Chapter 15
Urbanization and the Environment: An Asian Perspective

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Introduction

Few developing countries actively promote urbanization despite the well-researched finding of much higher urban productivity. According to a survey by the United Nations (UN), many national governments attempt to contain migration or expansion of cities (Quigley 2008). This can be attributed partly to the perception that urbanization is associated with worsening environment. Some may even view urbanization as synonymous with pollution, congestion, noise, and so on.

Is urbanization always bad for the environment? Answering this question is quite important for policy makers as well as for the research community. Slowing down urbanization by governments implies a loss of efficiency and growth potential. If it does not really help improve the environment, such a policy stance leads to a loss–loss outcome. On the other hand, it seems that little analytical work has been undertaken to explore the urbanization–environment nexus although normative discussions and speculations abound.

The purpose of this chapter is to offer a balanced assessment on the relationship between urbanization and the environment from the Asian perspective. As background information, unique features of Asia's urbanization will be outlined in the next section. This is followed by Sect. 3 which describes the environmental challenges Asia already faces. In Sect. 4, the beneficial impacts of urbanization on the environment are discussed, and the modeling results of the urbanization–environment nexus are provided. Finally, Sect. 5 summarizes the chapter.

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Table 15.1 Urbanization level and changes (actual and projected). (Source: Authors' estimates based on UN 2012)

Region	Level of urbanization (%)			Percentage point change (%)	
	2000	2010	2050	2000–2010	2010–2050
Europe	70.8	72.7	82.2	1.9	9.5
Latin America and the Caribbean	75.5	78.8	86.6	3.4	7.8
Northern America	79.1	82.0	88.6	2.9	6.6
Africa	35.6	39.2	57.7	3.6	18.5
Asia	35.5	42.5	62.9	7.0	20.4
China, People's Republic of	35.9	49.2	77.3	13.3	28.1
India	27.7	30.9	51.7	3.3	20.8

Urbanization in Asia: Unique Features

In a process similar to that much earlier in Europe, Latin America, and Northern America, Asia has been urbanizing for many years now and the process is projected to gain momentum in the coming decades. Unlike other regions, however, Asia's urbanization is different in several key aspects.

First, urbanization in Asia has been occurring rapidly and will continue to do so in the foreseeable future. Table 15.1, which is based on data and projections of the UN (2012), tabulates the level of urbanization and its change for different regions and two Asian economies. The last two columns of Table 15.1 show the total percentage point increase in the level of urbanization for the periods 2000–2010 and 2010–2050. While Asia increased its urbanization level by 7 percentage points in 2000–2010, Africa—the second fastest urbanizing region during the same period—only experienced a 3.6 percentage points increase. Similarly, during 2010–2050, Asia is projected to increase its urbanization level by 20.4 percentage points, but the projected increase for Africa is only a total of 18.5 percentage points.

More revealing is a comparison of the number of years from the start of a region's urbanization, when about 10 % of its population was urban, to when about 50 % of its population is urban. Figure 15.1 shows that this process lasted 210 years in Latin America and the Caribbean (from 10 % in 1750 to 49.3 % in 1960), 150 years in Europe (from 12 % in 1800 to 51.3 % in 1950), and 105 years in Northern America (from 9 % in 1825 to 51 % in 1930), and it will take 95 years or less in Asia (from 11 % in 1930 to 51 % in 2025). For countries within Asia, this process lasted only 61 years for the PRC and is estimated to last 55 years for Bhutan, 60 years for the Lao People's Democratic Republic, 65 years for Indonesia, and 90 years for Vietnam.

Second, the absolute increase in city population in Asia is unprecedented, partly due to its large population base and partly due to its fast speed of urbanization. Since the 1950s, Asia has added more than 1.4 billion people to its cities (Fig. 15.2). Almost 537 million were added during the 35-year interval of 1950–1985. However, in the following 15 years, 1985–2000, 465 million were added. More strik-

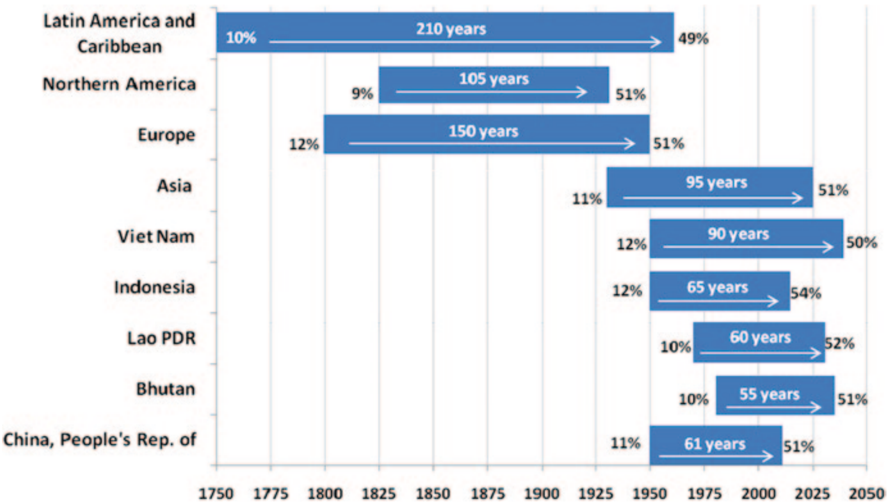


Fig. 15.1 Number of years from about 10 to 50 % of urbanization. Note: Extrapolation and interpolation were used to estimate urbanization level and corresponding starting years for Latin America and the Caribbean and Northern America. (Source: Authors' estimates based on Bairoch 1988 and UN 2012)

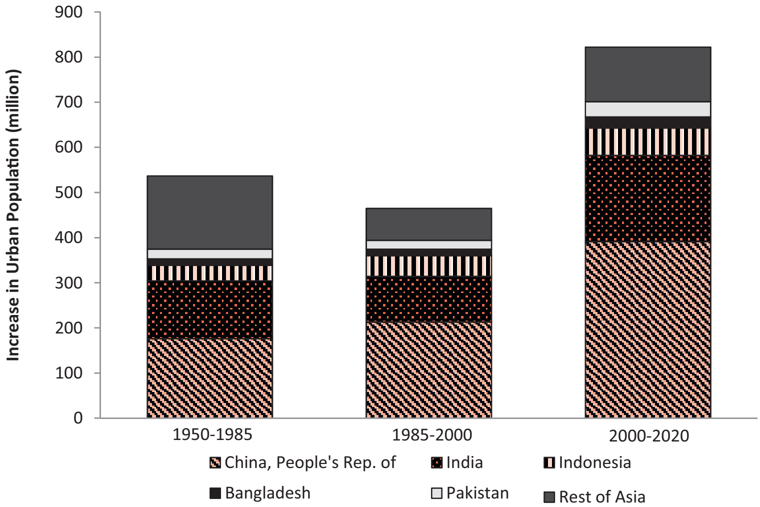


Fig. 15.2 Increase in urban population in Asia. Note: Data for 2010–2020 are based on projections of UN World Urbanization Prospects, 2011 Revision. (Source: Authors' estimates based on UN 2012)

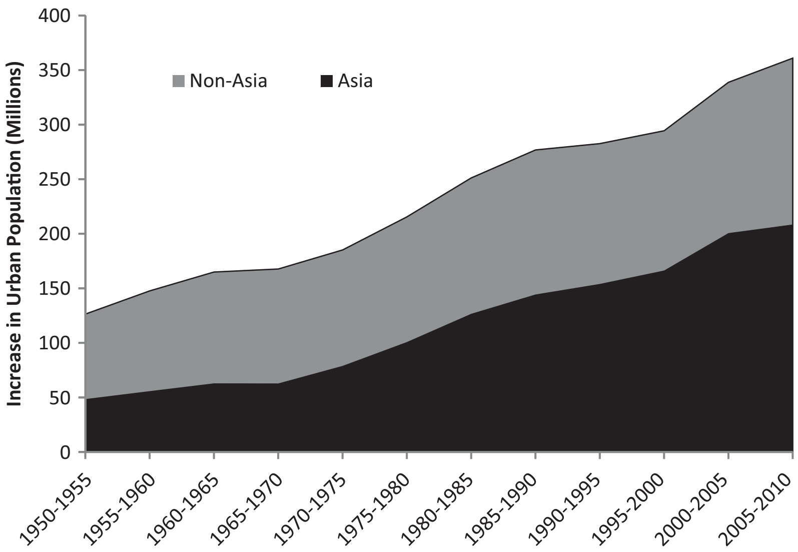
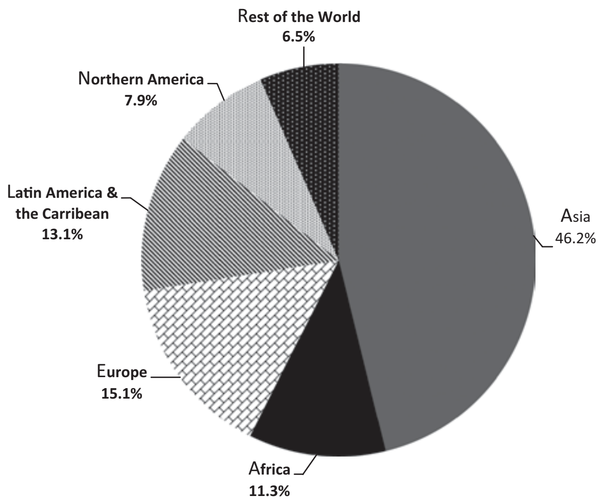


Fig. 15.3 Increase in urban population, 1950–2010. (Source: Authors' estimates based on UN 2012)

Fig. 15.4 Regional shares of global urban population, 2010. Northern America = Canada and the USA. (Source: Authors' estimates based on UN 2012)



ingly, from 2000 to 2020, a total of 822 million will be added. Figure 15.2 also provides geographic breakdowns of these numbers. Clearly, most of these increases are from Bangladesh, the PRC, India, Indonesia, and Pakistan, Asia's most populous countries.

To some extent, global urbanization is largely an Asian phenomenon (Fig. 15.3). Since the early 1980s, Asia has added more people to the global urban population than all the other regions combined. By the latest available statistics, Asia is now home to almost half of the total urbanites on earth (Fig. 15.4)—Asia's urban popu-

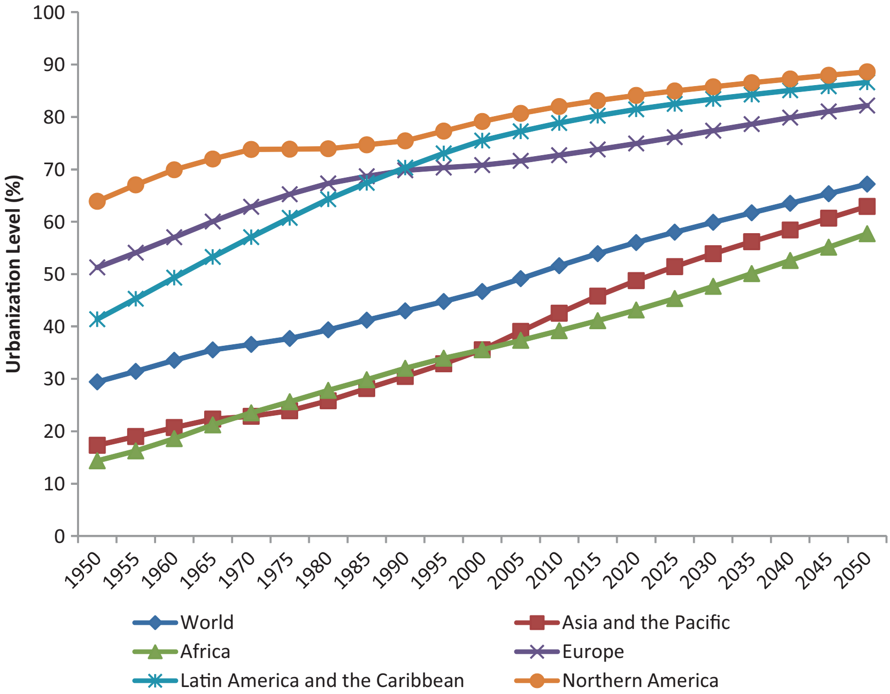


Fig. 15.5 Level of urbanization by region. Northern America = Canada and the USA. (Source: UN 2012)

lation is more than three times that of Europe, the second largest region in terms of urban population (UN 2012).

