

Sustainable and Smart Cities

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Abstract

This paper explores the challenges and opportunities that government officials face in designing coherent 'rules of the game' for achieving urban sustainability during times of growth. Sustainability is judged by three criteria. The first involves elements of day-to-day quality of life, such as having clean air and water and green space. The provision of these public goods has direct effects on the urban public's health and productivity. The second focuses on the city's greenhouse gas emissions. Developing cities are investing in new infrastructure, from highways and public transit systems to electricity generation and transmission. They are building water

treatment, water delivery, and sewage disposal systems. Residents of these cities are simultaneously making key decisions about where they live and work and whether to buy such energy-consuming durables as private vehicles and home air-conditioning units. Given the long-lived durability of the capital stock, short-term decisions will have long-term effects on the city's carbon footprint. The third criterion is a city's resilience to natural disasters and extreme weather events. This subsection focuses on how the urban poor can be better equipped to adapt to the anticipated challenges of climate change.

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Environmental progress in developing cities is daunting. When millions of people and thousands of firms choose to locate near each other and share air, roads, and rivers, pollution tends to rise unless polluters have an incentive not to pollute.

To mitigate pollution, government intervention is the textbook solution. But government officials face conflicting goals as they promote economic growth with limited information about polluter activities. In developing nations officials often face severe resource constraints that limit their ability to credibly monitor polluters—inhibiting their ability to implement fines and environmental regulations.

Despite these challenges, the World Bank’s environmental economists have been optimistic about the potential for developing cities to generate less pollution during times of growth. Dasgupta and others (2002) emphasize that the choices of urban citizens, firms, policy makers, regulators, and nongovernmental organizations all interact to determine whether a city can refute the traditional pessimistic outlook that economic growth causes environmental degradation.

This paper explores the challenges and opportunities that government officials face in designing coherent “rules of the game” for achieving urban sustainability during times of growth. Sustainability is judged by three criteria. The first involves elements of day-to-day quality of life, such as having clean air and water and green space. The provision of these public goods has direct effects on the urban public’s health and productivity. The second focuses on the city’s greenhouse gas emissions. Developing cities are investing in new infrastructure, from highways and public transit systems to electricity generation and transmission. They are building water treatment, water delivery, and sewage disposal systems. Residents of these cities are simultaneously making key decisions about where they live and work and whether to buy such energy-consuming durables as private vehicles and home air-conditioning units. Given the long-lived durability of the capital stock, short-term decisions will have long-term effects on the city’s carbon footprint. The third criterion is a city’s resilience to natural disasters and extreme weather events. This subsection focuses on how the urban poor can be better equipped to adapt to the anticipated challenges of climate change.

The cities that have performed well on these three criteria will enjoy several benefits. Their people will be healthier and more productive. Reduced exposure to pollution increases the likelihood that children are healthy and learn more in school and thus become more productive citizens. The adults in a low-pollution, resilient city will enjoy a higher quality of life, and the mobile skilled will be attracted to move there. Cities that provide a safe, clean, healthy environment are more likely to be home to citizens who enjoy a higher quality of life. Consequently, children in these cities are more likely to become able-bodied and productive adults. Improvements in environmental quality will help slow morbidity and mortality risk, and this will reduce the demand for costly health care. In this sense, investment in “sustainable cities” helps produce a richer future society. Cities that become “low-carbon” cities will help

mitigate global climate change. And if a global carbon treaty is agreed on, such low-carbon cities will have an edge in complying with its terms.

This paper proceeds by first investigating how the industrial, transportation, and household sectors contribute to urban sustainability challenges. Each sector has policy suggestions that could significantly mitigate local and global pollution. Exposure to this pollution depends on where goods are produced and where urbanites live. For instance, the urban poor tend to live in the most polluted and dangerous parts of the city. Several suggestions are offered for reducing this vulnerable group's exposure to risk and enhancing environmental justice in cities. The final section builds on this theme by discussing urban resilience in the face of climate change.

Reducing the pollution costs caused by the industrial sector

Few cities feature an industrial base that mirrors the country's overall industrial shares.¹ Individual firms will locate in the city where they can expect the highest profits. For example, labor-intensive industries might seek a city where the market price of labor (wages) is low; electricity-intensive industries might seek areas where electricity is cheap, such as near coal deposits. The geographic distribution of industries across cities has important environmental implications. Some cities will have an industrial base featuring heavy industry, others a low-pollution service industry. Cities that specialize in heavy industry—such as steel production, chemical production, and paper manufacturing—face a more difficult sustainability challenge than cities that specialize in services. Industrial cities suffer from higher local air and water pollution and tend to be major consumers of electricity for production.²

