SPECIAL FOCUS

Urbanization and commodity demand

Urbanization and commodity demand

The past 50 years have seen a rapid increase in urbanization rates globally, and this trend is set to continue over the next 30 years. While income and population growth are frequently cited as an important determinant of commodity demand, urbanization—the rapid growth of urban areas and their concentration of people, economic activity, and resources—also has the potential to have a major impact. Evidence from the literature shows that, after controlling for income and population, an increase in the share of the population living in urban areas is associated with higher energy consumption. However, high density cities have lower per capita energy consumption than less densely populated cities. For policymakers, this reinforces the importance of good planning and high-quality infrastructure in limiting the impact of urbanization on resource consumption, while also boosting the quality of life in cities.

Introduction

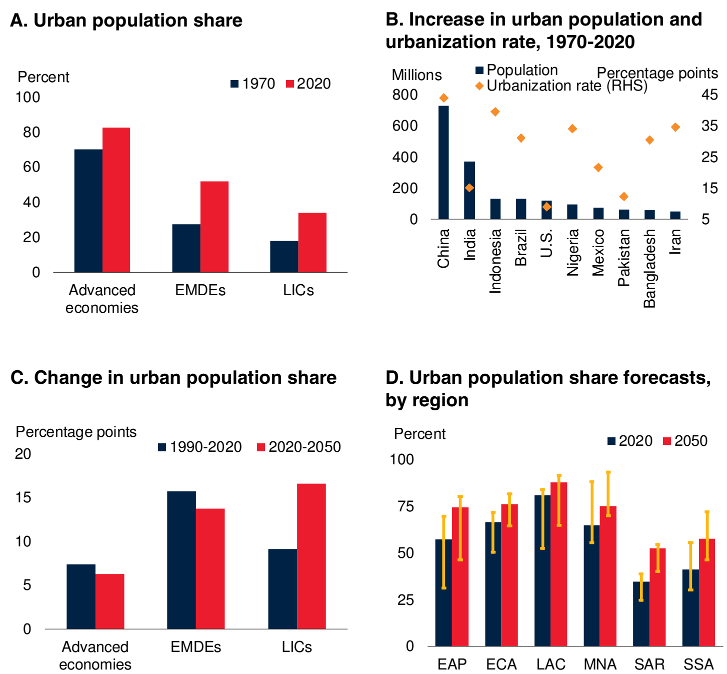
Over the past 50 years the share of the world's population living in urban areas has risen from 37 percent to 56 percent, an increase of three billion people (figure SF.1; United Nations 2019; World Bank 2021a). While this rise has been a global phenomenon, the sharpest increase has come from emerging market and developing economies (EMDEs), where the share of the urban population nearly doubled from 27 percent to 52 percent, due to both rural-urban migration and rapid population growth in urban areas.[1] The largest increase in the urban population came from China, where it rose by 700 million people and the share of the urban population rose from 17 percent to 61 percent between 1970 and 2020.

The demographic shift from rural to urban areas is set to continue, with the share of the urban population at the global level expected to reach 68 percent by 2050, before plateauing thereafter (United Nations 2019). Most of this growth is expected to occur in EMDEs and low-income countries (LICs), especially in South Asia and sub-Saharan Africa (SSA). However, the share of the urban population is expected to increase in all countries, although absolute numbers of urban populations may fall due to declining populations in some countries.

The increase in the share of the urban population has occurred alongside a sharp rise in commodity demand (figure SF.2). While population and income growth are two of the primary drivers of commodity demand, urbanization also has the potential to have a major impact, since urban areas can be very large and typically result in a

FIGURE SF.1 Urban population trends

Urban populations have risen rapidly over the past half-century. China saw the largest increase in its urban population share, followed by India. Over the next 30 years, most of the increase in the urban population is expected to occur in Sub-Saharan Africa and South Asia, with low-income countries seeing the largest increase in the share of urban population.



Sources: United Nations Population Division; World Bank.

Note: EMDEs = emerging market and developing economies. LICs – low-income countries. EAP = East Asia and Pacific, ECA = Europe and Central Asia, LAC = Latin America and the Caribbean, MNA = Middle East and North Africa; SAR = South Asia, SSA = Sub-Saharan Africa.

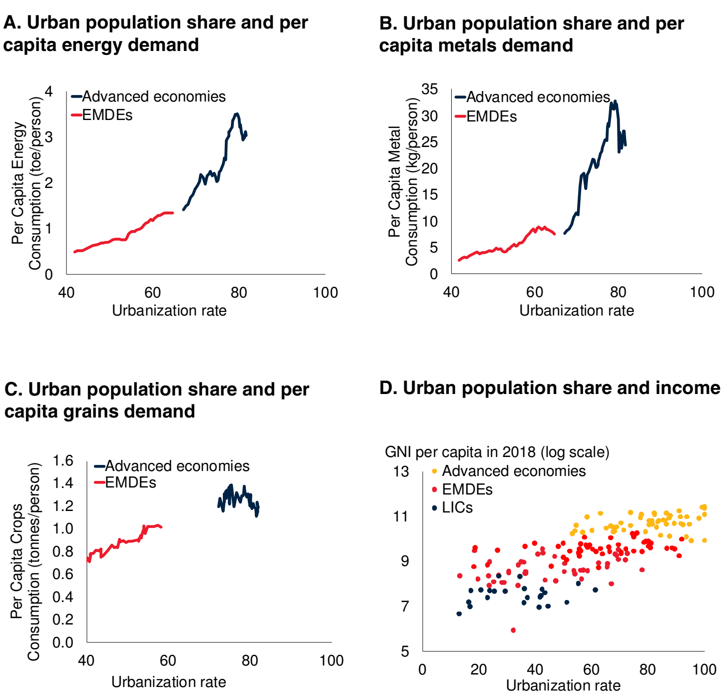
A.-D. Charts show data and forecasts for urbanization rates and urban populations from the UN Population Division's World Urbanization Prospects 2018 report.

D. Bars show average urbanization rates within regions. Lines show interquartile range of the urbanization rates of individual countries within regions.

[1] Throughout this special focus, the terms urbanization and urbanization rate refer solely to the share of people living in urban areas; it does not differentiate between different types of urban areas—for example, whether people live in high-density urban cores or low-density suburbs.

FIGURE SF.2 Urban population growth and commodity demand

The rising share of the urban population is correlated with rising rates of commodity demand, however, in practice this is mostly driven by rising income. While income is a primary driver of urban populations, the reverse relationship is also true, with urban growth potentially having positive impacts on economic growth through agglomeration effects. Indeed, all advanced economies have a high share of urban populations.