Third, contrary to the unprecedented expansion of city population, Asia's level of urbanization is still low. As shown in Fig. 15.5, the level of Asia's urbanization (i.e., the share of its population living in urban areas) has been lower than that of the world at least since 1950. Across regions, Asia was the least urbanized, even less than Africa, during 1970–2000. In 1960, only 20.7 % of Asia's population was urban versus 33.6 % for the world. In 2000, 46.7 % of the world's population lived in cities while only 35.5 % of the population in Asia did so. In 2010, these urbanization shares moved to 52 % and 43 %, respectively. Thus, the urbanization gap between Asia and the rest of the world has narrowed but remains large.

The gap in the urbanization level between Asia and the world will narrow further (UN 2012). By 2050, while 62.9 % of Asians will live in cities, this percentage will be 67.2 for the world. Asia's level of urbanization will be higher than Africa's (57.7 %), but still lower than Europe's (82.2 %), Northern America's (88.6 %), and Latin America and the Caribbean's (86.6 %).

Fourth, Asia is home to most of the world's megacities and its share has been increasing. There were only two megacities in the world in 1950: New York, with a population of 12.3 million, and Tokyo, with 11.3 million. By 1980, two more

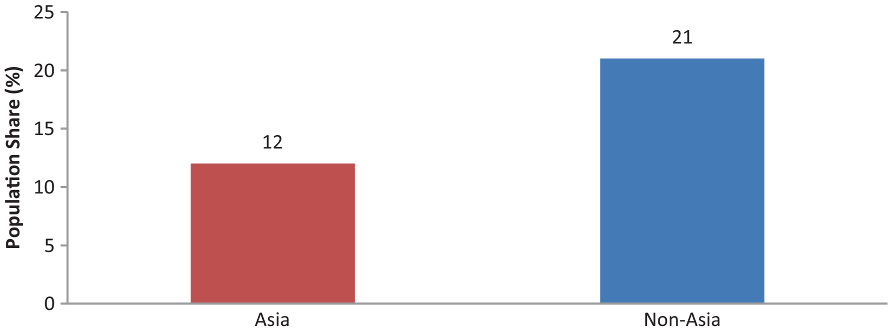


Fig. 15.6 Population share of largest cities of individual countries, 2009 (% of total urban population). (Source: Authors' estimates based on UN 2012)

megacities had emerged: São Paolo, with a population of 12.1 million, and Mexico City, with 13 million. However, by 2010, Asia had 12 of the world's 23 megacities. The UN (2012) predicts that these numbers will increase to 21 and 37, respectively, by 2025.[1] Cities such as Chongqing, Guangzhou, Jakarta, Lahore, and Shenzhen are expected to pass the 10-million mark soon. The large cities expected to grow the most include Dhaka, Lahore, Karachi, Kolkata, Manila, Mumbai, and Shanghai. Thus, while the majority of the world's megacities are in Asia, even more are emerging.

Although megacities are growing and their numbers are increasing, the largest city of each country in Asia is home to a smaller share of the total urban population than is the case in other regions. "Urban primacy" is indicated by the share of the country's urbanites who live in the largest city of the country. Relative to the rest of the world, Asia shows a much lower level of urban primacy (Fig. 15.6), indicating that its urban populations are less concentrated in the largest city of each country. In 2009, roughly 12 % of Asia's urban population lived in their country's largest cities, while outside of Asia, this share was 21 %. This suggests that the size of Asia's primate cities is likely to increase. Therefore, although Asian cities are already large, some of Asia's megacities are likely to become larger still, even relative to medium- and small-sized cities in the same country.

Fifth, Asia's cities feature much higher population densities than cities elsewhere in the world. The world's three most densely populated large cities are in South Asia, and 8 of the top 10 are in Asia (Fig. 15.7). The average urban area (settlements of 5,000 or more people) has 720 people per square kilometer in Asia, compared with about 500 in Africa, the region with the second highest urban density. Kenworthy (2008) notes that wealthy Asian cities have an average density of 150 people per hectare compared to 15 in Australia, New Zealand, and the USA.

[1] The raw data can be downloaded at esa.un.org/unpd/wup/CD-ROM/WUP2011-F17a-City_Size_Class.xls.

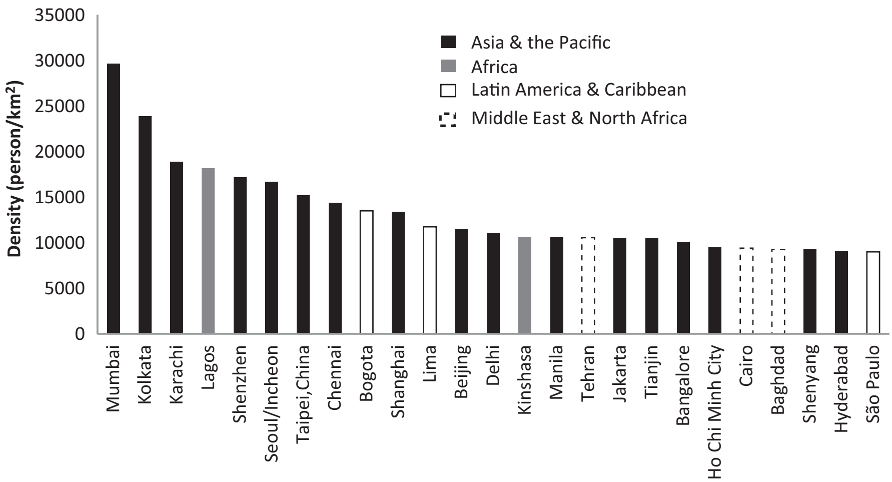


Fig. 15.7 Top 25 cities ranked by population density, 2007. (Source: City Mayors 2007)

Sixth, significant heterogeneity exists across subregions in Asia and across economies in terms of urbanization level and speed. For example, the level of urbanization is much higher for developed countries in Asia (Japan, Australia, and New Zealand). Their level of urbanization was 90.2 % in 2010, 49.6 percentage points higher than developing Asia as a whole. At the subregional level, East Asia was less urbanized than Central and West Asia and Southeast Asia until the late 1990s. Since 2005, however, East Asia has been the subregion with the highest level of urbanization, reaching 50.7 % in 2010 (Fig. 15.8). The PRC and the Republic of Korea exhibit faster urbanization than others (Fig. 15.9). The speed of urbanization in Bangladesh is also high.

Until 1995, the least urbanized developing subregion had always been the Pacific island countries and the most urbanized had been Central and West Asia. The difference in urbanization rates between the two subregions has been fairly stable, at about 15 %. However, in both subregions, urbanization has progressed slowly while Southeast Asia, South Asia, and particularly East Asia (basically, the PRC) have been urbanizing faster.

Thus, Asia's level of urbanization started from a relatively low base compared to the rest of the world, but it has been proceeding rapidly and on a vast scale. This is likely to continue at least until 2050, with an increasing formation of megacities and expansion of most cities. In addition, the population densities of Asian cities, already high, are likely to increase. These prospects raise daunting issues for Asia, not least of which are the environmental implications of this massive human and economic clustering.

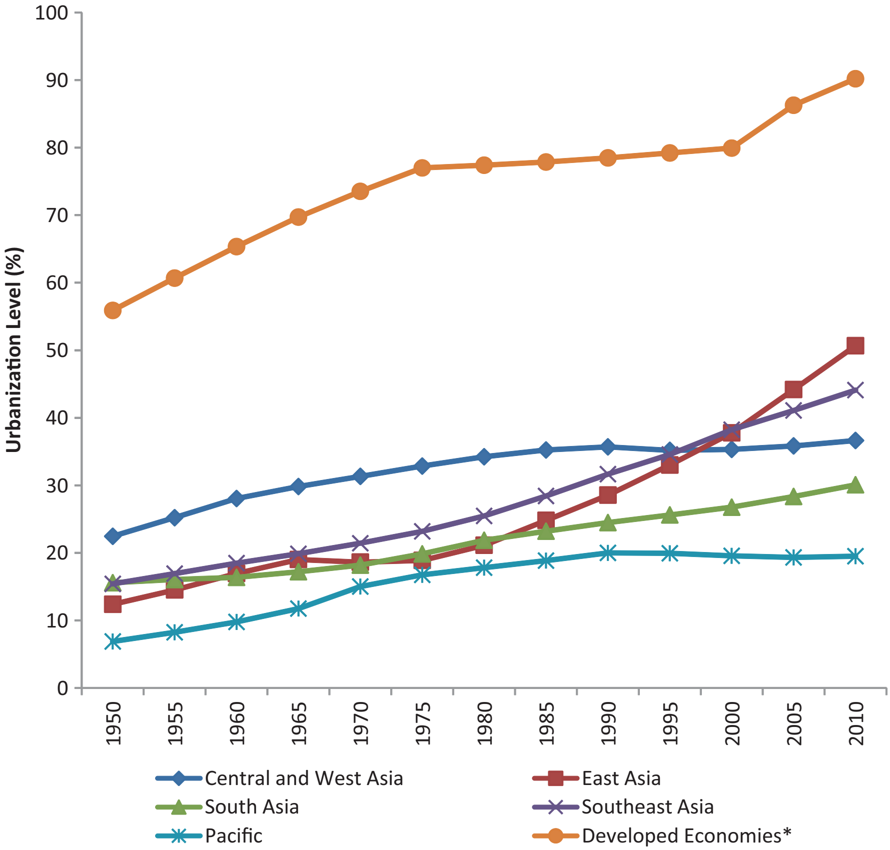


Fig. 15.8 Urbanization levels, ADB subregion. Note: * Developed economies include Australia, Japan, and New Zealand. (Source: UN 2012)

Environmental Implications of Urbanization in Asia

Urbanization-related challenges include high crime rates, unequal income distribution, and environmental challenges such as urban air pollution, increasing greenhouse gas (GHG) emissions, access to clean water and sanitation, and vulnerability to climate change-related risks. As shown in Fig. 15.10 and the recent Asian Development Outlook (ADB 2012a), inequality is generally greater in urban areas than in rural areas, so that urbanization may aggravate the problem of unequal income distribution. Even in the PRC, where inequality had been lower in urban than in rural areas, urban inequality has been growing faster and surpassed rural inequality in 2008.[2]

[2] The lower urban inequality in the PRC was largely due to the urban bias, which has gradually faded away but still exists (Wan and Zhang 2011).

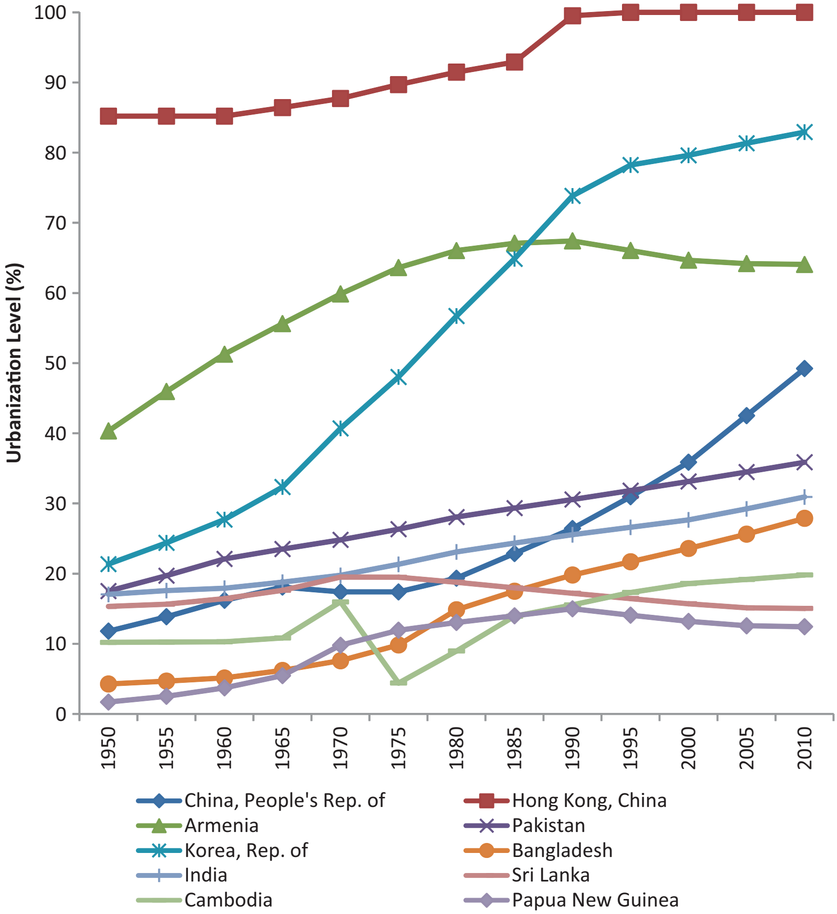


Fig. 15.9 Urbanization levels, selected Asian Economies. (Source: UN 2012)

New entrants to cities are likely to be poorer than incumbent residents and to live in slums or city fringes. In addition, because the cost of criminal activity is usually lower and gains larger in cities than in the countryside, urbanization may be accompanied by elevated local crime levels. Figure 15.11 is a scatterplot of the theft rate (number of theft incidents per 100,000 population) and level of urbanization using worldwide data. Clearly, the two variables are positively correlated. In addition, homicide rates are higher in cities than in most of the corresponding national averages (Fig. 15.12).[3]

[3] Other indicators of crime than theft and homicide rates are not available for a rural–urban comparison.