Government officials face tradeoffs in choosing how to reduce manufacturing pollution. They will be well aware that manufacturing offers fairly high wages for low-skill workers. In the United States, the service sector's share of employment has grown sharply as manufacturing's share has fallen. Labor economists have documented the large reduction in wages for workers displaced from manufacturing.³ Officials must also be aware that heavy industry contributes to ambient particulate and ozone and elevates water pollution.⁴ When such activity takes place in city center locations, this pollution creates "hot spots" that affect millions of people living in densely populated nearby neighborhoods. In such areas, quality of life declines, as do land prices due to spillover pollution. High pollution has direct impacts on the affected population's health and can have significant effects on children's development.⁵

One fairly inexpensive way for government to reduce manufacturing's pollution costs is to encourage the sector to move to dedicated industrial parks. China's government has created special economic zones—areas where urban planners seek to concentrate production activity and install infrastructure to increase industrial productivity. If such production areas are selected so that fewer people live downwind, urban planning can break the link between pollution production and residential area pollution exposure. Concentrating industry in a small space may also reduce auditing costs for regulators monitoring these polluters.

Over the long run, many manufacturing industries choose to move away from city centers, a dynamic that has played out from the United Kingdom to the United States and from the Republic of Korea to China.⁶ Land is expensive at the center of cities, and manufacturing is land intensive. As national and urban governments invest in transport infrastructure, the suburbanization of manufacturing accelerates, posing a pollution tradeoff for urban governments. Suburbanization offers the benefit of reducing industrial pollution exposure for millions of people who live in the city center, but it also encourages the population to live closer to these suburban jobs. This attracts the industry's supply chain (intermediate goods suppliers) to the suburbs, causing further suburbanization.

In the short run, governments have policy tools for reducing the emissions from industry. Several governments, including that of the United States, employ "command and control" regulation, requiring new factories to deploy state-of-the-art emissions control equipment. Such an approach raises production costs for new factories but does little to reduce the emissions from older ones. In fact, it encourages industry to rely longer on older, higher polluting factories to delay paying new regulatory costs associated with building new factories. Economists frown on an incentive system that implicitly rewards keeping old factories running and that imposes a regulatory tax on building and operating new factories. New factories tend to have much lower emissions per unit of output because they embody cutting-edge engineering techniques.

Urban officials seeking a vibrant employment base will worry about overregulating industries. If one city adopts regulation to reduce pollution while a rival city does not, some factories in the city with high regulation might shut down and move to the city with lax regulation. In such a "race to the bottom," firms seek geographical areas that reduce their regulatory costs. In this case, the high-regulation city would be "rewarded" for its efforts by job loss and falling incomes.⁷ This outcome would be less likely if the city that enacts the regulation has other attractive attributes, such as a good transportation system or a large home market that helps economize on other production costs.

Trading pollution permits

The ugly scenario of regulation-induced job loss highlights the importance of being smart about designing regulation. An equitable allocation of pollution permits can achieve the dual goals of pollution mitigation and continued industrial production.⁸ The pollution-permit market approach to industrial regulation starts with the government declaring a cap on total tons of pollution that may be released by industry in a given area surrounding the city. The pollution cap could be set in consultation with public health experts and atmospheric chemists, who would help quantify the social benefits of limiting urban pollution.

Once the cap is selected, polluting firms would bid for the permits. The market price for this new commodity would be set by the intersection of the aggregate demand curve for the right to pollute and the vertical supply curve. At this price, aggregate demand just equals aggregate supply. For example, suppose this price is \$22 per ton of sulfur dioxide released. Every polluting

firm that creates a ton of sulfur dioxide must buy a \$22 permit to release that amount of pollution.

This regulatory approach creates an incentive for firms not to pollute, and they will respond by looking closer at their production processes to economize on pollution. As shown by the United States' experience with the sulfur dioxide trading market, the net effect will be lower pollution at minimal cost, as those firms with an edge in abating pollution will be rewarded for doing so.⁹

The pollution permit system can add millions of dollars of government revenue if it requires polluters to purchase the permits. The government's alternative to keeping all this revenue is for it to freely allocate some of the permits to the affected industries. A skeptic can argue that if one city unilaterally starts such a market and does not freely allocate the permits, "leakage" can result as factories will be more likely to migrate to a city without regulation. In cities with a large informal industrial sector, such regulation in the formal sector could encourage more firms to join the informal sector, making them less likely to be regulated under the emissions cap. The extent of this "leakage" remains an empirical question, but regulators have an incentive to anticipate this effect—and a simple solution. Local governments can freely allocate the permits to industrial firms and then give them the right to sell them to each other at the market price.

If the government can keep some of the pollution permit revenue, its fiscal resources will increase. Environmental economists have argued that, with the revenue collected from pollution permit auctions, other distorting taxes (such as labor taxes) can be reduced.¹⁰ The famous "double dividend" motto is to "tax waste, not work."

Disclosing information

A second policy for reducing industrial pollution is for the state to collect and disseminate information about industrial polluter activity. Information is a public good, and governments' unique powers give them a cost advantage in requiring firms to report their emissions and in auditing the veracity of these reports. After the 1984 Union Carbide chemical disaster in Bhopal, India, the United States created the Toxic Release Inventory dataset, requiring manufacturing firms to publicize their emissions released to air, water, and land. Developing countries, such as Indonesia, have followed a similar path, and research suggests that this informal information regulation has been effective.¹¹ Such trusted information helps create accountability among those who used to keep information about their polluting activities private.