Sources: BP Statistical Review; United Nations Population Division; U.S. Department of Agriculture; World Bank; World Bureau of Metal Statistics.
Note: AE = advanced economies, EMDE = emerging and developing economies; LIC = low-income countries.
A.C. Median of per capita commodity demand and urbanization rates for advanced economies and EMDEs.
A. "toe/person" refers to tonnes of oil equivalent per person. Includes 31 advanced economies and 42 EMDEs.
B. Includes 24 advanced economies and 19 EMDEs. Refers to base metals only.
C. Includes 29 advanced economies and 100 EMDEs.

concentration of people, economic activity, and resources (Baffes, Kabundi, and Nagle 2021).[2] Indeed, despite covering less than 3 percent of the world's land area, urban areas currently account for roughly two-thirds of global energy consumption (UN Habitat 2020). They can also have significant ecological impacts, accounting for around 70 percent of CO_2 emissions, as well as causing significant air and water pollution due to the concentration of people living within them (Moran et al. 2018).

Urbanization can affect commodity demand through several channels, the magnitude of which depends heavily on the nature of urbanization (World Bank 2010). Urban areas in countries can take multiple forms, ranging from high-density mega cities, to smaller cities, to low-density urban sprawls that result in dependency on automobiles and prohibit walking (Benfield, Raimi, and Chen 1999; Burchell et al. 1998; Brody 2013).[3] At the same time, the reverse relationship may also occur: changes in commodity demand can affect urbanization. For example, fluctuations in agricultural prices may influence rural wages and make moving to urban areas more, or less, attractive. Given the sharp increase in the urban population that is expected to occur over the next 30 years, it is critical to understand how urbanization can affect demand for different types of commodities, beyond the broader impact of growth in population and income.

Against this backdrop, this Special Focus reviews the literature on the relationship between urbanization and commodity demand and asks the following questions:

- What is the nature of urbanization?
- What are the channels through which urbanization can affect commodity demand?
- What are the empirical effects of urbanization on commodity demand?

The Special Focus finds that there are several channels through which urbanization can change per capita commodity consumption and that these can have positive or negative effects on

[2] In addition to causing an increase in commodity demand, income growth (and industrialization) is also a key driver of urbanization—whereas the agricultural sector is almost by definition rural, manufacturing and service sectors tend to concentrate in urban areas. At the same time, increased urbanization can have beneficial effects on economic growth via agglomeration effects, economies of scale, and reduced transport costs.

[3] Causation may also run in the opposite direction, whereby the development of the automobile facilitated lower-density cities. In the United States, cities established before the rise of the automobile tend to be more compact and denser.

commodity demand. Urbanization has the potential to reduce consumption of commodities through economies of scale and efficiency effects. However, it can also lead to diseconomies of scale resulting from agglomeration, such as congestion. For example, a shift from rural to urban areas can result in shorter journey times and lower energy use in the transport sector, but these can be offset by increased congestion, which can lead to increased energy use and pollution.[4] The impact of these channels depends heavily on the nature of urbanization, especially population density.

Empirical studies estimating the impact of urbanization on commodity demand tend to focus on energy (either directly, or indirectly, via a focus on pollution or greenhouse gas emissions), with a much smaller body of literature for agriculture and even less for metals (Table 1). This special focus is the first study to bring together the available literature on the impact of urbanization and urban density on commodity demand for all commodity groups.[5] It further clarifies the literature by distinguishing between studies that consider the impact of the share of the population living in urban areas, and those that consider the impact of population density of different types of urban areas.

These studies have two main findings. First, an increase in the share of the urban population is associated with increased energy demand beyond that caused by changes in population and income. Second, high density cities are associated with lower per capita energy consumption than low density cities. While urbanization in the aggregate may increase energy consumption, compact, high-density cities have the potential to minimize this increase. These results demonstrate that strategic planning can maximize the beneficial aspects of cities and mitigate their negative externalities. The most successful urban areas are those that connect physical growth to economic demand and support this with good plans, policies, and investments that help avoid uncontrolled sprawl (Lall et al. 2021).

The nature of urbanization

Although the share of the population living in urban areas has risen globally, there is significant heterogeneity in what is considered an urban area. Furthermore, the density of urban areas varies significantly both across and within countries and has changed over time, which can lead to differences in the impact of urbanization on commodity demand.

Defining urban areas. Increased urbanization does not, per se, refer to people moving from sparsely populated rural areas to densely populated cities. One major complication in empirically assessing the impact of urban areas on commodity demand is that definitions of what constitutes an urban area differs greatly between countries. The minimum technical size of an urban area ranges from 200 people or more in Denmark and Sweden, to 50,000 or more in Japan (figure SF.3; United Nations 2019). Furthermore, some countries use metrics such as population density instead of population size. In addition, definitions of what areas to include in urban regions vary substantially across countries. For example, suburban areas may not be a technical part of the city but may be considered an urban area. The size of urban areas also varies considerably, from megacities containing 10 million or more people, to urban areas with fewer than 300,000 people. While a majority of the world's population lives in an urban area, two-fifths live in urban areas of less than 300,000 people.

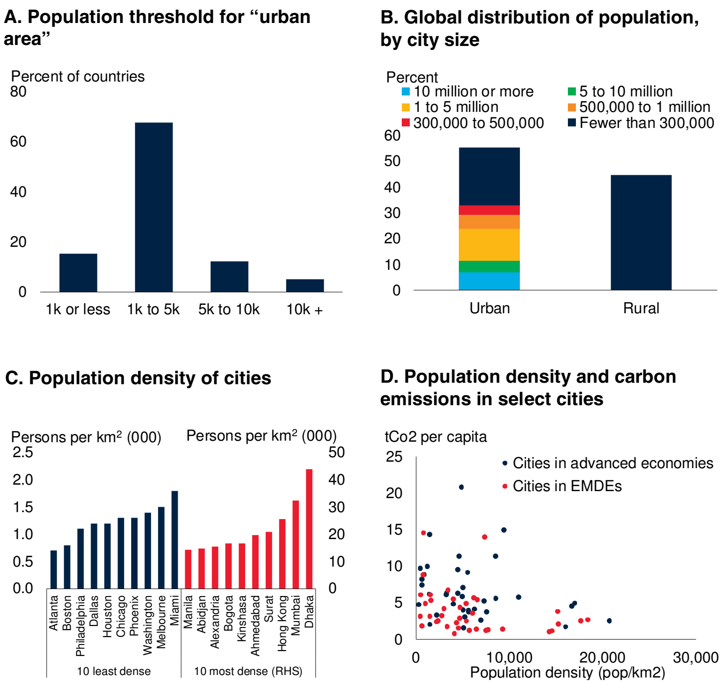
To facilitate the comparison of urban areas, the United Nations endorsed a new methodology by six international organizations (including the World Bank) to define cities, towns, and rural areas based on total population and population density within population grids (Dijkstra, Florczyk et al. 2020; United Nations 2020). Under this definition, the share of the population

[4] For example, in the United States 3.5 billion gallons of fuel was consumed in 2019 as a result of congestion (around 2.5 percent of total fuel consumption). As traffic levels declined in 2020 due to the COVID-19 pandemic, the amount of fuel consumption due to congestion halved to 1.7 billion gallons (around 1.4 percent of total fuel consumption; Texas A&M Transportation Institute 2021).