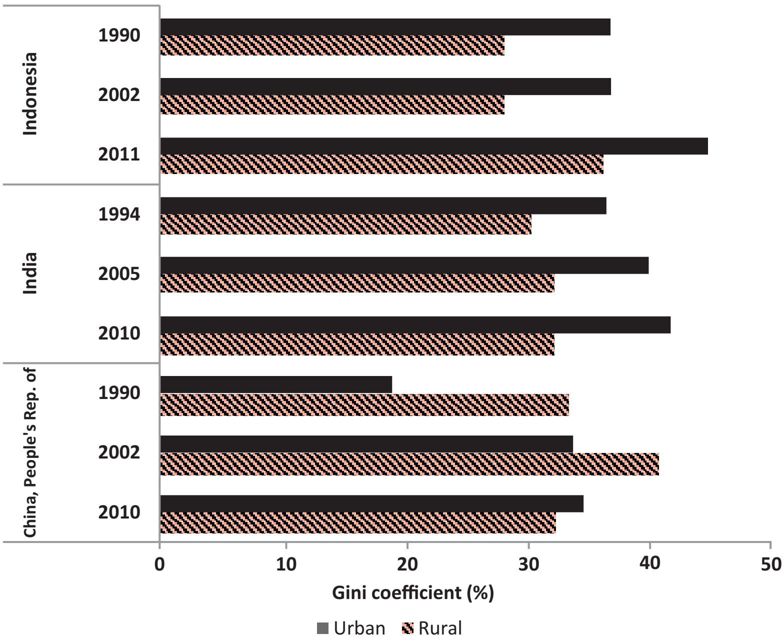


Fig. 15.10 Urban and rural inequality in Asia. (Source: Authors' 2012a and Authors' estimates)

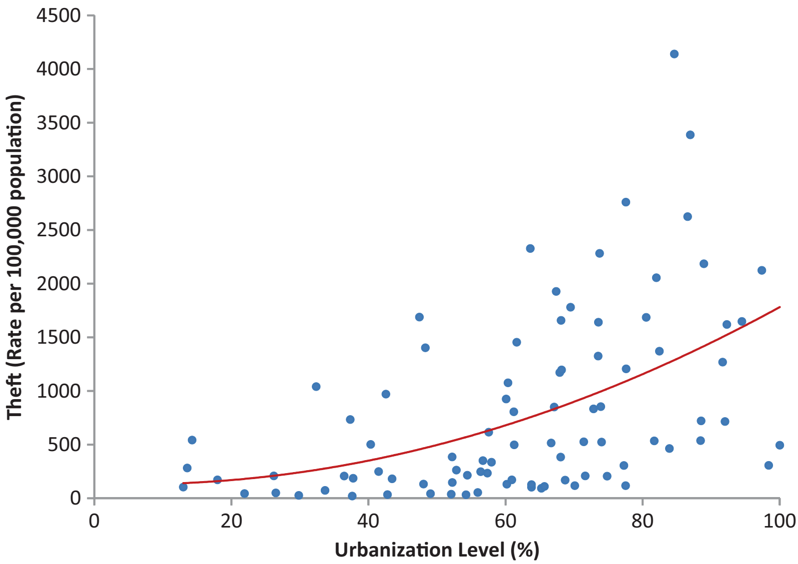


Fig. 15.11 Theft rate versus level of urbanization: Global data. (Source: UNODC 2012 and World Bank 2012)

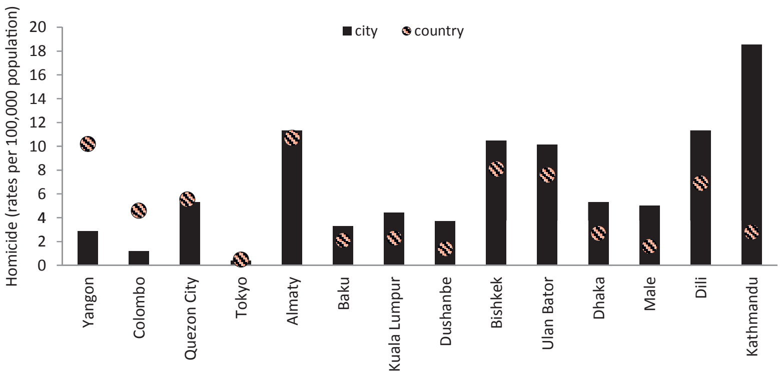


Fig. 15.12 Intentional homicide rates in selected countries. (Source: UNODC 2012)

Challenges to city life are numerous and include higher costs of housing, education, and health care. This chapter will focus on environmental issues in the context of urbanization. This focus is a response to the rising importance of the environment in sustaining growth, the unprecedented urbanization in the region, and the formidable environmental challenges faced by Asia. There is also a growing awareness that in future, for cities to have a competitive edge, they will have to be "green economies" (OECD 2011). Finally, while urbanization is often assumed to be associated with environmental degradation, little research has been done so far on this linkage.

Urban Air Pollution in Asia

While no two cities are the same, many of Asia's cities face common challenges, including a sharp increase in the number of registered vehicles, rising levels of industrial production, and to some extent a reliance on coal-fired power plants. All of these contribute to air pollution, and, in Asia, air pollution contributes to the premature death of half a million people each year (ADB 2012b).

From a public health perspective, particulate matter (PM) and carbon monoxide levels[4] are considered to be more associated with elevated morbidity risk than are ozone levels (Chay and Greenstone 2003, Currie and Neidell 2005). Data on PM10 are available from the World Health Organization and are used to rank cities that have an average PM10 level of 100 micrograms per cubic meter (μg/m^3) or higher. Of the world's 57 most polluted cities, 34—or almost 60 %—are in Asia (Fig. 15.13).

[4] Particulate matter (PM)—also known as particulates or suspended particulate matter (SPM)—is solid matter suspended in air or liquid. PM10 refers to particulate matter with diameter of 10 micrometers or less. Carbon monoxide is a colorless, odorless, and tasteless gas that is slightly lighter than air. It can be toxic to humans and animals when encountered in higher concentrations. In the atmosphere, however, it is short-lived and spatially variable, as it combines with oxygen to form CO_2 and ozone.

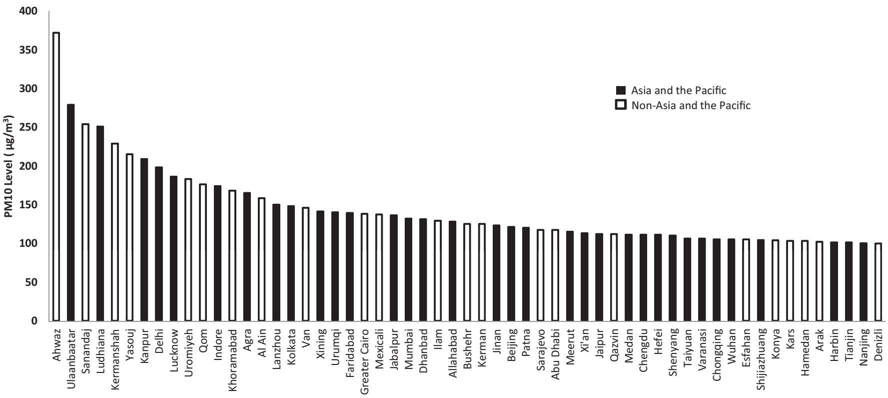


Fig. 15.13 Cities with PM10 above 100 μg/m³, 2008–2009. (Source: WHO 2012)

Figure 15.14 plots PM10 kernel density using observations for Asia and non-Asian cities.[5] Three interesting findings can be discerned. First, the density plot for Asian cities clearly lies to the right of the non-Asian cities, indicating that many of Asia's cities have much higher levels of pollution than cities in other regions. Second, the mode (most common value) of PM10 for non-Asian cities is only about 20 μg/m³ but is almost double that—nearly 40 μg/m³—on average in Asian cities. Third, if the European Union's air quality standard of 40 μg/m³ is used as the benchmark, less than 11 % of non-Asian cites do not meet the standard but a staggering 67 % of Asian cities fail to meet it.

The PRC has 12 of the world's 20 most polluted cities (World Bank 2007a). The World Bank (2007b) reported that, in 2003, 53 % of the 341 cities monitored—accounting for 58 % of the PRC's urban population—had annual average PM10 levels above 100 μg/m³, and 21 % of these cities had PM10 levels above 150 μg/m³. Only 1 % of the PRC's urban population lives in cities that meet the European Union's air quality standard of 40 μg/m³.

In Metropolitan Manila, depending on the year, 13 or more stations have monitored total suspended particulate (TSP) levels since 2000. Figure 15.15, plotting the distribution of the ambient (outdoor) pollution readings, shows that some parts of Manila have tremendously elevated TSP levels. In 2010, TSP levels were twice as high in Pasay City as in Mandaluyong City, largely due to differences in the traffic volumes. In 2011, 77 % of the monitoring stations' readings exceeded the nation's air pollution standard of 90 μg/m³.

In Thailand, the Bangkok data contain observations on ambient PM10, ozone, and carbon monoxide from 1997 to 2011. Using the ambient PM10 data and a simple econometric model with fixed effects for monitoring stations, one can show that ambient ozone (from automobile exhausts) has increased by 4.3 % per year in Bangkok. Thailand's State of Pollution Report 2010 also shows that the country's ambient ozone levels have increased over time. As the numbers of both vehicles and residents continue to increase, health costs can be expected to rise.

[5] Loosely speaking, a kernel density plot depicts the frequency of occurrence of a variable.

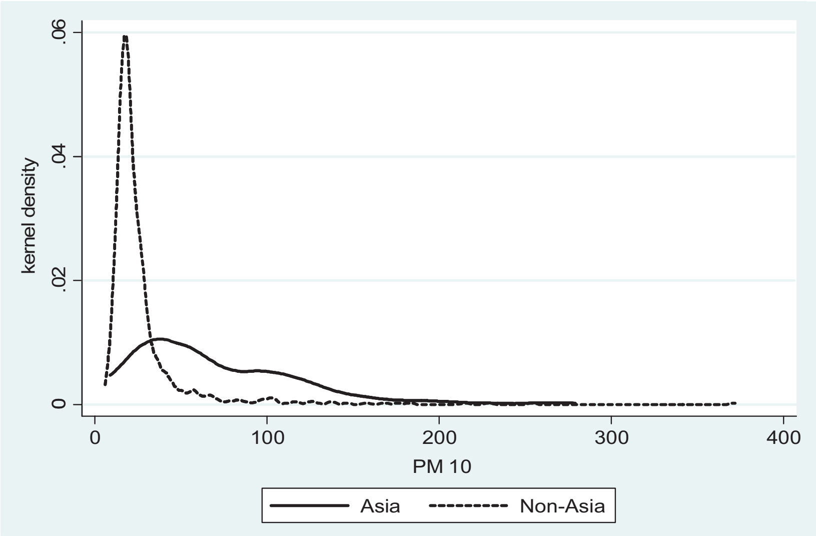


Fig. 15.14 PM10 kernel density, 2008–2009. (Source: Authors' estimates based on WHO)