As education attainment rates rise in developing cities, local communities will be empowered to take action.¹² Even in China, microblogs are active sources of information about environmental issues. In July 2012, *The New York Times* provided a case study of the power of environmental protest in China's cities.

China's days as the place to do cheap but dirty mining and manufacturing may not be over, but a growing environmental movement has made potentially polluting projects much harder to build and operate. Large and sometimes violent demonstrations against the planned construction in southwestern

China's Sichuan Province of one of the world's largest copper smelting complexes prompted local officials to continue backpedaling furiously on Wednesday. The local government of Shifang, the planned site of the smelter, announced in a statement that the construction of the immense \$1.6 billion complex had been not just suspended but permanently cancelled.¹³

In cities with greater demand for environmental news, the media will invest more resources to investigate. Media reports create accountability and improve local governance.¹⁴ They level the playing field in the competition between industry (which seeks to avoid regulation) and the millions of people exposed to pollution but who face transaction costs in banding together to change the status quo.¹⁵

Transportation infrastructure and the rise of car cities

Cities in developing countries are making major investments in urban transportation infrastructure—investments that will determine a city's urban form and its ability to move goods and people around the metropolitan area. This section focuses on the environmental consequences of these investments and offers some policy suggestions for minimizing the associated pollution costs.

As urbanites grow richer, they tend to use public transit less and private vehicles more—because private vehicles are convenient, high status, and time saving.¹⁶ This transport substitution is relevant for urban environmental performance because public transit tends to have much lower air pollution and greenhouse gas emissions than private vehicles. Buses and subways feature economies of scale, with fossil fuel consumption per mile of travel much lower than for private vehicles.

Government officials will recognize that vehicle use offers private benefits to households: greater personal freedom and more possible trading partners in the city. But driving imposes social costs that self-interested households will ignore because the urban air is public property, resulting in a “tragedy of the commons.” No one who chooses between public transit and a private vehicle has an incentive to consider such environmental costs when choosing a commuting mode.

The rising demand for private vehicles in developing cities is well known. Richer people tend to travel by private vehicles, which, though expensive, are faster and offer greater convenience than public transit. Transportation economists have broadly agreed that a 10 percent increase in income is associated with a 10 percent increase in per capita vehicle ownership.¹⁷ In 2010, Cairo had 7.4 private vehicles per 100 people.¹⁸ And with its roughly 8 million people, a 10 percent increase in per capita income would mean 59,200 more vehicles owned.¹⁹

Increased private vehicle and truck use creates an urban heat-island effect due to running cars and the construction of more paved road. Pollution costs from transportation scale up with private vehicle and freight truck mileage. The environmental impact can be mitigated by

regulations that reduce emissions per mile and government policies that encourage greater fuel economy (more miles per gallon).

Transportation's environmental impact can be shown with simple multiplication. Consider a city that is home to 1 million people and in which 10 percent of the population owns vehicles—so 100,000 vehicles are running in the city. If each vehicle runs an average of 5,000 miles a year, 500 million miles are driven in the city each year. Suppose that the average vehicle creates 2 units of pollution and consumes 0.1 gallons of gasoline per mile (10 miles per gallon). The annual environmental impact would be 1 billion units of pollution and 50 million gallons of gasoline consumed.

Government policy can affect each of the four margins sketched above. In studying total transportation emissions, this section focuses on vehicle ownership, use, and emissions per mile driven. It describes the tradeoffs that government officials face in choosing a transportation system. Such a system needs to allow millions of urbanites to move at fairly high speeds around the city, without creating high levels of pollution and while minimizing the fiscal costs of supplying infrastructure.

Almost all economists would advocate taxing carbon emissions as a direct way to reduce vehicle pollution. Such a tax would influence the likelihood that a household purchases a vehicle, the type of vehicle it purchases, and the use of this vehicle. But in 2012, Australia was one of just a few countries to introduce a carbon tax.²⁰ Political partisanship has precluded the United States from taking the global lead in reducing greenhouse gas emissions.²¹ These facts make it necessary to consider second-best policies to reduce the cost of pollution.

The most direct way to curb the growth of vehicle ownership is to raise its costs. Cities could follow Singapore and introduce a high vehicle-registration tax. Such a tax would be especially effective at reducing pollution if its rate could be set according to the vehicle's model year and fuel economy. Older vehicles tend to have much higher emissions per mile than newer vehicles; many developing countries import older vehicles from richer nations.²² A differentiated registration tax would discourage the import of older, fuel-inefficient vehicles.