[5] Ahlfeldt and Pietrostefani (2019) provide a summary of 180 studies that considered the economic impacts of population density. Of these, only 14 consider the impact on energy consumption, of which 9 are chiefly focused on CO_2 emissions, rather than energy consumption.

FIGURE SF.3 Urban population share and population density

The definition of an urban area varies greatly among countries. While a majority of the world's population lives in urban areas, these can look significantly different, with the largest share accounted for by "small" cities of less than 300,000 people. Even among the largest cities, their composition can vary enormously—population densities in some of the largest U.S. cities are an order of magnitude lower than the world's densest cities, which tend to be in EMDEs, especially Asia. High-density cities, particularly in advanced economies, are associated with much lower CO2 emissions than their low-density counterparts.



Sources: C40 Cities; OurWorldInData; United Nations UN Habitat (2020), World Bank.

A. Chart shows the variances in definitions among countries for the minimum number of inhabitants needed for a settlement to classify as an "urban area." Sample includes 100 countries. Some countries do not rely on a population threshold and instead consider other metrics, including population density, and are therefore not included here.

B. Chart shows the percent of the world's population living in urban and rural areas, with urban areas split by size of city.

C. Figure shows the 10 least dense and most dense cities from the world's largest 100 cities. Data from 2014. Hong Kong = Hong Kong SAR, China.

D. Y-axis shows tonnes of CO2 emissions per capita from transport. X-axis shows population density of 40 major cities. Data are from 2016 to 2019.

living in urban areas increases substantially (in 2015, by 22 percentage points), in part because several large countries (including China and India) classify most towns as rural areas (Dijkstra, Hamilton et al. 2020).

Density of urban areas. On average, the larger a city is, the denser it is. However, similar-sized cities can also vary substantially in terms of their density (Dijkstra, Florczyk et al. 2020). For example, cities in Asia have much higher density than cities in the United States—among the 100 largest cities in the world, 9 of the bottom 10 (in terms of population density) are in the U.S., and these have population densities that are orders of magnitude lower than the 10 densest cities, many of which are in India.

Nonetheless, the types of density also vary, because the shape of cities can be vastly different among countries. Richer cities tend to be more "pyramid shaped"—i.e., with more taller buildings and skyscrapers, whereas low- and lower-middle-income cities tend to be "pancake-shaped" or flatter (Lall et al. 2021). Population density can be accommodated either through vertical layering (via taller buildings), which can help increase floor space available to residents, or by crowding, which reduces living space per person. Many cities in LICs are dense because of crowding, which can reduce quality of life.

As such, the channels by which urbanization affects commodity demand may not apply equally to all urban areas and may even have opposite effects. For example, residents of high-density city centers with good mass transit systems are likely to have shorter travel times and lower transport energy requirements compared with suburban areas (Glaeser and Kahn 2010). However, high density cities, unless managed well, can suffer from low quality of living (Mercer 2019; World Bank 2021a). Poor infrastructure, including mass transit and sanitation, could also lead to different impacts of urbanization on commodity demand.

Changes over time. The composition and density of cities is changing over time. Cities can either grow outward, inward (in-fill of undeveloped spaces), or upward. In low-income and lower-middle-income countries, 90 percent of urban built-up area expansion occurred as horizontal or outward growth between 1990-2015; however, in high income countries around one-third occurred as infill (Lall et al. 2021). Population densities have increased as urban populations have grown faster than urban areas have expanded. Between 1990-2015 population densities of cities are estimated to have increased by 8 percent, with larger cities experiencing the biggest increase in density (Dijkstra, Florczyk et al. 2020). In contrast, small cities (less than 250,000 people) experienced declines in population density.[6]

Channels: From urbanization to commodity demand

The literature has identified several channels through which urbanization has affected commodity consumption. These include the impact of urbanization on transport behavior, infrastructure needs, household characteristics, and consumer choice. Most of the channels identified relate to energy consumption. In general, these channels have the potential to either increase or decrease commodity consumption, and may also vary between advanced economies and EMDEs (Madlener and Sunak 2011). While not the primary focus of this study, urbanization can also affect commodity supply, particularly for agriculture, via its impact on land availability and pollution. Developments in commodity markets also have the potential to influence urbanization patterns. For example, sharp falls in agricultural prices could accelerate shifts from rural to urban areas.

Transport. Several studies have investigated the impact of urbanization on transport, and, by association, energy demand. These studies have shown that urbanization can either raise or lower energy demand. A reduction in transport costs is often cited as one of the benefits of urbanization, contributing to improved economic growth. Changes in transport patterns have a particularly large impact, since transport accounts for 29 percent of total final energy consumption at the global level, compared to 21 percent for residential use (in the United States, transport accounts for 40 percent; IEA 2021).

Studies which find urbanization reduces energy demand typically focus on the fact that high density neighborhoods facilitate journeys by foot or by bike, while those with effective mass transit systems provide alternatives to personal motorize vehicles. In Europe, where cities are higher density and public transport is widely available, per capita consumption of gasoline is one-fifth the level in low-density U.S. cities, although this also reflects much higher fuel taxes in Europe (Newman 2006). Within the United States, studies have found that urban households use less transport energy than rural ones (figure SF.4; Kahn 2000; Liddle and Lung 2010). Furthermore, there is variation within U.S. cities. Those with the best public transit, such as New York, have the lowest energy consumption from transport. Similarly, households living in higher-density cities have lower levels of auto transport and fuel consumption than those in lower-density areas (Brownstone and Golob 2009).

In contrast, studies which find that an increase in the urban population increases transport energy demand focus on factors that can result in increased journeys. In the absence of mass transit systems, rising urban populations can result in increased dependence on cars, given residences and workplaces are typically separated in cities (Jones 2004). This issue can be exacerbated by urban sprawl, defined as the spread of low-density urban areas outside of the urban center, which can lead to increased auto use (Burchell et al. 1998; Hankey and Marshall 2010; VandeWeghe and Kennedy 2008). This trend can be observed in the United States, where urban density has declined for the last five decades, leading to an increase in travel distances and therefore energy consumption (Glaeser and Kahn 2010; Marshall 2007).

In EMDEs the move from rural to urban areas may lead to a shift from predominantly "muscle-powered" transport (e.g., walking or biking) to motorized transport (e.g., cars, motorcycles, and buses), leading to a net increase in energy use (Parikh and Shukla 1995).[7] This is particularly the case in instances where cities have not been well planned—for example, if urban expansion occurs via informal and unplanned settlements, with poorly designed zones between commuter and

[6] In contrast, earlier studies found that population densities had decreased over time. This was because they had a higher estimate of the increase in urban areas due to different methodologies (Angel et al. 2016; UN Habitat 2020).

