52*); **D**, Bulletin of China Marine Disasters 1995-2016, Bulletin of China Marine Environmental Status 2000, 2001, 2013-2016; **E**, Sea Around Us, http://www.seaaroundus.org/.