A second strategy to discourage vehicle purchases is a gasoline tax, which would collect revenue for the government and discourage driving. Parry and Small (2005) examine the traffic congestion, traffic safety, and environmental consequences of driving and conclude that the optimal gasoline tax would be between the low U.S. gasoline tax and the higher Western European tax. In 2012, gasoline in Nigeria cost \$2.32 a gallon, while in Egypt it cost \$1.73 a gallon and in Pakistan \$3.55 a gallon.²³ A higher tax in Egypt would collect new government revenue that could be used in part to provide higher quality public transit.

A third strategy for discouraging city driving is to price the use of public roads and increase public parking rates. London's city center charges roughly £8 per vehicle entering during rush hour. Information technology improvements have greatly reduced the costs of such a system.²⁴

In a similar spirit, Shoup (2005) advocates time-of-day pricing so that parking is more expensive when demand is high. The local government would collect more revenue from this scheme, and traffic congestion and pollution would decline because fewer vehicles would be cruising at low speeds for parking spots.

Urban drivers who could be induced by these public policies to drive less would be more likely to use public transit. In London, a perhaps surprising consequence of road congestion pricing is that many middle-class households that once drove are now using public transit—flexing their political clout to demand better service. If this new rider constituency can lobby government for more frequent and better service, public transit will be more competitive with private driving.²⁵ But in developing cities, the government is likely to face financing constraints. The World Bank, along with private international capital, is more likely to invest in projects with clear evidence of high demand.

Government investment in transportation infrastructure plays a major role in determining total urban emissions. In China and the United States, the construction of highways contributes to suburban growth.²⁶ Simply stated, by lowering transportation costs, areas farther from the city center become more valuable because the time cost of commuting there declines. Encouraging more people to live farther from the city center offers housing benefits but has environmental consequences: increased vehicle use and larger homes that require more water and electricity.

Subway investment tends to encourage city center development.²⁷ Beijing is investing in local infrastructure. Over the last 10 years, it has built new subways and Olympic Park, which played a pivotal role in the successful 2008 Summer Olympics. Four new subway lines were built over 2000–09, for a total investment of 50.3 billion yuan. Olympic Park cost 20.5 billion yuan to build over 2003–08.²⁸ These place-based investments were concentrated in some of Beijing's less desirable areas, triggering complementary private investment in new residential housing towers and new private restaurant chains.²⁹ Real estate prices have since increased near the subway infrastructure and Olympic Park, highlighting that gentrification can result from public investments that improve local quality of life. Downtown Beijing is both a major employment center, as major government offices are there, and a center of culture and shopping destinations.

Subways offer fast transport, but given the huge costs per mile it is likely to be cost-effective only in cities with an extremely high density. For decades, transportation economists have argued that too many cities build costly subways.³⁰ They argue that subway advocates often overstate the expected ridership to obtain funding for the project and that projects rarely deliver the ridership promised. Since subways are enormous irreversible investments, transportation economists advocate instead for investments in rapid buses that stop infrequently and have dedicated bus lanes. Such buses would offer the speed of a car and the environmental benefits of public transit.

Bogotá did this with TransMilenio, choosing bus routes targeted to the fastest growing areas.³¹ Despite the investments in dedicated bus lanes, full service bus stations, and a pay-and-park system, private vehicle use has been increasing 12.3 percent a year.³²

Governments can reduce total emissions by enacting regulations that reduce emissions per mile, and countries the world over focus their regulatory efforts on new vehicles. The United States first implemented emission control regulations in the early 1970s. Such regulations require that manufacturers produce vehicles that meet a given emissions standard and install specific equipment, such as a catalytic converter.

These regulations are easy to enforce but have several consequences. First, in nations with an older vehicle fleet, they might begin to reduce average emissions only years after being implemented. Suppose that a city's vehicle stock features vehicles that range in age from 0 to 33 years. Suppose also that 3 percent of the fleet is replaced each year with new vehicles. If only new vehicles face more stringent regulation, only years after the regulation is enacted will the fleet's average emissions decline. An unintended consequence is to encourage households to keep their old cars running longer, delaying the effects of the regulation.³³

The good news is that trends in air pollution across India's cities suggest that the phase-in of such emission control regulations has reduced urban air pollution. Greenstone and Hanna (2011) exploit the fact that different cities in India phased in catalytic converter regulation at different times. For example, the number of cities with such regulation increased from 4 in 1997 to 22 in 1998. Large reductions in vehicle emissions start roughly five years after regulations are adopted.

Stringent new regulations will not reduce the emissions from the stock of older vehicles. Based on remote-sensing data from the United States, engineer Donald Stedman has argued that a small share of the vehicle stock is the cause of most of the vehicle emission pollution.³⁴ To address this social externality, economists have advocated that police issue "pollution tickets" similar to speeding tickets. Such policing could sharply reduce used vehicle emissions. Those caught releasing high emissions would be fined a substantial sum, inducing households to invest in more vehicle maintenance. The approach could also regulate diesel trucks. An additional advantage is that it can substitute for a costly inspection and maintenance program for used vehicles.