[7] Since urbanization facilitates economies of scale and specialization as part of a broader industrialization process, it may result in the increased movement of raw materials and intermediate goods in the production process (Jones 1991, 2004).

FIGURE SF.4 Urban populations and transport-sector energy demand in the United States

Low levels of population density are associated with much higher energy consumption from transportation in the United States. Rural populations tend to drive more and walk less than their urban counterparts. Similarly, high rates of urban density facilitate the use of public transport, with commuter rates much higher in large, dense cities. Household energy use is higher in detached houses compared with apartments, and energy use is also higher in smaller households.

Sources: Federal Highway Administration, National Household Travel Survey 2017; World Bank.
A. Vertical axis presents data for total energy consumption per capita in the transport industry for 50 US states, whereas population density is shown on the horizontal axis. Data for 2019.

residential areas, and insufficient or non-existent infrastructure such as mass transit systems (Wahba 2019). In Nairobi, for example, poor planning and inadequate public transit means that around 10 percent of jobs are accessible by public transport within 45 minutes, compared to 25 percent in Buenos Aires, despite the latter having four times as many people (Quiros-Peralta 2015). Furthermore, the reliance of cities on commodities produced outside their borders, such as food, can result in increased energy use as these products need to be transported; this may not be the case for mostly self-sufficient rural areas (Parikh and Shukla 1995).

Infrastructure requirements. Densely populated cities have vast infrastructure needs, including mass transit, electricity generation, telecommunications, and water and sewerage services (Eberts and McMillen 1999). While large-scale infrastructure projects can be very resource-intensive, particularly in terms of energy and metal consumption, per capita usage of infrastructure can be much higher than in low-density areas. As such, economies of scale arising from network effects may make the provision of the service more efficient (World Bank 2021b). For example, urban access to the internet is 2.3 times higher than access in rural areas globally, as it is easier and cheaper to provide the service to a high-density population (ITU 2020). As a result, per capita resource demand could be lower than would be required to provide the same level of services to rural populations. At the same time, it is possible that urbanization and high-density living creates "new" demand for infrastructure. For example, a high-density urban population may have greater need for sanitation facilities than low-density rural areas. Consequently, the "need" for these services due to urbanization may lead to greater per capita commodity demand than otherwise.

Household size and type of accommodation. An increase in the share of the urban population can lead to differences in household characteristics, with either positive or negative impacts on energy consumption. As a result of higher land costs, apartments are much more common in cities than in rural areas, which are predominantly detached houses. Apartments have smaller energy use than detached houses due to fewer exterior walls, which reduces energy loss from heating and cooling (figure SF.5; Brounen, Kok, and Quigley 2012; Satterthwaite 2011).

However, this may be partly offset by differences in household composition. Average household size tends to be smaller in urban areas, as young people move away from their family home and also marry later (Cole and Neumayer 2004). Smaller households tend to have higher per capita energy consumption as they are less able to benefit from economies of scale in energy consumption compared with larger households (Liu et al. 2003). In a study of 300,000 Dutch households, an additional person per household reduced per capita natural gas consumption by 26 percent and electricity consumption by 18 percent (Brounen, Kok, and Quigley 2012). Urban sprawl has also been shown to lead to increased residential energy use (Ewing and Rong 2010).

Changes in the composition of energy demand. In addition to changes in the overall level of energy demand, urbanization can also lead to changes in the types of fuel consumed within a country, which could affect aggregate energy demand both positively and negatively. As households move from rural to urban areas, they typically move from more basic forms of energy, such as biomass, toward more modern energy forms, such as electricity from centralized power stations fueled by coal or natural gas (Barnes, Krutilla, and Hyde 2005). For example, in sub-Saharan Africa 68 percent of urban households have access to electricity, compared to 15 percent in rural areas (Hommann and Lall 2019). Consumption of natural gas or kerosene for heating and cooking may also rise in place of solid fuels, with the proportion of households cooking with coal and wood falling sharply with population density (Gollin, Kirchberger, and Lagakos 2017). This shift has the potential to reduce commodity demand as the provision of energy in the form of centrally generated electricity or natural gas is typically more efficient than the burning of biomass (Pachauri and Jiang 2009; Poumanyvong and Kaneko 2010).

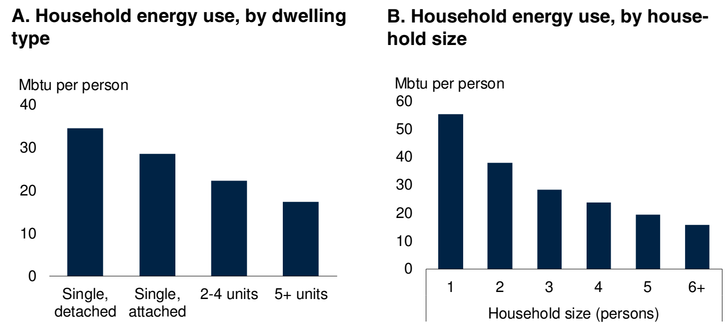
However, greater access to better-quality, cheaper energy such as electricity may lead to increased consumption of energy (Gillingham, Rapson, and Wagner 2015; IEA 2008).

The "heat island" effect. Urban areas give rise to the "heat island" effect, whereby man-made structures such as roads and buildings absorb and re-emit heat from the sun to a greater degree than natural landscapes, and also provide less shade and moisture (Imhoff et al. 2010). This can be exacerbated by a concentration of human activities that emit heat, such as the use of air conditioners. As such, urban areas, particularly cities with larger and more dense populations, tend to be hotter than rural or natural areas, although the effect can vary between cities depending on the extent of green space. Estimates for the United States indicate the annual average temperature of a city can be 1.8 to 5.4°F hotter than its surroundings, although estimates can vary significantly between studies, and also fluctuate between night and day, and summer and winter (EPA 2008). These variations can increase energy demand for cooling in hotter countries and during summer; however, it can reduce energy demand for heating in cooler countries and in winter. The heat island effect is expected to change and increase as global temperatures rise (Hibbard et al. 2017).

Increased consumer choice. Consumers living in cities benefit from a larger range of goods and services to consume, which can result in increased consumption (if consumers have access to new products). Access to larger markets enables producers and retailers to specialize and supply a wider variety of goods and services. All else equal, a rise in consumption due to increased choice, beyond that driven by increased income, would result in a net positive increase in commodity demand. For example, urban diets are typically more varied and include a greater share of meat, processed food (including convenience food), and exotic food, which require more energy and other commodities both in their production and transport (Hovhannisyan and Devadoss 2020; Regmi and Dyck 2001). However, empirical

FIGURE SF.5 Urban populations and household energy use in the United States

Household energy use is lower in apartments compared to single-family homes due to greater energy efficiency, but is higher in smaller households due to economy of scale effects in heating and lighting.