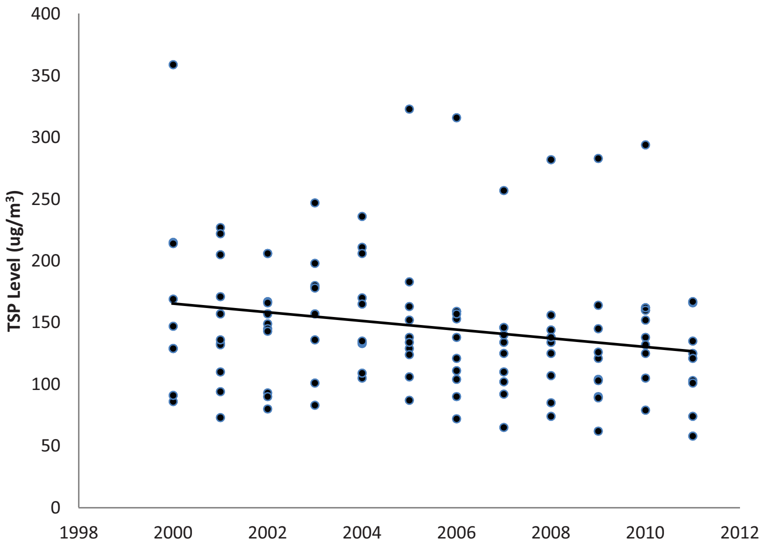


Fig. 15.15 Total suspended particulates at Manila sites. (Source: Environmental Management Bureau 2002, 2009)

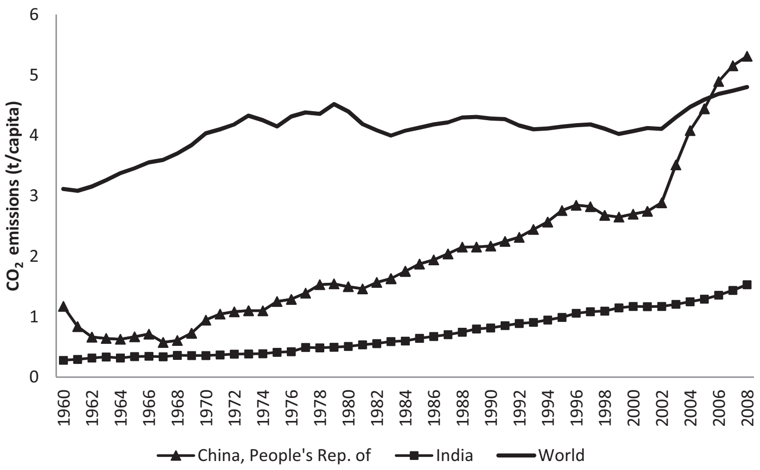


Fig. 15.16 CO_2 emissions. (Source: World Bank 2012)

Greenhouse Gas Emissions

Because urbanization raises per capita incomes and richer people consume more fossil fuels, urban growth and GHG emissions appear to be directly linked. As there is no global price on carbon, polluters (ranging from vehicle owners to electric power plants) face little incentive to economize on emissions. Thus, the increasing trend in GHG emissions is of utmost concern, although on a per capita basis the current level of carbon emissions in Asia is lower than that in developed countries. For example, on a per capita basis and during 2000–2008, the regional average emission for Asia grew by 97 % while that for the world grew by only 18 %.

Asia certainly faces enormous challenges in terms of its total volume of CO_2 emissions. By this criterion, three of the top five emitting countries are in Asia: the PRC, India, and Japan. This is not surprising, as the total volume of any pollutant is a product of population and per capita emission. While per capita emissions tend to rise over time as economies grow, the enormous population base in many Asian nations also presents a key contributor to this challenge.

In terms of per capita CO_2 emissions, Fig. 15.16 shows the time series trends for the world, the PRC, and India. The PRC's amazing growth in emissions, starting in the early 1990s and becoming more rapid from early 2000, is clear and has been concentrated in cities. If the PRC's per capita emissions were to reach the levels of the USA, global carbon emissions would increase by more than 50 %. As India continues to grow and urbanize, its per capita emissions are likely to rise as well (Sridhar 2010).

The rise in the number of private vehicles and their increasing use in Asia have contributed significantly to rising GHG emissions. The number of vehicles per 1,000 people in the PRC increased from 10 in 1998 to 37 in 2010, while in the Philippines the increase was from 9 in 1990 to 33 in 2007 (ADB 2011). Because private vehicles offer flexibility and often move faster than public buses, the demand for private vehicles will likely continue to rise as Asia's cities grow richer (Zheng et al. 2011). According to some estimates, the income elasticity of demand for vehicles is unitary. This means that a 10% increase in per capita income is associated with a 10% increase in a nation's per capita vehicle ownership rate. When combined with the high density in Asian cities, the result could be serious traffic congestion and pollution. Solutions to this high-density-related congestion problem include aboveground rail projects, as in Bangkok, and underground transit, as in the PRC and Delhi.

Increasing demand for electricity is another source of GHG emissions, particularly for nations that rely on coal for power. According to the Asian Development Bank (ADB 2011), 79% of the PRC's electricity is generated by coal, and India uses coal to generate 69% of its electricity. The carbon emissions factor of natural gas is 50% lower than that of coal, while wind and solar have zero carbon emissions factors. These enormous differences highlight how the global GHG emissions associated with electricity consumption vary depending on the energy source. Unfortunately, across Asia today, renewable sources provide only a tiny share of overall power generation, although they are becoming a dominant destination for investment in power generation (Newman and Wills 2012a, 2012b). For example, in 2006, the PRC set a 2020 target of 8% share of primary energy to come from renewable sources but reached this so quickly that they raised the target to 15% by 2020. In 2010, the PRC invested $48.9 billion in renewables, making it the world leader in renewable energy investment (UNEP and Bloomberg New Energy Finance 2011).

Access to Clean Water and Sanitation

A key determinant of a city's "greenness" is whether it can supply clean water and sanitation, and properly dispose of solid waste. Such service delivery will reduce infectious disease rates and lower infant mortality, and should translate into increased life expectancy. The challenges that Asia's poor cities now face resemble the challenges that Western cities faced in the early twentieth century (Cain and Hong 2009, Cain and Rotella 2001, Ferrie and Troesken 2008). In 1880, the average urbanite in the USA lived 10 years less than the average rural resident (Haines 2001). Dirty water was the primary cause, and urban growth exacerbated this problem.

The current status of water and sanitation in Asia is disturbing. By the latest estimate, almost 1.9 billion Asians are without basic sanitation, representing over 70% of the global total (ESCAP, ADB, and UNDP 2012). Only 22% of India's population had access to flush toilets in 1992, and progress in raising that share is slow (Bonu and Kim 2009).

Worse still, except in Southeast Asia, all other subregions in Asia will not meet their sanitation targets as set in the Millennium Development Goals (MDGs). Given that the MDG target is merely to halve the 1990 number of people without access to water supply and sanitation by 2015, a country that had a 20 % access rate in 1990 would still have 40 % of its residents without basic sanitation by 2015 even if it manages to achieve the MDG target. Current projections indicate that more than 290 million people in India may still live without basic sanitation in 2015 (ESCAP, ADB, and UNDP 2012).

Turning to water, more than half (approximately 400 million) of the world's people who are deprived of safe drinking water reside in Asia. To supply water to 400 million people requires huge investments that the countries may not be able to afford. Worse still, low-income countries in the region are projected not to meet the water MDG. In many parts of Dhaka, water is supplied for only 2 hours a day; in some areas, the quality is poor and people complain of receiving straw-colored, sticky, and smelly water. The situation is even worse for slum dwellers, who in many cases have no access to piped water supply even if they are willing and able to pay for it (Wan and Francisco 2009). For example, Dhaka Water Supply and Sewerage Authority officials note that, by law, water can be supplied only to legal landholders (Wahab 2003).

Further, in many Asian countries water is still heavily subsidized. Thus, it is questionable whether the current water supply is economically sustainable even for people who already have gained access. In addition, rivers in Asia are heavily polluted, which adds to the growing scarcity of freshwater sources.

Garbage collection in Asia is another major challenge, especially because people who earn more usually consume and dispose of more (Beede and Bloom 1995). Richer cities may be able to invest in the collecting and disposing of solid waste but poorer cities often lack the resources to do so. For example, in some of India's cities, an estimated 30–35 % of total waste remains uncollected from the city roads (Sridhar and Mathur 2009). Kolkata and Mumbai dump or burn all their garbage in the open. Chennai and Delhi dispose 100 % and 95 %, respectively, of their waste in sanitary landfills (Zhu et al. 2008). Although a higher proportion of urban residents have access to these basic services than do rural residents, Asian cities are hard pressed to raise funds and ensure such service delivery to their rapidly expanding populations.

Resilience to Climate Change

Urbanization increases vulnerability because life and asset losses are much larger in cities than in the countryside when a disaster strikes. In this context, the issue of climate change becomes particularly relevant to cities. Climate change is recognized to have caused extreme weather and rising sea levels. While there are many unknowns about the extent and timing of these impacts, the consensus is that the challenge is real and imminent, and that different cities will face different but urgent challenges (Kahn 2010).

Among the consequences of climate change are an increase in the intensity and frequency of floods and sea-level rise. Poorer cities that are below sea level are the

Table 15.2 Urban population at risk of coastal flooding by region, 2000. (Source: Authors' estimates based on McGranahan et al. 2007)

	Total urban population (million)	Urban population at risk (million)	Share of population at risk (%)	Total urban land area ('000 km^2)	Urban land area at risk ('000 km^2)	Share of land area at risk (%)
Africa	280	32	11	310	18	6
Asia	1,390	251	18	1,167	129	11
Latin America	312	24	8	663	42	6
Europe	571	40	7	800	56	7

most susceptible. This is especially relevant for Asian nations such as Bangladesh and the Pacific island countries, though data for the latter are often unavailable. Many Asian cities, and especially some megacities, have been built in the deltas of major rivers where ports could link the cities to the global economy.

Therefore, it is not surprising that many Asian cities are flood prone. Some such cities may have extensive experience dealing with floods. For example, Dhaka has an elaborate set of mud banks for protection. However, increased flooding induced by climate change may well push these cities' infrastructures beyond their current capacities, as it occurred in Bangkok in late 2011. Developing further coastal engineering protection will place an increasing burden on the resources of such cities.

In 2000, 18 % of Asian urbanites were at risk of coastal flooding (Table 15.2), versus 11 % for Africa, 8 % for Latin America, and 7 % for Europe. In terms of total urban population, 251 million Asians were exposed to this risk, compared with 40 million Europeans, 32 million Africans, and 24 million Latin Americans. Similar high comparative proportions of total and urban land are found in low-lying coastal areas of Asia relative to other continents. These areas are at greater risk of not only a future sea-level rise but also coastal flooding arising from more frequent and intense storms.

Using the proportion of urban population that is exposed to flooding risks as a measure of vulnerability, vulnerability to inland or coastal flooding differs significantly across subregions and countries. In terms of coastal flooding (Table 15.3), the region's vulnerability is 19.6 %, with Southeast Asia being most vulnerable (36.1 %) followed by East Asia (17.5 %) and South Asia (14.3 %). At the country level, the most vulnerable economies are the Maldives (100 %), Vietnam (73.9 %), Thailand (60 %), and Bangladesh (50.3 %).

Turning to inland flooding (Table 15.4), the overall vulnerability for Asia is 15.1 %, moderately lower than the coastal flooding vulnerability. East Asia is most vulnerable (19.8 %), followed by Southeast Asia (14.7 %) and South Asia (14.2 %). At the country level, about three-quarters of the urban population of Cambodia are at risk of inland flooding. The vulnerability is 38.6 % for Vietnam, 35.7 % for Bangladesh, 34 % for the Lao PDR, and 29 % for Thailand. One-fifth of the urban population of the PRC and 12 % of India's urbanites, in total more than 120 million people, are at risk of inland flooding. Even landlocked countries have substantial

Table 15.3 Population and area at risk of coastal flooding, 2000. (Source: Balk et al. 2012)

Country	Urban population at flood risk	% population at flood risk	Urban land area (km^2) at flood risk	% urban land area at flood risk
Central and West Asia				
Georgia	230,982	7.5	159	4.9
Pakistan	2,227,119	4.6	364	1.5
Subtotal	*2,458,101*	*4.8*	*523*	*1.9*
East Asia				
China, Rep. of	78,277,824	18.5	33,243	13.4
Hong Kong, China	811,925	14.1	104	14.2
Korea, Rep. of	2,034,832	5.3	1,369	7.4
Taipei, China	3,022,216	21.4	2,604	21.3
Subtotal	*84,146,796*	*17.5*	*37,320*	*13.4*
South Asia				
Bangladesh	15,428,668	50.3	4,522	45.9
India	31,515,286	10.5	11,441	5.9
Maldives	6,421	100.0	3	100.0
Sri Lanka	961,977	22.8	744	22.5
Subtotal	*47,912,352*	*14.3*	*16,710*	*8.1*
Southeast Asia				
Brunei Darussalam	24,965	11.2	256	24.2
Cambodia	281,944	15.0	137	21.3
Indonesia	22,720,666	27.9	8,176	26.4
Malaysia	3,687,052	26.5	3,775	28.1
Myanmar	4,512,823	36.2	1,087	24.2
Philippines	6,807,578	27.4	1,872	22.8
Singapore	550,057	14.0	62	12.0
Thailand	12,471,874	60.0	9,207	34.8
Vietnam	12,862,429	73.9	3,877	66.4
Subtotal	*63,919,387*	*36.1*	*28,448*	*31.1*
The Pacific				
Timor-Leste	1,369	4.2	7	5.3
Developed Member Economies				
Japan	29,022,184	25.7	17,322.81	17.5
Asia	*227,460,189*	*19.6*	*100,332*	*14.3*

Global Rural–Urban Mapping Project (GRUMP) estimates for urban population and urban areas are used in the computation of percentages of population and area at risk (http://sedac.ciesin.columbia.edu/gpw)

vulnerability: Tajikistan (16.4 %), Bhutan (14.5 %), Afghanistan (12.5 %), and Kyrgyz Republic (12 %).