Another strategy for reducing vehicle emissions is to mandate cleaner gasoline. One major public health success has been to require unleaded gasoline, which richer nations are more likely to do.³⁵ Urban lead emissions have declined sharply in richer nations, improving public health by reducing lead's negative impacts on child development. Until recently, leaded gasoline was the key source of widespread exposure to lead in urban Africa. With its elimination from all of Sub-Saharan Africa in 2007, ambient lead emission levels will continue to decline, offering direct health benefits for children and the exposed population.³⁶

Today, environmentalists are counting on the widespread purchase and use of electric and hybrid vehicles. At first glance, one would assume that these vehicles have a smaller carbon footprint and lower net environmental impact. However, the net environmental impact of these “cleaner” vehicles hinges on the source of electricity that powers them. If the electricity is generated by a coal-fired power plant, the electric vehicle can hurt the environment more than the conventional gasoline vehicle. But if it is generated using renewables or natural gas, the rise of the electric vehicle fleet is more likely to offer urban environmental benefits.

The household sector

Households choose where to live in each city, with implications for urban pollution and their own pollution exposure. In any city, different income groups live in different neighborhoods and homes. In some, such as Beijing and Paris, the very rich live downtown in the high-amenity walking center. Many richer households also seek out the suburbs for cheaper, newer housing.³⁷

The suburbanization of households offers private benefits but imposes social costs, as the spread out population drives more and uses public transit less. Suburbanites are more likely to own a vehicle and use it more than city center residents. Relative to urbanites in city centers, where the price of land is higher per square foot, suburbanites have larger homes that require more air conditioning and use more electricity and fossil fuels for heating.

Poor urban households tend to locate where housing is cheapest and riskiest. The risks they face are from spikes in air and water pollution, natural disasters caused by flooding and landslides, exposure to infectious disease due to high population density, and unreliable electricity and access to clean water. A policy objective should be to quantify the actual environmental risk that the urban poor face. This exposure will have higher social costs if the individuals who choose to live there are misinformed or have false perceptions about the negative effects on their health. In many developing countries, the urban poor live in informal areas with no basic public services, such as sewers and drains. The lack of sanitation and waste disposal amplifies the negative impacts of small-scale hazards.³⁸ Without access to clean water and electricity, the poor are at greater risk of disease epidemics and exposure to extreme heat.

Given that exposure to air and water pollution poses morbidity and mortality risks, it also reduces worker productivity and the capacity for children to learn in school—and increases a household’s demand for costly medical treatment.³⁹

The urban poor also face the challenge of increased rural-to-urban migration in their cities. Farmers move to the city when their expected urban standard of living exceeds their standard of living in the countryside. As they move to cities, they increase population density in urban slums, raising rents and lowering wages for those already there.

In designing “good” housing policies for protecting the environment, it is important to distinguish policies to reduce the social costs of suburbanization of the middle class and wealthy from those to improve the quality of life of the urban poor by reducing their pollution exposure.

Public policies that relax controls on city center land use and enhance the quality of life can help reverse the suburbanization trend. Over the last 20 years, an active urban economics literature has sought to identify policies that encourage households and firms to aggregate at high density near the city center against those that—either intentionally or unintentionally—deflect activity to the fringe of the greater metropolitan area. City centers with low crime and good schools and other public services are more likely to attract residents; those offering a high-amenity “consumer city” will be more successful.⁴⁰

An ongoing housing debate focuses on the costs and benefits of limiting tall buildings in city centers.⁴¹ In India’s cities, limits on floor-area ratios (FARs) increased suburban growth because urban development cannot “go vertical” and is deflected to the periphery.⁴² Good urban planning would consider the benefits of allowing tall buildings near major public transit nodes. Cities could also create a market where they sell extra floor area ratio to real estate developers, allowing taller building zones near bus rapid transit nodes.⁴³ Ahmedabad, India, earned about \$26 million from the sale of FAR bonuses in 2011, 4.5 percent of the city’s revenue and 5 percent of its investment budget.

As new housing is built to accommodate urban growth, cities are more likely to become low-carbon cities if new buildings comply with energy efficiency standards, such as the United States’s Energy Star standard.⁴⁴ Where electricity prices are high and expected to rise, the operating expenditure savings from such buildings can be large. Energy-efficient buildings demand less electricity, reducing the probability of blackouts and the need for (polluting) power plants.⁴⁵

Millions of urban poor live in low-quality informal housing—that is well known. Arnott (2008) offers a sketch of the fundamental tradeoffs that the state faces in dealing with this:

The limited fiscal capacity of developing country governments makes the provision of urban infrastructure, including transportation, water, electricity, solid waste disposal, sewage, fire and police protection, schools, and medical facilities, more difficult. In informal settlements, these problems are compounded by the government’s poor knowledge of their current state and inability to control their future development. Furthermore, even a benign government faces a policy dilemma in deciding on the quality of infrastructure to provide informal settlements. On one hand, if it turns a blind eye to violation of regulations and provides the same level of services to informal as to formal settlements, it encourages the development of more informal settlements in the future. This problem is particularly acute for squatter settlements, since the government is naturally loath to implicitly endorse settlements that were established through the expropriation of government or private property. On the other hand, informal settlements contain the bulk of poor households, who would benefit considerably from the provision of at least basic public services. Also, not providing informal settlements with basic services encourages crime and contagion, externalities that hurt all residents, and produces neighborhoods that will remain blighted for years to come.