Sources: U.S. Energy Information Administration; World Bank.

studies suggest that the link between increased consumer choice and rising commodity demand is primarily driven by income, not urbanization per se. For example, household survey evidence from China and India shows the quantities of food consumed by rural households and urban households with similar income levels are comparable (Pandey et al. 2020; Stage, Stage, and McGranahan 2010).

Production. In addition to the effects on commodity demand, rapid urbanization can affect agricultural production, although as with commodity consumption, these effects can be either positive or negative. If urbanization leads to people living in higher-density areas, it may reduce the proportion of land used for habitation and increase the availability for agricultural uses (Satterthwaite, McGranahan, and Tacoli 2010). Further, a reduction in population in rural areas can promote the creation of larger farms, allowing efficiency gains and thereby increasing agricultural production (Stage, Stage, and McGranhan 2010).[8] However, high-density cities can also lead to increased levels of localized pollution and degrade water supplies and soil quality, decreasing agricultural supply (Angel, Sheppard, and Civco 2005). The increased share of land used by cities can also result in the loss of agricultural land if cities are located in particularly fertile and irrigated areas. In China, for example, 4.3 million hectares of cropland were converted to built-up land between 1987 and 2010 (Acharya et al. 2021).

Commodity demand and urbanization. Just as urbanization can affect commodity demand, the reverse relationship may also occur: changes in global commodity demand has the potential to impact urbanization via changes in global commodity prices. If commodities are produced in rural areas, such as agricultural products, then an increase (decrease) in global commodity prices which increases (decreases) rural real wages might be expected to slow (accelerate) urbanization as it decreases (increases) the incentives to move to rural areas (Bruckner 2012). In addition, fluctuations in commodity prices such as oil may alter the characteristics of cities within a country by affecting transport costs. In SSA, for example, rising oil prices and transport costs have been shown to increase economic activity in cities near major ports relative to otherwise identical cities that are further away (Storeygard 2013). As a result, future urban growth in SSA may be more likely to occur in large coastal cities.

Empirical effects of urbanization on commodity demand

The literature can be broadly split into two fields: studies that investigated the effect of the overall share of the urban population and studies that considered urban density (differences between high- and low-density urban areas within a country; Table 1). While many studies explore the role of energy on urbanization, far fewer examine agriculture and virtually none for metals. Empirical analysis of the topic is limited by data availability, particularly for commodity consumption at the sectoral level. The considerable differences in the definition of an urban area between countries also present a challenge.

Sample of studies. The majority of the studies focusing on the overall share of urban populations were cross-country studies using panel datasets and focused on aggregate energy consumption, although some looked at individual channels. This group also included some single-country studies, including two studies looking at food consumption. In contrast, the studies examining urban density focused on individual countries (frequently the United States, given greater data availability) and on individual channels, such as energy demand from transport or dwellings. These studies were all in advanced economies (Canada, Japan, the Netherlands, and the United States), likely reflecting the greater data availability of sectoral energy consumption. All of the studies included in the literature review controlled for per capita income.

[8] Causality may also run in the opposite direction, whereby efficiency gains in agriculture can act as a catalyst for urbanization by freeing up labor.

Share of urban populations. Of the cross-country studies examining the impact of the share of the urban population on commodity demand, almost all found a positive, statistically significant relationship whereby a higher urban population share caused higher energy demand.[9] One study found that the relationship varied by income level, with a negative relationship for LICs, but a positive relationship for higher-income countries; this was attributed to efficiency gains arising from shifts to more modern fuels such as centrally-generated electricity (Poumanyvong and Kaneko 2010). Another study of nine Pacific Islands found a positive, significant relationship for four islands, an insignificant relationship for another four, and a negative relationship for one (Mishra, Smyth, and Sharma 2009). The one single-country study also found a positive relationship between urbanization and energy demand (Liu 2009). Only one study found a negative relationship between the urban share of the population and energy consumption (from transport; Liddle 2004).

Two studies investigated food consumption in China and India (Hovhannisyan and Devadoss 2020; Pandey et al. 2020). The studies found little aggregate impact of urban population shares on food consumption after controlling for income. The two studies had different findings in terms of the impact on the composition of diets, however, with the former finding a shift from grains and vegetables to meats, eggs, and fruits, while the latter found little impact. The single study which investigated metals consumption found a positive impact of urbanization on metals demand (Baffes, Kabundi, and Nagle 2021).[10]

Urban density. Of the studies examining the impact of urban density, all found a negative relationship with energy demand. These considered a variety of channels, including transport, dwellings, dwellings and transport together, and consumption from the service sector.[11] Higher-density cities had lower energy demand than lower-density ones, at least in advanced economies. The extent to which these results apply to EMDEs is unclear. Many cities in EMDEs, particularly in sub-Saharan Africa, struggle with high road congestion and commuting costs due to poor planning, inadequate transport infrastructure, and limited public transit options, despite high population density (Hommann and Lall 2019; World Bank 2021b). Indeed, in a study considering the effect of population density on CO_2 emissions, the relationship was found to vary with income. Areas with higher population density were found to have higher CO_2 emissions at very low levels of per capita income, but lower CO_2 emissions at higher income levels (above $1,000 per capita; Dasgupta, Lall, and Wheeler 2021).

Conclusions and policy implications

The share of the global population living in urban areas has risen rapidly over the past 50 years alongside a major increase in commodity consumption. While income and population growth are the primary drivers of commodity demand, urbanization also affects commodity demand through several channels. This is because urban areas have huge resource needs, both in terms of their construction and in their day-to-day use due to high concentrations of population.

In aggregate, an increase in the share of the urban population is associated with increased energy demand. But the impact also depends on the nature of urbanization, with compact, high-density cities having lower per capita energy consumption than low-density cities due to greater resource efficiency and economies of scale, particularly in advanced economies. For food, urbanization appears to change patterns of

[9] See Baffes, Kabundi, and Nagle (2021); Salim and Shafiei (2014); Poumanyvong and Kaneko (2010); Poumanyvong, Kaneko, and Dhakkal (2012); Mishra (2009); Parikh and Shukla (1995); and York (2007).

[10] Urbanization was not the primary focus of this study and was included as a control variable.

[11] These studies considered various channels, including transport (Brownstone and Golob 2009); dwellings (Brounen, Kok, and Quigley 2012; Lariviere and Lafrance 1999); dwellings and transport together (Glaeser and Kahn 2010; Larson and Yezer 2015); and consumption from the service sector (Morikawa 2012).

consumption, but there is less evidence that it causes an overall increase in demand. In the case of metals, the limited research available shows a positive relationship between urbanization and metals demand. An important avenue for further research would be to explore the impact of urban density on a broader range of commodities—and importantly account for differences in income levels (extending the analysis in Dasgupta, Lall, and Wheeler 2021). Since growth in cities is expected across EMDEs, this could help in assessing the impact of different types of city design on resource use.