Tables 15.5 and 15.6 list the 40 most vulnerable cities in Asia that have a population of 1 million or more (as measured in 2000). Focusing on coastal flooding (Table 15.5), half of the 40 most vulnerable cities are in the PRC. Among the 11 cities with a vulnerability of more than 90 %, 8 are in the PRC, including Shanghai and Tianjin—the PRC's largest cities. The other three are Bangkok in Thailand, Khulna in Bangladesh, and Palembang in Indonesia. Another 13 cities have vulnerability levels between 60 % and 89 %, notably including Kolkata and Ho Chi Minh City.

Table 15.4 Population and area at risk of inland flooding, 2000. (Source: Balk et al. 2012)

Country	Urban population at flood risk	% population at flood risk	Urban land area (km^2) at flood risk	% urban land area at flood risk
Central and West Asia				
Afghanistan	540,078	12.5	430	23.8
Armenia	198,941	7.4	192	12.9
Azerbaijan	254,474	6.0	526	9.1
Georgia	319,048	10.4	369	11.4
Kazakhstan	860,190	9.8	1,561	13.9
Kyrgyz Republic	189,534	12.2	367	12.6
Pakistan	3,092,548	6.4	2,230	9.0
Tajikistan	286,229	16.4	408	11.6
Turkmenistan	64,777	3.2	620	11.1
Uzbekistan	813,736	8.5	1,615	10.9
Subtotal	*6,619,555*	*7.7*	*8,318*	*11.1*
East Asia				
China, Rep. of	90,700,145	21.4	45,610	18.4
Korea, Rep. of	2,920,496	7.6	1,010	5.5
Mongolia	176,968	12.2	190	16.5
Taipei, China	890,354	6.3	668	5.5
Subtotal	*94,687,963*	*19.8*	*47,478*	*17.0*
South Asia				
Bangladesh	10,954,609	35.7	3,721	37.8
Bhutan	21,504	14.5	30	15.5
India	36,056,326	12.0	25,564	13.3
Nepal	160,508	5.9	214	8.5
Sri Lanka	792,244	18.8	442	13.4
Subtotal	*47,985,191*	*14.2*	*29,971*	*14.4*
Southeast Asia				
Brunei Darussalam	1,634	0.7	14	1.3
Cambodia	1,428,121	76.0	641	100.0
Indonesia	4,394,972	5.4	2,417	7.8
Lao PDR	302,825	34.0	276	26.1
Malaysia	495,254	3.6	749	5.6
Myanmar	2,361,353	19.0	1,050	23.4
Philippines	3,713,398	14.9	968	11.8
Thailand	6,070,291	29.2	7,002	26.5
Vietnam	6,716,973	38.6	1,893	32.4
Subtotal	*25,484,820*	*14.7*	*15,010*	*16.3*
The Pacific				
Timor-Leste	869	2.7	6	4.6
Developed Member Economies	*179,484,278*	*15.1*	*105,799*	*14.0*
Japan	4,705,880	4.2	5,016	5.1
Asia	*179,307,311*	*15.1*	*105,610*	*14.0*

Global Rural–Urban Mapping Project (GRUMP) estimates for urban population and urban areas are used in the computation of percentages of population and area at risk (http://sedac.ciesin.columbia.edu/gpw)

Lao PDR Lao People's Democratic Republic

Table 15.5 Top 40 Asian cities (>1 million population) in vulnerability to coastal flooding. (Source: Balk et al. 2012)

Country	City	Population at flood risk (million)	% of city population	City area at flood risk (km^2)	% of area at risk
China, People's Rep. of	Tianjin	5.5	100.0	2081	100.0
China, People's Rep. of	Panjin	1.0	100.0	690	100.0
Bangladesh	Khulna	1.1	99.9	394	99.8
China, People's Rep. of	Nantong	1.0	99.8	286	99.9
China, People's Rep. of	Changzhou	2.0	99.0	362	99.0
China, People's Rep. of	Jiangyin	1.2	96.8	492	96.8
China, People's Rep. of	Suzhou	1.3	95.8	368	91.2
Indonesia	Palembang	1.3	94.2	473	89.5
Thailand	Bangkok	8.8	93.3	4805	80.2
China, People's Rep. of	Wuxi	1.3	91.1	397	91.0
China, People's Rep. of	Shanghai	14.0	90.8	2416	98.2
India	Kolkata	14.0	89.0	1441	62.9
China, People's Rep. of	Ningbo	1.7	85.6	779	85.6
Indonesia	Ujung Pandang	1.2	85.4	295	68.7
Vietnam	Ho Chi Minh	4.4	79.3	890	72.6
Indonesia	Surabaya	3.8	76.3	777	55.4
Bangladesh	Chittagong	2.4	72.5	517	61.7
Japan	Niigata	1.0	68.5	1244	49.9
Myanmar	Yangon City	2.8	66.9	587	69.9
China, People's Rep. of	Wuhu	0.8	66.3	210	72.4
India	Palwancha	0.8	66.2	937	67.6
China, People's Rep. of	Taizhou	1.2	65.3	423	66.4
China, People's Rep. of	Shantou	3.6	63.8	1084	63.6
India	Surat	2.2	61.0	300	19.2
Indonesia	Pekalongan	0.9	59.2	335	50.3
India	Kochi	0.9	57.3	260	44.6
China, People's Rep. of	Hangzhou	3.1	55.4	931	62.2
Bangladesh	Dhaka	5.0	55.0	874	61.5
China, People's Rep. of	Wenzhou	2.0	53.8	755	53.7
Malaysia	Georgetown	0.6	50.8	456	43.0
China, People's Rep. of	Putian	0.6	49.2	176	39.1
China, People's Rep. of	Huaiyin	0.5	48.7	203	46.9
Indonesia	Tegal	0.5	47.2	175	41.4
India	Mumbai	8.1	46.3	848	40.1
China, People's Rep. of	Dandong	0.5	42.9	219	51.9
China, People's Rep. of	Yingkou	0.7	42.7	431	42.7
China, People's Rep. of	Haikou	0.6	41.4	246	41.1
Vietnam	Hanoi	1.1	40.6	429	64.5
China, People's Rep. of	Shenzhen	11.0	38.2	4319	49.2
Indonesia	Semarang	0.8	37.9	344	42.2

Turning to inland flooding at the city level (Table 15.6), again the vulnerability level is lower than that for coastal flooding. The top three cities are Phnom Penh (99 %), Wuhan (82 %), and Palembang (80 %). Of the top 40 most vulnerable cities, 19 are in the PRC. Some of the large cities that are vulnerable to inland flooding include Dhaka (60 %), Ho Chi Minh City (50 %), and Bangkok (46 %).

Table 15.6 Top 40 Asian cities (>1 million population) in vulnerability to inland flooding. (Source: Balk et al. 2012)

Country	City	Population at flood risk (million)	% of city population at risk	City area at flood risk (km^2)	% of area at risk
Cambodia	Phnom Penh	1.0	98.5	204	98.8
China, People's Rep. of	Wuhan	5.3	81.8	956	81.8
Indonesia	Palembang	1.1	80.2	257	48.6
India	Patna	1.1	72.4	436	72.3
Bangladesh	Dhaka	5.4	59.7	680	47.9
China, People's Rep. of	Nanjing	2.2	56.0	749	55.6
Vietnam	Ho Chi Minh	2.8	50.4	306	25.0
China, People's Rep. of	Tianjin	2.8	50.1	795	38.2
China, People's Rep. of	Huangshi	0.6	49.6	170	45.5
China, People's Rep. of	Huainan	0.6	49.5	277	49.4
China, People's Rep. of	Wuhu	0.6	46.8	140	48.4
Thailand	Bangkok	4.4	46.2	2165	36.1
China, People's Rep. of	Bangbu	0.5	44.0	198	44.5
India	Guwahati	0.5	43.8	159	34.6
India	Allahabad	0.7	42.2	230	43.2
Myanmar	Mandalay	0.5	40.2	167	41.4
China, People's Rep. of	Panjin	0.4	38.3	208	30.1
China, People's Rep. of	Changsha	1.2	37.2	187	28.0
Bangladesh	Khulna	0.4	37.0	131	33.1
India	Vijayawada	0.5	36.0	141	21.4
Vietnam	Hanoi	0.9	33.2	252	38.0
India	Varanasi	0.6	32.6	211	33.6
Indonesia	Surakarta	0.4	32.6	96	24.1
China, People's Rep. of	Nanning	0.4	30.4	173	30.4
China, People's Rep. of	Hengyang	0.3	28.6	94	28.1
India	Kolhapur	0.7	28.6	1035	29.2
China, People's Rep. of	Xinxiang	0.5	27.7	146	23.4
China, People's Rep. of	Nanchang	0.7	27.1	196	24.6
China, People's Rep. of	Shanghai	3.7	24.5	292	11.9
Korea, Rep. of	Pusan	1.2	24.5	196	12.6
India	Bhubaneswar	0.3	23.4	141	22.2
India	Palacole	0.3	23.2	385	27.8
China, People's Rep. of	Yichang	0.3	22.8	137	20.2
China, People's Rep. of	Qiqiha'er	0.3	22.0	110	22.0
India	Kanpur	0.3	21.5	171	20.5
China, People's Rep. of	Harbin	0.7	21.1	270	22.0
China, People's Rep. of	Luoyang	0.3	20.6	93	20.4
Philippines	Quezon City	2.9	20.4	198	9.1
China, People's Rep. of	Jinan	0.6	20.3	156	20.2
Bangladesh	Chittagong	0.7	20.2	104	12.4

Our research results show that coastal flooding is more concentrated than inland flooding. Both are serious in South Asia, Southeast Asia, and the PRC. Several megacities face high vulnerability to coastal flooding and moderate vulnerability to inland flooding at the same time, such as Kolkata (89 % coastal and 15 % inland) and Shanghai (91 % coastal and 25 % inland). A number of large cities feature more than 50 % of vulnerability to both types of flooding: Dhaka, Bangladesh; Ho Chi Minh City, Vietnam; Palembang, Indonesia; and Tianjin, the PRC.

Asia has more than 750 urban settlements (of at least 5,000 people, most much larger), the population of which is fully in low-lying zones with 100 % vulnerability to coastal flooding, and about half as many with 100 % vulnerability to inland flooding. These smaller cities and towns are especially noteworthy because their populations are growing fast. Further, some of them are close to vulnerable large cities. Agglomeration economies have many benefits for growth, but any flood risks they share need to be accounted for in planning.

The size of population affected by flooding risks in Asia is enormous. A study commissioned by ADB (Balk et al. 2012) estimates that over 303 million Asian urbanites were at risk of coastal flooding in 2010 and this is projected to increase to 410 million in 2025. In terms of inland flooding, about 245 million urban Asians were found to be at risk in 2010, and by 2025 this number will reach 341 million. While it is not possible to predict the damage such floods will do to property or to predict the loss of life, poor cities will face greater challenges than rich ones in adapting to this new reality.