The World Bank (2011) highlighted recent trends in Dar es Salaam and São Paulo. In Dar, the population is growing roughly 6 percent a year, so its total population doubles every 12 years. Dar's urban poor face heavy rainfall, flooding, and drought. And about 70 percent of the city's population lives in low-quality, risky housing featuring weak infrastructure with little access to clean water and sanitation. Drainage channels are regularly blocked, flooding houses with sewage-infested wastewater and enabling water-borne diseases to come into direct human contact. Roughly 40 percent of the city is below sea level. In São Paulo, the main hazards include heavy rains, flooding, landslides, and washouts. More than 85 percent of high-risk households (890,000) are in slums. Of those households, 52 percent lack access to sanitation facilities, 33 percent lack access to paved roads in their neighborhoods, and 20 percent lack proper sewage treatment.

To protect the urban poor from hazardous environmental challenges, cities will need a new revenue source. For instance, cities could increase their property taxes. A property tax offers a consistent revenue stream, and this stability would help government officials plan capital expenditures into the medium term.⁴⁶ If property ownership is concentrated among a few large land owners, such a tax will be progressive. It can also improve economic efficiency if the money is used for productive local public goods, such as roads and basic infrastructure.

Assuming the government invests in improving public goods in slums, who will be the real beneficiaries? Will the urban poor's quality of life improve, or will the value of these improvements become capitalized into local land prices so that land owners would be the winners? If housing rents are determined in a competitive market, land owners will gain most of these benefits. But if there are barriers like rent control, those who already live in the area will benefit.

Urban adaptation to climate change

A third criterion for judging a city's environmental performance is its resilience in the face of climate shocks. Residents in many developing cities face significant flood risk, disrupted electricity supply, and intense heat waves. Increased migration to these cities increases the number of urbanites at risk, and climate change will only intensify the risks. For these anticipated challenges, the goal for public policy is to implement "no regrets" policies.

While there are many unknowns about climate change, ongoing economic research highlights direct impacts on the urban sector and indirect impacts on agriculture.

Higher temperatures have large, negative effects on economic growth, but only in poor countries, where a 1° Celsius increase in a given year reduces that year's economic growth about 1.1 percentage points.⁴⁷ In rich countries, temperature changes have no discernible effect on growth. Perhaps surprisingly, both agriculture and the urban sector suffer in hotter years. And poor countries produce fewer scientific publications in hotter years, suggesting that higher temperatures impede innovation.

If climate change is expected to significantly reduce farmers' profits, and if they are unable to substitute and produce another agricultural product, they will have strong incentives to move to cities—accelerating urbanization.⁴⁸ As millions of farmers urbanize, they are likely to be poor and to live in the riskiest, cheapest parts of the city. Their arrival will increase urban density, raise rental prices in slums, and reduce wages for incumbents. The net effects include fewer consumption opportunities for the incumbent poor, more heavily taxed basic services, and greater risk of infectious disease. Such migration will also lower the incomes of the incumbent poor, leaving them with fewer resources to cope with climate shocks.

Policy suggestions

In nations with few cities, migration within a metropolitan area offers one strategy for protecting the population. While migrating within a city is unlikely to reduce extreme heat exposure, World Bank researchers have emphasized the importance of reducing the number of people living in areas at high risk of natural disasters. Lall and Deichman (2010) argue that zoning enforcement must attempt to prevent settlement of the most risky areas. This is not easy. Informal settlements can spring up overnight and, once established, are difficult to relocate. Tools like Google Earth can be used regularly to see if informal communities are reemerging in risky areas.

Government zoning can reduce the number of people living in areas whose locations and attributes put them at significant risk. Whether zoning is enforced depends on the government's resources. If safer areas of the city can be identified, encouraging greater density in such areas would promote adaptation.

If informal area residents are given formal title to the land they occupy, households will have stronger incentives to invest in their communities and their property.⁴⁹ In return for receiving formal title, such communities would become part of the city's jurisdiction and be offered such basic services as water and electricity—but they would be expected to pay for the services, as well as property taxes. Whether informal residents would consider this a good deal remains an open question. Government officials could conduct small pilot studies to see how sweet an offer must be to encourage informal communities to integrate into the city.

Access to electricity is an important adaptation step, because it allows urban households to cool themselves and refrigerate perishable goods. It also reduces mortality risks associated with heat waves.⁵⁰ And it raises the poor's quality of life.⁵¹

Flexible electricity pricing can mitigate future climate change impacts. On extremely hot days, demand for power will soar. If cities do not implement peak-time pricing, there will likely be broad blackouts. U.S. research has documented that both the residential and commercial sectors respond to announcements of higher electricity prices by reducing consumption.⁵² If consumers respond to higher prices by reducing consumption, developing cities will need to build fewer power plants to cope with rising electricity demand and can instead rely on dynamic pricing. The

rise of “smart meters” and real-time information about electricity consumption and pricing allows cities to be “smart” about how they encourage consumers to change their behavior.