Cities are on the frontlines of the climate change and the energy transition; although they occupy less than 3 percent of global land, they consume over two-thirds of the world's energy and account for 70 percent of global greenhouse gas (GHG) emissions. They are also particularly at risk from climate change, with 90 percent of the world's urban areas situated on coastlines and therefore at risk from rising sea levels. With urban populations expected to continue to increase rapidly, strategic urban planning that integrates transport and land use will become even more important in limiting the impact of urbanization on commodity consumption, and, crucially, GHG emissions.[12] It is not urbanization alone that causes an increase in GHG emissions, but rather differences in the design of cities, the methods of transport used, the choice of fuel for energy, and the efficiency and means by which buildings are heated and cooled (World Bank 2010).

Critical policy measures will include the expansion of the capacity, affordability, and access of public mass transport systems, as well as investment in energy efficiency measures for buildings. Fiscal policies can also play an important role. For example, fuel taxes have been shown to increase population density and preserve open space (Creutzig 2014, Creutzig et al. 2015). Zoning laws are also important for boosting population density. They can, for example, encourage "building up" instead of out, which can help reduce long commutes, increase usage of public transit, and lower energy use and greenhouse gas emissions (Lall et al. 2021). Early planning and installation of transportation infrastructure is particularly crucial in rapidly growing cities such as in Sub-Saharan Africa, as it can help guide and shape future urban growth, and prevent urban sprawl (Hommann and Lall 2019).

[12] The development of green and sustainable cities is a key component of the World Bank's Climate Change Action Plan, and in line with the UN's Sustainable Development Goal 11 to make cities and human settlements inclusive, safe, resilient, and sustainable (World Bank 2021c).

TABLE SF.1 Literature review of urbanization and commodity demand

Author(s)	Data	Main topic	Main findings
Baffes, Kabundi, and Nagle (2021)	Panel of 63 advanced economies and EMDEs, 1965-2017	Aggregate energy and metal consumption	Urbanization has a positive effect on energy and metal consumption (positive on coal and natural gas consumption but negative effect on oil).
Dasgupta, Lall, and Wheeler (2021)	1,236 cities in 138 countries, 2014-2020	CO_2 emissions	Urban areas with higher population density have higher CO_2 emissions at very low levels of per capita income, but lower CO_2 emissions at higher income levels (above $1,000 per capita).
Hovhannisyan and Devadoss (2020)	Panel data on consumer food expenditure in China, 2005-12	Food consumption	Urbanization has reduced demand for grains, vegetables, and fats and oils while increasing demand for meats, fruit, and eggs.
Pandey et al. (2020)	Consumer expenditure survey data covering 124 food commodities at the household, district, and state level in India	Food consumption	Although urbanization leads to varied diets, most of the change in food consumption patterns between urban and rural areas is due to income, not urbanization.
Larson and Yezer (2015)	Theoretical model calibrated with empirical estimates of model parameters with calibration target of 10 U.S. cities.	Energy use from transport and dwellings	A doubling in urban population leads to a 2.6 percent reduction in energy use from transport and dwelling use.
Salim and Shafiei (2014)	Panel of 29 OECD countries, 1980-2011	Aggregate energy use (renewable and non-renewable)	Urbanization has a positive effect on non-renewable energy use (due to changing consumer needs and increased transport demand) but little effect on renewable energy use.
Sadorsky (2013)	Unbalanced panel of 76 developing countries, 1980-2010	Energy intensity	Urbanization has an insignificant effect on energy use in most versions of the model; income is a statistically significant negative driver of energy intensity.
Brounen, Kok, and Quigley (2012)	Sample of 300,000 households in the Netherlands, 2008-09	Energy use from dwellings	Apartments and row homes had significantly lower energy consumption than detached and semi-detached homes. An additional person per household reduced per capita natural gas and electricity consumption by 26 percent and 18 percent, respectively.
Morikawa (2012)	Microdata covering up to 66,000 service sector firms in Japan, 2007-08	Energy use by service sector	The efficiency of energy consumption in service companies is higher in densely populated cities. Energy efficiency increases by 12 percent when density doubles.
Poumanyvong and Kaneko (2010)	Panel dataset of 92 countries (low- medium- and high-income), 1975-2005	Aggregate energy consumption	Urbanization results in lower energy use in low-income countries (perhaps due to switching from inefficient to efficient fuels). Urbanization leads to increased energy use in middle- and high-income countries.
Poumanyvong, Kaneko, and Dhakal (2012)	Panel dataset of 92 countries (low- medium- and high-income), 1975-2005	Energy use from transport	Urbanization leads to more energy use in transport for all income groups, especially high-income countries.
Glaeser and Kahn (2010)	Single-year survey and census data for U.S. metropolitan areas	GHG emissions from energy use	Higher-density cities have lower emissions than low-density cities. This is due to lower emissions from driving and electricity, while emissions from public transport and heating are higher.
Brownstone and Golob (2009)	Single-year survey data for California, U.S.	Energy use from transport	Lower-density households travel more and consume more fuel, both a result of increased travel time, as well as self-selection of less efficient cars.
Liu (2009)	China, 1978-2008	Aggregate energy consumption	Urbanization has a positive effect on energy consumption – much smaller than that of income and decreasing over time.
Mishra (2009)	Nine Pacific island countries, 1980-2005	Aggregate energy consumption	In aggregate, a 1 percent increase in the rate of urbanization generates a 2.4 percent increase in energy consumption. However, the effect was positive in only 4 of the 9 countries (negative in 1, and insignificant in the other).
York (2007)	Panel of 14 EU countries, 1960-2000	Aggregate energy consumption	Urbanization leads to more energy consumption.
Liddle (2004)	Panel data, 23 OECD countries, 1960-2000	Energy consumption by transport	Highly urbanized and more densely populated countries have lower personal transport consumption.
Lariviere and Lafrance (1999)	Single-year data on electricity consumption, 45 cities in Canada	Electricity consumption	High-density cities use slightly less electricity than lower-density ones.
Parikh and Shukla (1995)	Panel dataset of 72 countries, 1965-87	Aggregate energy consumption	A 1 percent rise in urbanization leads to a 0.28 percent rise in energy use. This is driven by transport and is attributed to greater intra-urban commuting and congestion.

References

Acharya, G., E. Emilie, S. Jaffee, and E. Ludher. 2021. *Rich Food, Smart City: How Building Reliable, Inclusive, Competitive, and Healthy Food Systems is Smart Policy for Urban Asia.* Washington, DC: World Bank.