Loss of Natural Ecosystems and Amenities

The loss of biodiversity in the Asian region has been well documented as urbanization proceeds (Millennium Ecosystem Assessment 2005). Asian cities are much more densely populated than most other cities and hence do not take up proportionately as much rural land and natural ecosystems. However, their densities provide less opportunity for green spaces within the cities. Thus, many Asian cities are struggling to provide sufficient natural amenities—access to “green spaces” for environmental and human health, rivers, parks and wildlife corridors; green space for recreation-related activities; and green elements in the urban landscape. The resolution of this issue is being addressed with new design approaches and technologies to enable both greater biodiversity and natural amenities. One of these approaches is “biophilic urbanism” (Newman et al. 2008). A biophilic city brings landscaping into and onto every element of the built environment, such as buildings, walls, and roads (Beatley 2010).

Urban Slums and Urban Poverty

Asia has the largest share of the world’s slum-dwelling population. In 2010, the region was home to 506 million slum dwellers, more than 61 % of the world’s total. Some subregions within Asia are far worse affected than others. East and Southeast Asia harbor 55 % of the slum dwellers in the region, and South Asia alone hosts almost 38 % of the region’s slum dwellers (UN-HABITAT 2008).

In many low- and middle-income nations, urban poverty is growing compared to rural poverty. Urban residents are more dependent on cash incomes to meet their essential needs than rural residents are, and income poverty is compounded by inadequate and expensive accommodation, limited access to basic infrastructure and services, exposure to environmental hazards, and high rates of crime and violence.

Asia's Environmental Challenges: The Environmental Kuznets Curve

Clearly, Asia is already facing tremendous urbanization-related challenges. As far as the environment is concerned, air pollution is serious and GHG emissions have been increasing. Natural amenities either are lost or must be compensated for as cities grow. Pressures are mounting to provide water, sanitation, and waste disposal to very fast-growing urban populations, and cities are becoming more vulnerable.

Worse still, most of the special features of Asia's urbanization highlighted earlier exacerbate the environmental challenges. First, a low level of urbanization implies that Asia still has some way to go in dealing with these challenges. Ignoring or deferring action on issues such as environmental degradation is not an option because it risks consequences in the near term and vastly greater expenses in the medium to long run. Second, the fast pace of urbanization means little time for adjustment or learning. Many countries have been insufficiently prepared for the changes urbanization requires in urban planning, development of appropriate skills, and urban financing. Third, bigger cities are certainly harder to manage and more of them can only add to the challenges as Asia's megacities expand in population and grow in numbers. Finally, a high density makes cities more vulnerable to catastrophic events and disease. Especially in poor cities such as Delhi, Dhaka, Wuhan, and those in the Pacific island countries, such events can mean serious loss of lives and assets (ADB 2012c).

To gauge the environmental outlook as Asia continues its growth, the Environmental Kuznets Curve or EKC is a useful tool. While there are alternative views regarding the theoretical foundation and empirical robustness of the EKC, many studies have found an inverted U-shape relationship between environmental indicators and gross domestic product (GDP) level. Grossman and Krueger (1995) and De Bruyn (1997) state that the inverted U-shape is driven by a combination of forces: the level of output or scale of economic activity (scale effect), the composition of output (structural effect), and the state of technology (technical effect). Holding everything else constant, increasing output leads to more environmental damage, shifting resources and production to less-polluting or less-emitting industries such as services helps improve environment, and finally technology advance is beneficial to environment. As different countries experience or prioritize different forces at different development stages, the EKC naturally differs between countries and periods. Underlying the priority setting are personal and institutional preferences for environmental quality versus material outputs.

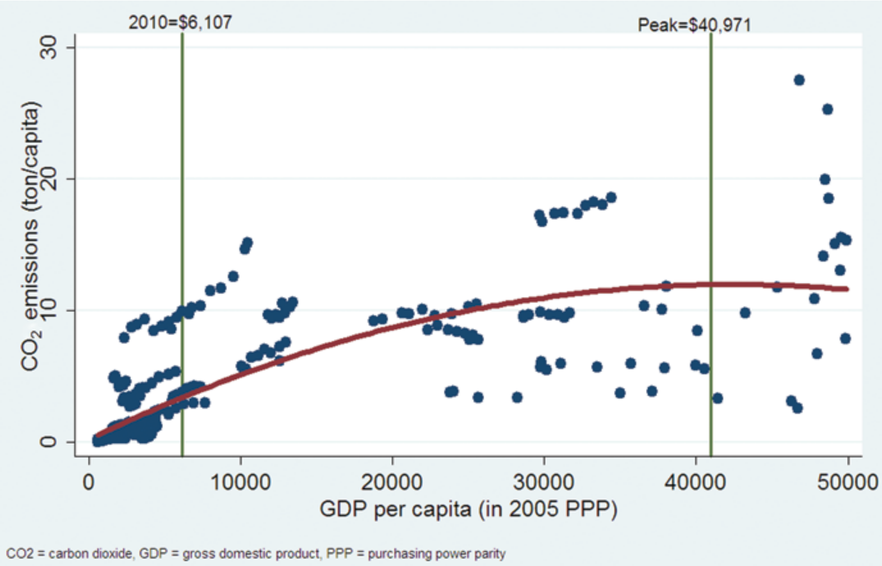


Fig. 15.17 Scatterplot of CO_2 emissions (t/capita) and GDP per capita (in 2005 PPP). *PPP* purchasing power parity. (Source: Authors' estimates based on World Bank 2012)

Not only does the EKC differ across countries and time, but it also differs with various environmental indicators. Typically, local pollutants are more likely to display an inverted U-shape relation with income, while global impacts such as CO_2 are less likely to do so. This is understandable as both ordinary citizens and policy makers are likely to consider local impacts as more important than global ones. Consequently, the peaks of the inverted U-curves are found to correspond with significantly different income levels. For example, the sulfur emissions peak corresponds with income levels ranging from \$ 3,137 to \$ 101,166 at 1990 prices (Stern 2003), whereas CO_2 peaks correspond with \$ 19,100 (Selden and Song 1995) or \$ 25,100 (Cole et al. 1997).

Where does Asia stand on the EKC? If the findings cited above are used to make inferences, Asia is still on the rising side of the curve, as the average income in Asia is roughly \$ 3,900 at 1990 prices. At the current stage of Asia's development, millions of people move to cities and firms locate there to employ them. The sheer scale of activities associated with urbanization and industrialization (such as transport, building construction, garbage and waste disposal, and power generation) could contribute to environmental degradation. Thus, in the absence of appropriate interventions, Asia's environment is likely to become worse before it gets better.

To properly assess the environmental outlook for Asia, it is necessary to estimate Asia's EKC. Using data from the World Development Indicators, Fig. 15.17 presents a scatterplot of per capita GDP against per capita CO_2 emissions. The trend line clearly resembles a standard EKC. To formally estimate an EKC for Asia, 374

Table 15.7 The environmental Kuznets curve for Asia. (Source: Authors' estimates)

Independent variable	Coefficient	Standard error
Ln(GDP per capita)	5.48***	0.502
Ln(GDP per capita)^2	−0.251***	0.029
Constant	−27.54***	2.169
Observations	374	
R^2	0.753	

*** significant at 1 %

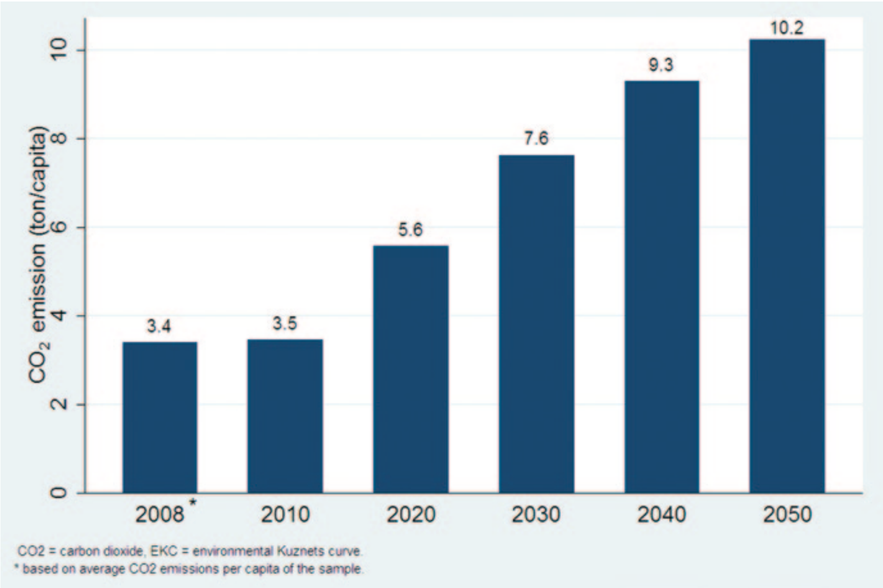


Fig. 15.18 Projected per capita CO_2 emissions based on estimated EKC. (Source: Authors' estimates)

observations from 42 ADB member countries were used to produce the modeling results in Table 15.7. Based on this model, the peak of the inverted U-curve corresponds to a GDP level of $ 40,971 (at 2005 price levels). Clearly, the GDP per capita of most developing Asian countries is far from the "CO_2 turning point."

Using the estimated EKC, the future level of per capita CO_2 can be simulated using GDP projections of Kohli et al. (2011). Figure 15.18 presents the "business-as-usual" scenarios: per capita CO_2 would rise from the 2008 level of 3.4 tons to 7.6 tons in 2030 and further to 10.2 tons in 2050. These scenarios imply a disastrous future for Asia and the globe. Clearly, action is needed and interventions must be found and implemented.

The Environment–Urbanization Nexus in Asia

The conventional EKC is a relationship between GDP and an environmental indicator. Owing to the positive correlation between urbanization and GDP (Fig. 15.19), the EKC could be used to infer that urbanization in Asia may lead to environmental degradation. However, this inference is problematic as the urbanization–GDP curve is far from being a good fit. In reality, a country can achieve the same level of per capita GDP with different levels of urbanization. On the other hand, countries with the same level of urbanization can have quite different GDPs per capita. For example, many countries in sub-Saharan Africa have been as urbanized as those in Asia for many years, yet they have been much poorer. For decades, the urbanization level in Latin America was as high as that in Europe, but Europe always enjoyed higher income. As shown in Fig. 15.19, there are vast deviations of data from the fitted lines.

Therefore, it is inappropriate to rely on the EKC to infer an urbanization–environment relationship and conclude that the environment will further degrade as Asia urbanizes. Indeed, urbanization can produce beneficial environmental outcomes as it facilitates improved productivity, development of the service sector, and access to environment-related infrastructure; promotes green innovation and technology; prompts traditional manufacturing to relocate away from city centers; nurtures middle class and property owners who are more pro-environment than the general populace; and leads to lower fertility rates and higher educational levels.

Urban Agglomeration Helps Improve the Environment

Urban agglomeration in itself is benign for the environment. First, it comes with higher productivity due to the positive externalities and scale economies. For Asia as a whole, urban productivity is more than 5.5 times that in the rural areas (UN-HABITAT 2010). Thus, the same level of output can be produced using fewer resources with urban agglomeration than without. In this sense, urbanization helps reduce the ecological footprint.

Second, development of the service sector is closely associated with urban agglomeration. The tertiary sector could not prosper without urbanization because most services require a certain degree of concentration of clients. As service production generally pollutes and emits less than manufacturing activities, urbanization enhances the beneficial structural effect underlying the EKC, as discussed in the previous section.