When urban households and firms know that the price of water and electricity can fluctuate, they have strong incentives to invest in durables and to economize on scarce resources. If such cities are experiencing population growth, water and electricity prices should rise to reflect the growing scarcity. By contrast, when governments protect urban households and firms by setting price ceilings for water and electricity, self-interested decision makers have little incentive to conserve. If cities can solve the political problem of allowing utility prices to fluctuate with underlying demand conditions, they will be much less likely to suffer from water and electricity shortages, especially during extreme weather shocks.

Such variable pricing can inflict real costs on the poor. An increasing block tariff rate with a low bottom rate for households that consume a low level of electricity or water would allow them to afford basic necessities.

Can a low-carbon city be resilient, or does increasing its adaptability to climate change always increase carbon production? The answer hinges on how power is created. Increasing electricity consumption while reducing carbon emissions requires cities to reduce their emissions per unit of power generated. One way to do this is to transition from coal to natural gas or to renewables. China and India have sharply increased their exports of renewable power equipment (wind turbines, solar panels).⁵³ If these countries reduce their cost of renewable power generation, domestic consumers could benefit from purchasing such products.

Anticipating the rise of the fat tail

Extreme weather events are increasing in frequency and intensity. Some areas are suffering from extreme rainfall, others from persistent drought. Relative to historical probabilities, some very unlikely events are taking place. Consider the July 2012 mass flooding in Beijing. The city had not invested in a costly drainage system to handle such heavy rain. Had the rain fallen in Dalian or Tsingdao, which have higher design standards, the consequences would have been manageable. But because Beijing’s government and residents have little experience in handling flood conditions, the consequences were catastrophic. This heavy rain is a “fat tail” event. And as climate change unfolds, the likelihood of these low-probability but potentially catastrophic events increases.

In poorer cities, climate events exacerbate pre-existing public health challenges. One example is Freetown, Sierra Leone, where a cholera epidemic has broken out due in part to an exceptionally rainy season that flooded shantytowns. *The New York Times* reports: “Cholera, transmitted through contact with contaminated feces, was made worse this year by an exceptionally rainy season that flooded the sprawling shantytowns in Freetown and Conakry, the capitals of Sierra Leone and neighboring Guinea. In both countries, some two-thirds of the population lack toilets, a potentially lethal threat in the rainy season because of the contamination of the water supply.

Aid workers said the number of cases of the highly contagious disease continued to increase, particularly in Freetown, where most live in slums and children swim in polluted waters.”⁵⁴

Investments in drainage systems are a type of insurance. But it is highly unlikely that the city will need a costly drainage system. So, urban officials face a tough tradeoff in choosing how to allocate scarce public funds to invest in “climate proofing” their city.

But moral hazard lurks

“Climate proofing” a city will likely increase in-migration and slow out-migration. Consider New Orleans. After Hurricane Katrina, some argued that encouraging more people to leave New Orleans would be a good strategy for improving many people’s quality of life.⁵⁵ The U.S government did not follow this strategy and instead made an enormous, irreversible place-based investment in rebuilding New Orleans. While New Orleans’s population has shrunk in recent years, its population would have fallen even more without such place-based investments.

Government investment in sea walls and other defensive barriers is likely to attract private investment in hotels and other components of urban infrastructure that attract households and firms. While this might stimulate economic activity, it also puts more assets and people at risk from the next natural disaster. And it can lull individuals into a false sense of security as engineers climate-proof cities and reassure the general public of the soundness of these structures. But the consequences of underestimating nature can spell disaster if these government investments fail, causing even more death and destruction.

Pro-economic growth

City policies that encourage economic growth actually facilitate climate resilience. As individuals grow wealthier, they gain access to a broader range of private market strategies for protecting themselves from risk. Examples include eating higher quality food, using better health care, and occupying sturdier housing. “An emerging conclusion is that the key to adaptation among the urban poor is to continue to address the basic poverty reduction and sustainable development agenda in cities to improve the livelihoods and resilience of the poor—ensuring adequate and effective delivery of health care, education, water, energy, public transport, and waste management; providing safety nets and increasing food security; upgrading facilities and infrastructure in slums and other informal settlements; and providing security of tenure and property rights.”⁵⁶

Conclusion

As cities grow, the urban poor’s population density will likely increase, and they will likely concentrate in the most precarious parts of the city. The urban poor are moving to cities seeking a better life, and the sources of many jobs tend to be in polluting industries. As urbanites grow richer, they consume more electricity and are more likely to pursue private vehicles. These individually rational choices have serious social consequences.