Ahlfeldt, G., and E. Pietrostefani. 2019. "The Economic Effects of Density: A Synthesis." CEPR Discussion Paper 13440, Centre for Economic Policy Research, London.

Angel, S., S. Sheppard, and D. Civco. 2005. *The Dynamics of Global Urban Expansion.* World Bank: Washington, DC.

Angel, S., A. M. Blei, J. Parent, P. Lamson-Hall, N. G. Sánchez, D. L. Civco, R. Q. Lei, and K. Thom. 2016. *Atlas of Urban Expansion—2016 Edition*. New York: NYU Urban Expansion Program at New York University, UN-Habitat, and the Lincoln Institute of Land Policy.

Baffes, J., A. Kabundi, and P. Nagle. 2021. "The Role of Income and Substitution in Global Commodity Demand." *Oxford Economic Papers*, 1 -25. https://doi.org/10.1093/oep/gpab029.

Barnes, D., K. Krutilla, and W. Hyde. 2005. *The Urban Household Energy Transition*. Milton Park, England: Routledge.

Benfield, F., M. Raimi, and D. Chen. 1999. *Once There Were Green Fields: How Urban Sprawl is Undermining America's Environment, Economy and Social Fabric.* New York: Natural Resources Defense Council.

Brody, S. 2013. "The Characteristics, Causes, and Consequences of Sprawling Development Patterns in the United States." *Nature Education Knowledge* 4 (5):2.

Brounen, D., N. Kok, and J. Quigley. 2012. "Residential Energy Use and Conservation: Economics and Demographics." *European Economic Review* 56 (5): 931-945.

Brownstone, D., and T. Golob. 2009. "The Impact of Residential Density on Vehicle Usage and Energy Consumption." *Journal of Urban Economics* 65 (1): 91-98.

Bruckner, M. 2012. Economic Growth, Size of the Agricultural Sector, and Urbanization in Africa." *Journal of Urban Economics* 71 (1): 26-36.

Burchell, R., N. Shad, D. Listokin, and H. Phillips. 1998. *The Costs of Sprawl Revisited.* Report 39. Transit Cooperative Research Program, Transportation Research Board. National Academy Press, Washington, DC.

Cole, M., and E. Neumayer. 2004. "Examining the Impact of Demographic Factors on Air Pollution." *Population and Environment* 26: 5-21.

Creutzig, F. 2014. "How Fuel Prices Determine Public Transportation Infrastructure, Modal Shares and Urban Form." *Urban Climate* 10: 63–76.

Creutzig, F., G. Baiocchi, R. Bierkandt, P. P. Pichler, and K. C. Seto. 2015. "A Global Typology of Urban Energy Use and Potentials for an Urbanization Mitigation Wedge." *Proceedings of the National Academy of Sciences* 112 (20): 6283 –6288.

Dasgupta, S., S. Lall, and D. Wheeler. 2021. "Urban CO2 Emissions: A Global Analysis with New Satellite Data." Unpublished paper, World Bank, Washington, DC.

Dijkstra, L., A. Florczyk, S. Freire, T. Kemper, M. Melchiorri, M. Pesaresi, and M. Schiavina. 2020. "Applying the Degree of Urbanisation to the Globe: A New Harmonised Definition Reveals a Different Picture of Global Urbanisation." *Journal of Urban Economics* 125 (2).

Dijkstra, L., E. Hamilton, S. Lall, and S. Wahba. 2020. "How Do We Define Cities, Towns, and Rural Areas?" *Sustainable Cities* (blog), World Bank, March 10, 2020. https://blogs.worldbank.org/sustainablecities/how-do-we-define-cities-towns-and-rural-areas.

Eberts, R., and D. McMillen. 1999. "Agglomeration Economies and Urban Public Infrastructure." In *Handbook of Regional and Urban Economics, Vol. 3, Applied Urban Economics*, edited by P. Cheshire, and E. S. Mills, 1455-1495. Amsterdam: ScienceDirect.

EPA (United States Environmental Protection Agency). 2008. *Reducing Urban Heat Islands: Compendium of Strategies.* Draft. https://www.epa.gov/heat-islands/heat-island-compendium.

Ewing, R., and F. Rong. 2010. "The Impact of Urban Form on U.S. Residential Energy Use." *Housing Policy Debate* 19 (1): 1-30.

Federal Highway Administration. 2017. "National Household Travel Survey." U.S. Department of Transportation, Washington, DC. https://nhts.ornl.gov/downloads.

Gillingham, K., D. Rapson, and G. Wagner. 2016. "The Rebound Effect and Energy Efficiency Policy." *Review of Environmental Economics and Policy* 10 (1): 68-88.

Glaeser, E., and Kahn, E. 2010. "The Greenness of Cities: Carbon Dioxide Emissions and Urban Development." *Journal of Urban Economics* 67 (3): 404-418.

Gollin, D., M. Kirchberger, and D. Lagakos. 2017. "In Search of a Spatial Equilibrium in the Developing World." Working Paper 2017-09, Centre for the Study of African Economies, University of Oxford, Oxford.

Hankey, S., and Marshall, J. 2010. "Impacts of Urban Form on Future US Passenger-vehicle Greenhouse Gas Emissions." *Energy Policy* 38 (9): 4880–4887.

Hommann, K., and S. Lall. 2019. *Which Way to Livable and Productive Cities? A Road Map for Sub-Saharan Africa.* International Development in Focus series. Washington, DC: World Bank.

Hibbard, K. A., F. Hoffman, D. Huntzinger, and T. O. West. 2017. "Changes in Land Cover and Terrestrial Biogeochemistry." In *Climate Science Special Report: Fourth National Climate Assessment, Volume I,* edited by D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, 405-442. Washington, DC: U.S. Global Change Research Program.

Hovhannisyan, V., and S. Devadoss. 2020. "Effects of Urbanization on Food Demand in China." *Empirical Economics* 58 (2): 699-721.

Imhoff, M., P. Zhang, R. Wolfe, and L. Bounoua. 2010. Remote Sensing of the Urban Heat Island Effect Across Biomes in the Continental USA." *Remote Sensing of Environment* 114 (3): 504-513.

IEA (International Energy Agency). 2008. *World Energy Outlook 2008*. Paris: International Energy Agency.

IEA (International Energy Agency). 2021. *World Energy Balances 2021*. Paris: International Energy Agency.

ITU (International Telecommunications Union). 2020. "Measuring Digital Development: Facts and Figures 2020." International Telecommunications Union, Geneva.

Jones, D. 1991. "How Urbanization Affects Energy-Use in Developing Countries." *Energy Policy* 19 (7): 621– 630.

Jones, D. 2004. "Urbanization and Energy." *Encyclopedia of Energy* 6: 329–335.