Third, environment-related infrastructure and services such as piped water, basic sanitation, and solid waste disposal are much easier and more economical to construct, maintain, and operate in an urban than a rural setting. In other words, urbanization facilitates the supply of the relevant facilities and services to a larger share of the population. On the other hand, urbanization promotes growth that helps enhance affordability and demand. It is thus not surprising that many more urban

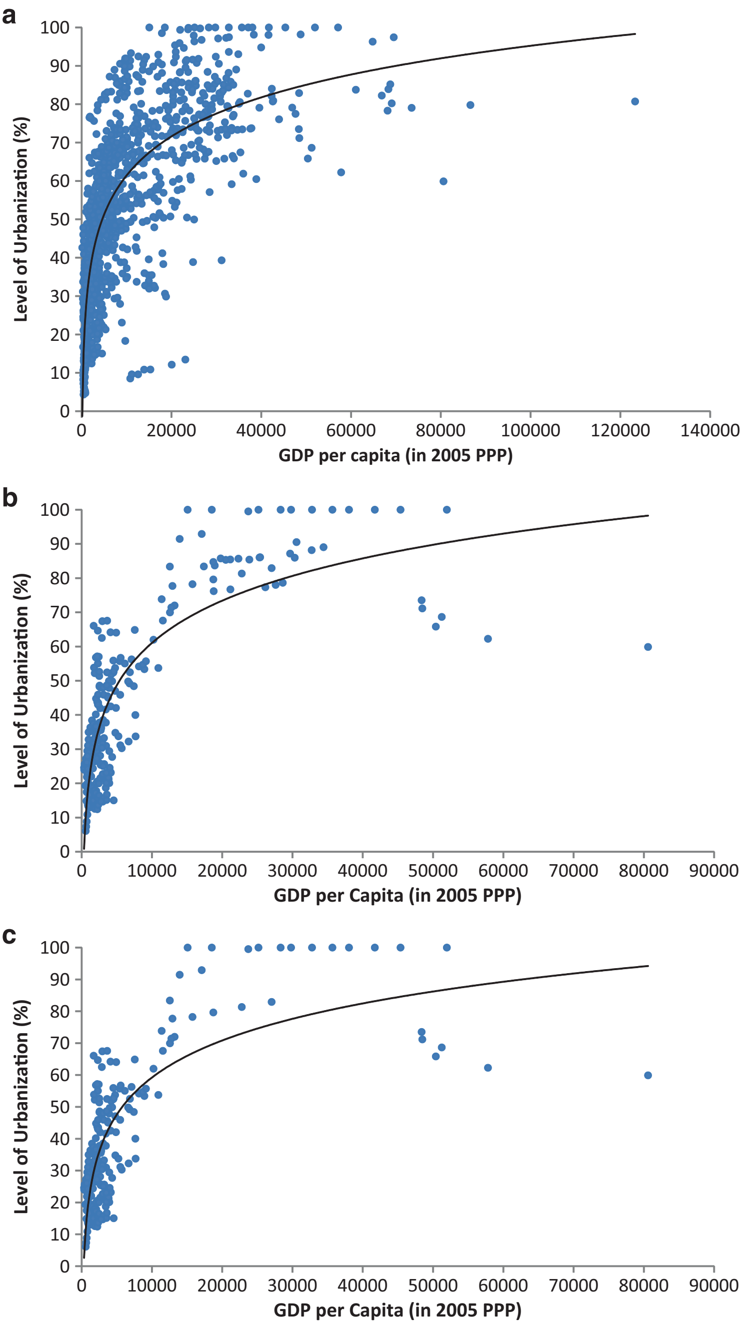


Fig. 15.19 GDP per capita and level of urbanization, 1980–2010. **a** All countries, **b** Asia and the Pacific, **c** For developing member countries. (Data source: World Bank 2012)

residents have access to infrastructure and other services than rural residents (Wan and Zhang 2011, ESCAP, ADB, and UNDP 2012). For example, city residents in India have much greater access to flush toilets—60 % in 1992 (relative to a national average of 22 %) and this increased to 79 % by 2006 (Bonu and Kim 2009).

Fourth, urbanization facilitates innovations, and this applies to green technologies as well. In the long run, the environment-friendly equipment, machines, vehicles, and utilities determine the future of the green economy, and Asia's cities are likely to play a key role in producing and exporting low-cost, high-quality, renewable power generation equipment and electric vehicles. When new forms of industry open, firms usually cluster in cities featuring high levels of human capital. When the technology is mature, they decentralize and relocate to low-wage regions for mass production (Duranton and Puga 2001). As a consequence, Asian urban growth and openness to global markets facilitates the rise of the global green economy.

Green innovations accompanying urbanization in Asia will be helped by the vast size of Asia's own market. In the presence of fixed costs, the scale of the market is a key determinant for developing new products. The billions of people who seek to purchase energy-efficient products will create a huge opportunity for entrepreneurs who can serve them. Acemoglu and Linn (2004) demonstrated this in the case of new drug development, and their logic holds for green products. If billions of people seek energy-efficient air conditioners to offset hot summers, there will be significant incentives to invest in developing such products. Some of the producers will succeed and, in a globalized world market, the payoff will be huge.

Many Asian economies already export green technology. Sawnhey and Kahn (2012) note that developing countries' exports of renewable energy products have grown significantly. For example, the PRC's share in the US imports of core wind and solar energy equipment, including solar panels, cells, and blades, has increased steadily. In particular, the PRC's share of US imports of solar modules grew from 0 to 43 % during 1989–2010, and India's share of US imports of wind turbines grew from 0 to 10 % during 1996–2010.

Fifth, for any given population, high density associated with urban agglomeration can benefit the environment. The urban economics literature shows that compactness is one of the most important determinants of energy use (Glaeser and Kahn 2004). In this volume, the chapter by Arifwidodo provides evidence of this from Indonesia. High density can create greater viability for public transport and entail less or shorter travel. It also facilitates walking and cycling rather than driving or taking public transport (Newman and Kenworthy 1999).

Finally, the enhanced economic freedom arising from urbanization allows people to improve their standard of living in many ways, including through better food, shelter, and health care. Urbanization benefits education and can help increase a population's health and robustness in the face of disease. Urban growth also generates revenues that fund infrastructure projects, reducing congestion and improving public health.

Manufacturing Relocation and Rise of the Middle Class and Property Owners

Urbanization can help alleviate environmental problems by prompting relocation of traditional manufacturing away from major city centers. This is partly attributable to rising land prices in city centers as urbanization proceeds. In fact, Sridhar and Reddy (2010) provide evidence from the potential of land as a tool for financing urban infrastructure. The development of infrastructure such as ports and highways also facilitates such movements (Henderson 2002). Manufacturing firms recognize that by choosing a less centralized location they can pay lower wages and land prices while still enjoying access to consumer markets and intermediate input suppliers. As Asia's nations invest in better transport infrastructure, manufacturing can move further from the major cities and these jobs will be replaced by knowledge economy and service jobs with lower ecological footprints. For example, in 1970, Seoul's shares of population and manufacturing in the Republic of Korea were 62 % and 61 %, respectively. However, by 1993, while Seoul's population remained at 61 % of the country's total, its manufacturing share had fallen to 30 %. Between 1983 and 1993, Seoul's share of national manufacturing jobs fell from 21 to 14 % and Pusan and Taegu's shares fell from 23 to 14 % (Henderson 2002). These examples echo the trend of decentralization of manufacturing employment that has taken place elsewhere (Glaeser and Kahn 2004).

The migration of heavy industry away from major cities has generated large public health benefits through improved air and water quality in many cities around the world (Kahn 1999, 2003). In a case study of the 2008 Summer Olympics in Beijing, Chen et al. (2011) found significant improvements in ambient air quality as the authorities changed transport patterns and shut down factories. Kahn (2003) documents the sharp reduction of pollution in the Czech Republic and Poland as they closed energy-inefficient manufacturing plants that were built under communism.

The economic damage caused by exposure to pollution is a function of the number of people exposed and is reflected by their willingness to pay to avoid pollution. When a factory moves from a major city to a less populated area, the aggregate damage caused is likely to decline because fewer people are exposed to the pollution. As an older factory closes at the origin and a new factory with better technology is built at the new destination, emissions per unit of output are also likely to fall.

Urbanization also helps nurture the middle class and raises private ownership of properties in cities. The expanding middle class will demand a better environment, and property owners are a powerful interest group with a stake in enacting policies to curb environmental degradation. They directly gain from improvements in the local quality of life, not least because the improvements will lead to higher local real estate prices. Put simply, land is more valuable in nicer areas with natural and human amenities, which is well documented in many real estate studies (see Gyourko et al. 1999 for a review; and Zheng and Kahn 2008 on the PRC). Zheng and Kahn (2008) document that real estate prices are higher in low-pollution parts of Beijing that feature green space and are close to public transit stations.

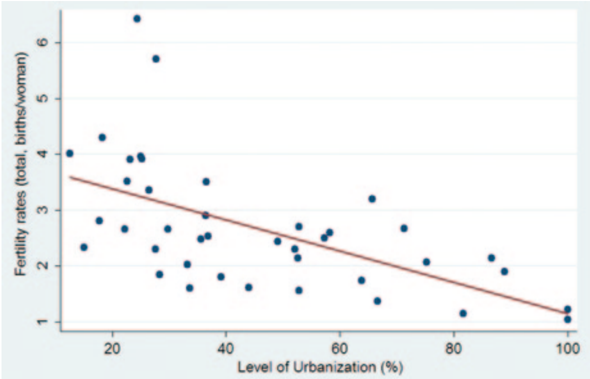


Fig. 15.20 Fertility rates versus level of urbanization in Asia. (Source: World Bank 2012)

Declining Fertility and Increasing Educational Attainment

Urbanization is also beneficial to the environment due to its close association with declining fertility.[6] The economics of demography offers a simple explanation (Becker 1991). Women who live in cities have more opportunities for education and to work in the labor force than rural women. Consequently, urban women respond by working more, marrying later, and having fewer children. As young women anticipate that they will have the opportunity to work in cities, they invest more in their education as teenagers and this further encourages them to work in the marketplace. The net effect is to slow population growth, which means less adverse environmental consequences than would otherwise be the case.

Anecdotal evidence from Asia supports the above arguments. In nations such as Vietnam, the fertility rate has declined dramatically, from the 1980 level of 5.4 to 1.8 in 2010 (World Bank 2012). In rich cities in the PRC such as Shanghai, the birth rate has fallen below the population replacement rate. Around the world, the same correlation is observed. Figure 15.20 highlights this negative correlation for Asian nations.

Using 1980–2010 data from 31 Asian countries (194 observations), total raw fertility can be regressed on levels of urbanization, GDP per capita, and education. Literally interpreted, the modeling results indicate that every 1 percentage point increase in the urbanization level led to 5 fewer births per 100 women who are of reproductive age.[7] To directly assess the impact of urbanization on population growth, an econometric model is fitted to cross-country data from Asia. The empirical results tabulated in Table 15.8 imply that every 1 percentage point increase in the urbanization level led to a 0.02 percentage point reduction in the net population growth rate. This translates into a total reduction of 169.28 million in the population increase that might have happened without urbanization during 2010–2050, more

[6] The fertility rate is the ratio of live births per woman of reproductive age in a given year.

[7] This result is not shown in any table but is available upon request.

Table 15.8 Population growth and urbanization. (Source: Authors' estimation)

Independent variable	Coefficient	Standard error
Urbanization	−0.019***	0.005
GDP per capita	0.000***	0.000
Education[a]	−0.049***	0.015
Constant	2.534***	0.250
Observations	194	
R^2	0.1623	

*** significant at 1 %

[a] Education refers to percentage of complete tertiary schooling attained in female population

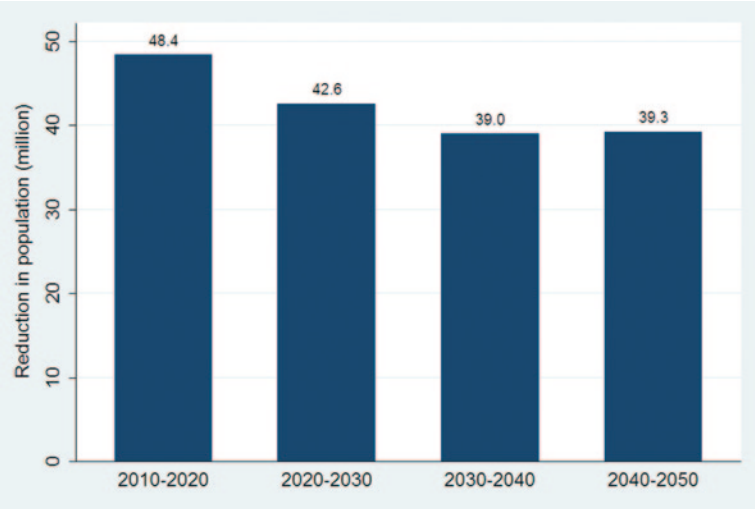


Fig. 15.21 Reduction in projected population due to urbanization. (Source: Authors' estimates)

or less evenly distributed over different decades (Fig. 15.21). Under the "business-as-usual" scenario of Fig. 15.18, this amounts to an additional 1,727 million tons of CO_2 in 2050, 65 million tons more than the combined emissions of India and Vietnam in 2009 (Howes and Wyrwoll 2012).