Given these facts, how can “smart” sustainable cities arise? An optimist can point to the successes of New York and London, highlighting that urban areas can make sharp environmental progress in just a few decades. Such progress requires a delicate balance of urban planning and leveraging market forces to send proper signals of resource scarcity. Improvements in information technology and advances in knowledge of how to mitigate pollution and the health benefits of such steps suggest that more cities will pursue “smart” sustainable growth. Urban officials now have real-time information about the subgroups of their constituents most at risk and the technology to connect with them more efficiently.

Cities that can improve their environmental performance will benefit from having a healthier, more productive populace that enjoys a better quality of life. Clean air, clean water, and low risk facilitate the development of human capital for the young and increase the likelihood that they will become productive adults. Because human capital is the engine of economic growth, urban policies that encourage “greenness” promote the population’s health. Ensuring the population’s health is not merely an aesthetic choice—it is a cornerstone for a productive society.

Notes

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- ¹ Glaeser 2011; Moretti 2012.
- ² In India, for example, Ankleshwar focuses on chemical production (see World Bank's Growth Poles). The industrial plants in Ankleshwar process large quantities of basic chemicals, solvents, acids, and fuels to manufacture more than 25 percent of Gujarat's (5 percent of India's) pharmaceuticals, chemicals, pesticides, and dyes (Kathuria and Sterner 2006).
- ³ Neal 1995.
- ⁴ Cai, Chen, and Gong 2012.
- ⁵ Currie and Neidell 2005; Currie and Schmieder 2009; Currie 2011.
- ⁶ Henderson, Lee, and Lee 2001.
- ⁷ Jaffee and others 1995.
- ⁸ Stavins 1998.
- ⁹ Schmalensee and others 1998.
- ¹⁰ Metcalf 2007.
- ¹¹ See Pargal and Wheeler (1996) and López, Sterner, and Afsah (2004).
- ¹² Kahn 2002.
- ¹³ Bradsher 2012.
- ¹⁴ Besley and Burgess 2002; Banerjee and others 2011.
- ¹⁵ Olson 1965.
- ¹⁶ Glaeser, Kahn, and Rappaport 2008.
- ¹⁷ Ingram and Liu 1998.
- ¹⁸ Ahram Online 2011.
- ¹⁹ This expected growth in vehicles is calculated based on $(.074) * 1.1 * 8 \text{ million} - .074 * 8 \text{ million}$.
- ²⁰ Packham and Massola 2012.
- ²¹ Cragg and others 2012.
- ²² Davis and Kahn 2010.
- ²³ Randall 2012.
- ²⁴ Leape 2006.
- ²⁵ Leape 2006.
- ²⁶ Baum-Snow 2007; Baum-Snow and others 2012.
- ²⁷ Zheng and Kahn 2012.
- ²⁸ The official exchange rate used here is 6.5 yuan per dollar.
- ²⁹ Zheng and Kahn 2012.
- ³⁰ Meyer, Kain, and Wohl 1965; Pickrell 1992.
- ³¹ For an excellent series of case studies documenting success stories, see Suzuki, Cervero, and Iuchi (2011).
- ³² Suzuki, Cervero, and Iuchi 2011.
- ³³ Stavins 2005.
- ³⁴ "Fuel Efficiency Automobile Test Data Center," University of Denver, www.feat.biochem.du.edu/.
- ³⁵ Hilton and Levinson 1998.
- ³⁶ Nweke and Sanders 2011.
- ³⁷ Brueckner, Thisse, and Zenou 2000; Margo 1992; Zheng, Fu, and Liu 2006.
- ³⁸ In Santo Domingo's largest slum, 45 percent of houses near a river flood when it rains. Housing prices reflect this risk with the poorest living in the lowest quality housing in the areas most at risk. In Caracas and Rio de Janeiro, poor families occupy steeply sloped land prone to landslides (Lall and Deichmann 2010).
- ³⁹ Zivin and Neidell 2012; Currie 2011.
- ⁴⁰ Glaeser, Kolko, and Saiz 2000.
- ⁴¹ Glaeser, Gyourko, and Saks 2005.
- ⁴² Brueckner and Sirdhar 2012.
- ⁴³ Suzuki, Cervero, and Iuchi 2011.

⁴⁴ “ENERGY STAR for Multifamily Housing,” U.S. Environmental Protection Agency and U.S. Department of Energy, www.energystar.gov/index.cfm?c=multifam_housing.bus_multifam_housing.

⁴⁵ Davis 2011.

⁴⁶ Bahl and Martinez-Vazquez 2007.

⁴⁷ Dell, Jones, and Olken 2009.

⁴⁸ Wang and others 2010.

⁴⁹ Fields 2005.

⁵⁰ Greenstone and Hanna 2011.

⁵¹ Dinkelman 2011.

⁵² Wolak 2010.

⁵³ Sawhney and Kahn 2012.

⁵⁴ Nossiter 2012.

⁵⁵ Glaeser 2005.

⁵⁶ Hoornweg and others 2011, page 11.

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