Kahn, M. 2000. "The Environmental Impact of Suburbanization." *Journal of Policy Analysis and Management* 19 (4): 569-586.

Lall, S. V., M. Lebrand, H. Park, D. Sturm, and A. J. Venables. 2021. *Pancakes to Pyramids: City Form to Promote Sustainable Growth.* Washington, DC: World Bank.

Lariviere, I., and G. Lafrance. 1999. "Modelling the Electricity Consumption of Cities: Effect of Urban Density." *Energy Economics* 21 (1): 53-66.

Larson, W., and A. Yezer. 2015. "The Energy Implications of City Size and Density." *Journal of Urban Economics* 90 (November): 35-49.

Liddle, B. 2004. "Demographic Dynamics and Per Capita Environmental Impact: Using Panel Regressions and Household Decompositions to Examine Population and Transport." *Population and Environment* 26 (1): 23–39.

Liddle, B., and S. Lung. 2010. "Age-Structure, Urbanization, and Climate Change in Developed Countries: Revisiting STIRPAT for Disaggregated Population and Consumption-Related Environmental Impacts." *Population and Environment* 31 (5): 317-343.

Liu, J., G. Daily, P. Ehrlich, and G. Luck. 2003. "Effects of Household Dynamics on Resource Consumption and Biodiversity." *Nature,* 421 (6922): 530-533.

Liu, Y. 2009. "Exploring the Relationship Between Urbanization and Energy Consumption in China Using ARDL and FDM." *Energy* 34 (11): 1846-1854.

Madlener, R., and Y. Sunak. 2011. "Impacts of Urbanization on Urban Structures and Energy Demand: What Can We Learn for Urban Energy Planning and Urbanization Management?" *Sustainable Cities and Society* 1 (1): 45– 53.

Marshall, J. 2007. Urban Land Area and Population Growth: A New Scaling Relationship for Metropolitan Expansion." *Urban Studies* 44 (10):1889–1904.

Mercer. 2019. "2019 City Ranking." Quality of Living City Ranking. https://mobilityexchange.mercer.com/ Insights/quality-of-living-rankings.

Mishra, V., R. Smyth, and S. Sharma. 2009. "The Energy-GDP Nexus: Evidence from a Panel of Pacific Island Countries." *Resource and Energy Economics* 31 (3): 210-220.

Moran, D., K. Kanemoto, M. Jiborn, R. Wood, J. Tobben, and K. Seto. 2018. "Carbon Footprints of 13,000 Cities." *Environmental Research Letters* 13(6): 4041.

Morikawa, M. 2012. "Population Density and Energy Efficiency in Energy Consumption: An Empirical Analysis of Service Establishments." *Energy Economics* 34 (5): 1617-1622.

Newman, P. 2006. "The Environmental Impact of Cities." *Environmental Urbanization* 18 (2): 275–295.

Pachauri, S., And L. Jiang. 2009. "The Household Energy Transition in India and China." *Energy Policy* 36 (11): 4022-4035.

Pandey, B., M. Reba, P. Joshi, and K. Seto. 2020. "Urbanization and Food Consumption in India." *Scientific Reports* 10: 17241.

Parikh, J., and V. Shukla. 1995. "Urbanization, Energy Use and Greenhouse Effects in Economic Development: Results from a Cross-National Study of Developing Countries." *Global Environmental Change* 5 (2): 87-103.

Poumanyvong, P., and S. Kaneko. 2010. "Does Urbanization Lead to Less Energy Use and Lower CO2 Emissions? A Cross Country Analysis." *Ecological Economics* 70 (2): 434-444.

Poumanyvong, P., and S. Kaneko, and S. Dhakal. 2012. "Impacts of Urbanization on National Transport and Road Energy Use: Evidence from Low-, Middle- and High-income Countries." *Energy Policy* 46: 268-277.

Quiros-Peralta, T. 2015. "Mobility for All: Getting the Right Urban Indicator." Connections Transport & ICT Note 25, World Bank, Washington, DC.

Regmi, A., and J. Dyck. 2001. "Effects of Urbanization on Global Food Demand." Changing Structure of Global Food Consumption and Trade/WRS-01-1, USDA Economic Research Service, Washington, DC.

Salim, R., and S. Shafiei. 2014. "Non-renewable and Renewable Energy Consumption and CO2 Emissions in OECD Countries: A Comparative Analysis." *Energy Policy* 66 (C): 547-556.

Sadorsky, P. 2014. Do Urbanization and Industrialization Affect Energy Intensity in Developing Countries?" *Energy Economics,* 37(c): 52-59.

Satterthwaite, D. 2011. "How Urban Societies Can Adapt to Resource Shortage and Climate Change." *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 369 (1942): 1762 -1783.

Satterthwaite D., G. McGranahan, and C. Tacoli. 2010. "Urbanization and its Implications for Food and Farming." *Philosophical Transactions of the Royal Society* 365 (1554): 2809-20.

Stage, J., J. Stage, and G. Mcgranahan. 2010. "Is Urbanization Contributing to Higher Food Prices?" *Environment and Urbanization* 22 (1): 199-215.

Storeygard, A. 2013. "Farther on Down the Road: Transport Costs, Trade and Urban Growth in Sub -Saharan Africa." Policy Research Working Paper 6444, World Bank, Washington, DC.

Texas A&M Transportation Institute. 2021. *2021 Urban Mobility Report.* Austin, Texas: Texas Department of Transportation.

United Nations. 2019. *World Urbanization Prospects: The 2018 Edition.* New York; United Nations.

United Nations. 2020. *Statistical Commission: Report on the Fifty-First Session (3–6 March 2020).* Economic and Social Council, Official Records, 2020, Supplement No. 4. United Nations, New York. https://unstats.un.org/unsd/statcom/51st-session/documents/Report-2020-Draft-EE.pdf.

UN-Habitat. 2020. *World Cities Report 2020: The Value of Sustainable Urbanization*. Nairobi, Kenya: United Nations Human Settlements Programme.

VandeWeghe, J. and C. Kennedy. 2007. "A Spatial Analysis of Residential Greenhouse Gas Emissions in the Toronto Census Metropolitan Area." *Journal of Industrial Ecology* 11 (2): 133-144.

Wahba, S. 2019. "Smarter Cities for an Inclusive, Resilient Future." *Sustainable Cities* (blog), World Bank, December 3, 2019. https://blogs.worldbank.org/sustainablecities/smarter-cities-inclusive-resilient-future.

World Bank 2010. "Cities and Climate Change: An Urgent Agenda." Urban Development Series; Knowledge Papers, 10. Washington, DC: World Bank.

World Bank. 2021. *Demographic Trends and Urbanization.* Washington, DC: World Bank.

York, R. 2007. "Demographic Trends and Energy Consumption in European Union Nations, 1960–2025." *Social Science Research* 36(3): 855–872.