As discussed earlier, one major function of cities is to gather intellectual capital so people can become more educated by learning from and interacting with each other. Intensified competition in cities also motivates urbanites to accumulate human capital. In addition, cities offer better and more opportunities for learning. The positive association between urbanization and education is evident in Fig. 15.22.

Improved educational attainment, in turn, can affect the environment at least in two ways. First, similar to urbanization, education helps lower fertility, as reflected by the negative and significant coefficient of the education variable in Table 15.8. Second, the more educated often opt for a better living environment by voting for environmental regulation (Kahn 2002). They are also more willing to sacrifice con-

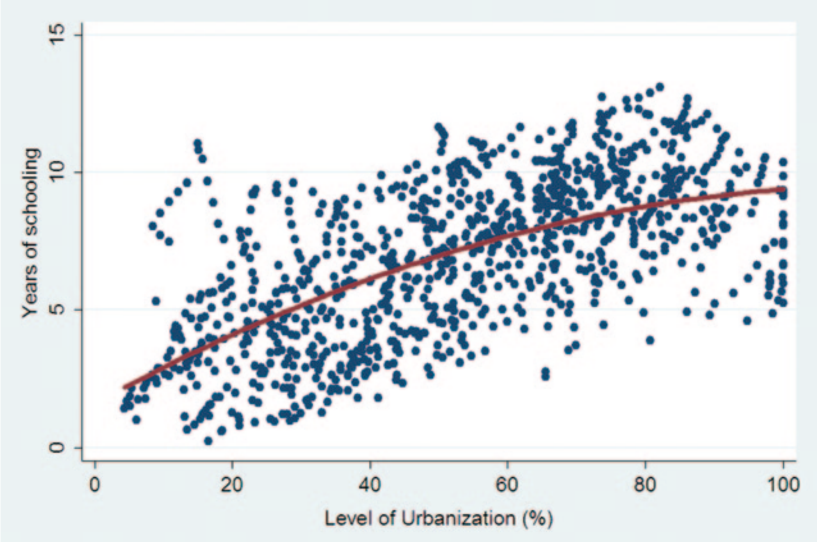


Fig. 15.22 Education versus urbanization in Asia, 1980–2010. (Sources: UN 2012 and Barro-Lee 2010)

sumption today for returns in the long run (Moretti 2004a, Becker and Mulligan 1997). In addition, politicians are likely to respond by supplying policies that urban voters desire.

Are the educated in Asia also pro-environment? The World Values Survey offers the opportunity to address this question. The survey data allow one to observe the personal priorities of people who are of the same age but live in different nations. For Asia, the data cover the PRC; India; Indonesia; the Republic of Korea; Malaysia; Taipei,China; Thailand; and Vietnam. In 2007, the survey focused on four attitudinal questions regarding whether respondents (1) prioritize environmental protection over economic growth, (2) are willing to sacrifice income to protect the environment, (3) would pay higher taxes to protect the environment, and (4) support greater regulation to protect the environment.

Table 15.9 reports the results. The top rows focus on Asian respondents and stratify the data by educational attainment. A positive correlation between educational attainment and prioritizing green issues is clearly shown. For example, 47 % of respondents in Asia who have at least a university education prioritize the environment over economic growth, while only 32 % with no formal education have this prioritization. As another example, while less than 50 % of those without a formal education are willing to sacrifice personal income for environment, this percentage is as high as 81 % for university graduates.

The bottom two rows of Table 15.9 compare the attitudes of all respondents versus those who live in Asia. The data show that respondents from Asia are more willing to sacrifice personal income to protect the environment (72 %) than the world average (62 %). They are 7 percentage points more likely to support higher taxes for

Table 15.9 Percentage of respondents' willingness to support environmental protection (Source: Authors' estimates based on World Values Survey data)

Population subgroups	Sacrifice growth (%)	Sacrifice income (%)	Pay higher taxes (%)	Support regulation (%)
By educational attainment				
No formal education	32.3	49.5	43.2	42.1
Less than secondary education	42.4	68.7	58.3	60.4
Secondary education	45.2	75.3	62.8	60.8
At least some university education	46.8	80.8	67.7	61.0
World	49.3	61.8	53.3	67.2
Asia	43.4	71.8	60.4	58.5

environmental protection, although relatively more Asians prioritize growth over environment. In other words, they do not want to see growth slow in the region but are willing to sacrifice personal income for better environment ex-post. These findings suggest a culture in Asia that is forging greener urbanism.

Quantifying the Environment–Urbanization Nexus

The channels and mechanisms through which urbanization affects the environment, as discussed in this chapter, imply that the relationship between urbanization and the environment may differ from the conventional EKC. While it is difficult to pin down the impacts of each channel, econometric models may be used to estimate a relationship. In doing so, it is crucial to control for GDP in the model so that the effects of urbanization on environmental indicators can be properly identified and quantified. Thus, the model to be estimated takes the following form:

$$\text{Ln } CO_2 \text{ or Ln } PM10 = \alpha_0 + \alpha_1 \text{Ln GDP} + \alpha_2(\text{Ln GDP})^2 + \beta_1 Urb + \beta_2 Urb^2 + \beta_3(\text{Ln GDP})^* Urb + u,$$

where *Ln* = natural logarithm; CO_2 = average emission of carbon dioxide (tons per capita); *PM10* is measured in micrograms per cubic meter; *GDP* = GDP per capita in 2005 PPP; *Urb* = level of urbanization; *u* is the usual disturbance term; and α's and β's are parameters to be estimated.

The model is fitted separately to 1990–1999 and 2000–2008 data for Asian economies from the World Development Indicators (World Bank 2012). The interactive term was found to be highly insignificant in all models except one. Table 15.10 summarizes the estimation results. Despite the parsimonious specification, the models fit the data well and are of good quality in terms of the usual statistical and economic criteria.

Based on the modeling results, the environment–urbanization curves are plotted in Fig. 15.23. The plots show an inverted U-pattern, similar to the conventional EKC in shape. Thus, environmental degradation occurs in the early stage of urbanization when productivity gains and agglomeration effects are low, which can be

Table 15.10 The environment–urbanization model. (Source: Authors' estimation)

Models for	1990s		2000s	
Independent variables	Coefficient	Standard error	Coefficient	Standard error
	Ln (CO_2)			
Ln(GDP per capita)	1.781***	0.415	6.922***	1.088
Ln(GDP per capita)^2	−0.064**	0.025	−0.414***	0.083
Urbanization	0.102***	0.006	−0.082*	0.049
Urbanization^2	−0.001***	0.000	−0.001***	0.000
Ln(GDP per capita)* urbanization			0.026***	0.008
Constant	−12.381***	1.700	−31.214***	3.610
Observations	370		374	
R^2	0.829		0.821	
	Ln (PM10)			
Ln(GDP per capita)	−1.161***	0.345	−1.870***	0.482
Ln(GDP per capita)^2	0.046**	0.021	0.101***	0.028
Urbanization	0.027***	0.006	0.033***	0.007
Urbanization^2	−0.0002***	0.000	−0.0004***	0.000
Constant	9.746***	1.408	11.670***	1.979
Observations	310		304	
R^2	0.359		0.241	

* significant at 10 %; ** significant at 5 %; *** significant at 1 %

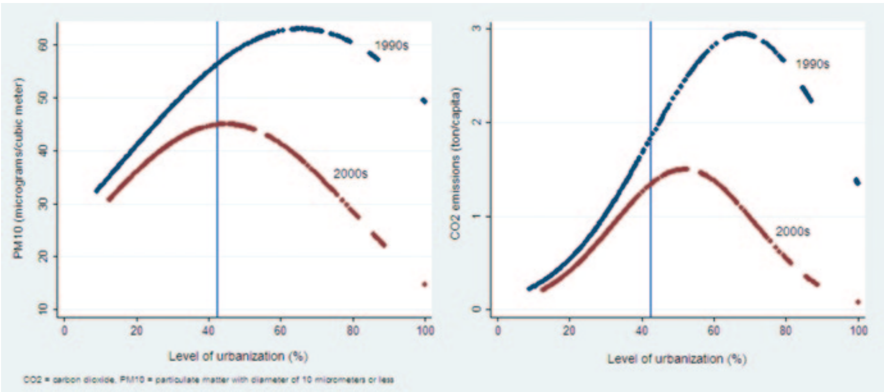


Fig. 15.23 Environment-urbanization relationship in Asia. (Source: Authors' estimates)

overweighed by its negative effects. After reaching a certain level when agglomeration and productivity improvement become significant, urbanization leads to reductions in pollution and emissions.

An important and interesting finding emerges when the urbanization–environment curves for the 1990s and 2000s are compared. Figure 15.23 shows that over time the curves for CO_2 emissions per capita and PM10 (μg/m^3) shifted down and to the left. Shifting down means much lower emissions and pollution at the same level of urbanization. Shifting left means the peak of the inverted U-curve comes sooner

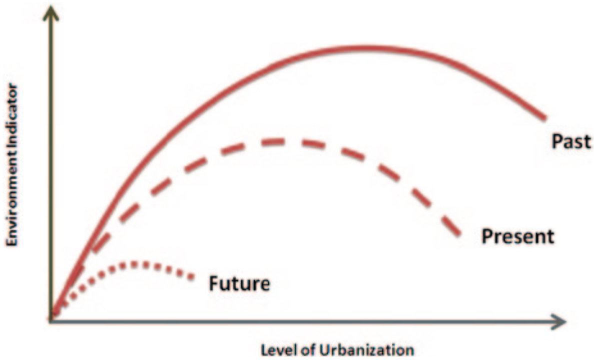


Fig. 15.24 Illustrative environment–urbanization curve. (Source: Authors' illustration)

under the technologies and policy environment of the 2000s. For example, the peak of the 1990s curve for CO_2 emissions occurs at a 68 % urbanization level, while that of the 2000s curve occurs at 52 %. For PM10, the peak under the 2000s curve corresponds to a 45 % level of urbanization rather than 66 % under the 1990s curve. These results are consistent with the literature, which indicates that local pollution usually starts to decline earlier than nonlocal pollution.

The shift of the environment–urbanization curve, like the conventional EKC, is primarily driven by technology advances, structural changes, and regulations. The gap between the two curves corresponding to the same urbanization rate measures the impact of the shifts on pollution or emissions. At the 2010 level of urbanization for Asia, the impacts amounted to 20 % reductions for PM10 (μg/m^3) and 27 % for CO_2 emissions per capita, forcefully demonstrating the large impacts of technology and government policies.

Thus, urbanization can significantly decrease the amount of environmental degradation. Holding everything constant, including technology and policy, by 2050, CO_2 emissions per capita will be halved and the PM10 (μg/m^3) level will be cut by 37 % even if nothing else but urbanization changes. Because technology keeps improving and pressures from various sources are mounting, the environment–urbanization curve will almost certainly continue to shift down and left, as illustrated in Fig. 15.24. Therefore, the future of Asia's environment will most likely be bright as urbanization proceeds, with careful management.

Summary

Asia is fast urbanizing and rapid urbanization poses significant quality-of-life challenges such as rising inequality and crimes. In particular, it adds tremendous pressure on the local and global environment. Today, Asia has some of the world's most polluted cities and most steeply rising GHG emissions. In addition, most of the unique features of Asia's urbanization tend to aggravate environmental problems.

Despite these challenges, there are reasons to be optimistic, as urbanization can help address environmental degradation. It leads to declining fertility rates, increasing levels of education, growing support for "greening," relocating industry away from city centers, and advancing technology. Also, by nurturing the urban middle class and property owners, urbanization can help ameliorate adverse environmental impacts as educated, informed urban middle-class members and property owners are usually pro-environment and they tend to support "low-carbon" products—products that enable a reduction in carbon emissions. The combined effects of these forces can lead to better environmental outcomes as Asia urbanizes, as reflected by the shift of the environment–urbanization curve.

As such, it would be counterproductive for governments to contain urban expansion even for environmental concerns. However, Asia has not reached the peak of its EKC, which indicates a grim outlook in the absence of well-designed interventions. Thus, the development and implementation of policies promoting green cities is urgently needed. In the long run, interventions to facilitate the use of renewable and adoption of new technologies are indispensable. In the short or medium term, policies such as congestion pricing and increasing block water/electricity tariffs can be implemented to help reduce resource consumption. For developing economies to avoid "brown" development now that must be cleaned up later at a vast cost, timely introduction and enforcement of environmental regulations are essential. Finally, urban planning must consider the irreversible nature of urban investment by embracing new urban forms such as compactness, transit-oriented development, and green cities.

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