

Will Climate Change Cause Enormous Social Costs for Poor Asian Cities?

MATTHEW E. KAHN*

Climate change could significantly reduce the quality of life for poor people in Asia. Extreme heat and drought, and the increased incidence of natural disasters will pose new challenges for the urban poor and rural farmers. If farming profits decline, urbanization rates will accelerate and the social costs of rapid urbanization could increase due to rising infectious disease rates, pollution, and congestion. This paper studies strategies for reducing the increased social costs imposed on cities by climate change.

Keywords: adaptation, Asia, cities, climate change, natural disasters

JEL codes: Q54, R11

I. Introduction

Between 1950 and 2014, Asia's average urbanization rate increased from 20% to roughly 50%.¹ For Asia's poorer cities, urbanization has simultaneously caused rising per capita incomes and increasing social costs (Tolley 1974, Glaeser 1998, Henderson 2002). Gross national product is not a sufficient statistic for measuring well-being (Stiglitz, Sen, and Fitoussi 2010; Jones and Klenow 2016). A country's quality of life is also determined by its life expectancy, literacy rate, and nonmarket public goods such as a clean environment.

Quality of life indicators are lower in poorer cities as residents cope with negative externalities ranging from air and water pollution, infectious diseases, and crime to congestion and general overcrowding in poor slums. Poor people cannot afford high-quality goods and services, and local governments lack the capacity to provide public goods such as clean water. Negative externalities fester. For comparison, the infant mortality rate per 1,000 live births in Bangladesh is 31 and in Singapore it is 2.² If richer cities have higher nonmarket quality of

*Matthew E. Kahn: Professor, Department of Economics, University of Southern California. E-mail: kahnme@usc.edu. I would like to thank Lauren Phillips, the participants at the Asian Development Review Conference on Urban and Regional Development in Asia held in Seoul in July 2016, the managing editor, and an anonymous referee for helpful comments and suggestions. The usual disclaimer applies.

¹See [https://esa.un.org/unpd/wup/Archive/Files/studies/United%20Nations%20\(1969\)%20-%20Growth%20of%20the%20World's%20Urban%20and%20Rural%20Population,%201920-2000.pdf](https://esa.un.org/unpd/wup/Archive/Files/studies/United%20Nations%20(1969)%20-%20Growth%20of%20the%20World's%20Urban%20and%20Rural%20Population,%201920-2000.pdf) and <https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf>

²See <http://data.worldbank.org/indicator/SP.DYN.IMRT.IN>

life indicators than poorer cities, then simple cross-city comparisons of per capita income understate inequality across Asia's cities.

Climate change risk could further exacerbate disparities in quality of life indicators within Asia. Urbanites in Asia's poor cities are less likely to own air conditioners and have access to healthy food and medical care. The poor live in lower-quality housing in geographic areas that face greater natural disaster risks. Poor people also live in areas with higher population densities and thus are more likely to be exposed to infectious disease such as cholera. Poor countries also have less capacity to cope with such outbreaks and with heat waves and other natural disasters.

This paper presents a research agenda for studying how the social costs of climate change adaptation are evolving for poor cities and poor urbanites in Asia. In the first section, I focus on the major challenges that poor urbanites will face because of climate change, including the acceleration of urban growth rates as poor cities experience an influx of rural migrants driven to urban areas by falling agricultural profits. Farm production is sensitive to extreme temperature and rainfall conditions. Farmers who are unable to adapt to shifting conditions will likely move to cities for alternative sources of income. Such migration increases the population density of slums and exacerbates the risk of infectious disease. Rapid urban growth can overwhelm a city's infrastructure, especially in cities with weak public revenue collection institutions. The poor are at the greatest risk from natural disasters both because of where they tend to live and their limited coping strategies in the face of new risks (Kahn 2005). This discussion highlights that Asia's poor people and economies will bear the brunt of climate shocks. The rich have access to higher-quality housing and medical care. Since food is a relatively small budget item for the rich, higher food prices will not affect their purchasing power. Furthermore, the rich live in parts of cities that are safer and have more developed coping strategies for natural disasters.

While Asia's poor face major new risks because of climate change, there are countervailing forces in play as well. With the rise of big data, governments and individuals have greater access to real-time information about emerging threats. Increased international flows of capital have given local governments the capacity to fund public infrastructure projects. An open question concerns the incentives for mayors and city governments in developing countries to take costly steps to improve the quality of life of the urban poor. Such investments will ultimately increase the migration of rural poor to these cities. Anticipating this effect, some mayors and city governments are discouraged from making such investments. Feler and Henderson (2011) present evidence of this dynamic in Brazil.

Asia's collective ability to adapt to anticipated but ambiguous new climate risks hinges on the well-being of the urban poor. If this group can successfully adapt to new challenges, then Asia's overall urbanization experience is more likely to yield long-term economic growth and improvements in living standards.

II. The Urban Disaster Scenario

The Intergovernmental Panel on Climate Change continually updates its geographic threat maps by highlighting what challenges each continent is likely to face because of climate change.³ The extent of these challenges hinges on the relationship between the global concentration of ambient carbon dioxide and global temperatures (Weitzman 2009). While there is considerable uncertainty about these equations, research highlights that almost all models predict that parts of Asia will face extreme heat and greater risk of natural disasters and drought (Pillai et al. 2010; Westphal, Hughes, and Brömmelhörster 2015).

As reported in Revi (2008), some climate models predict that India's mean surface temperature will rise between 3.5 and 5 degrees Celsius and that mean annual precipitation will increase between 7% and 20%. This will be accompanied by an increase in monsoon precipitation and a decline in precipitation in drought-prone central India.

As climate change intensifies the volatility and impacts of these shocks, how will poor Asians cope? Poor urbanites will face higher food prices and increased risk of morbidity and mortality from extreme heat and natural disaster risk (Banks, Roy, and Hulme 2011). Both rural and urban productivity will decline, especially for those activities that take place outside of an air-conditioned environment.

III. Rural Migration to the Cities

Hundreds of millions of people live and work on farms in Asia. Worsening episodes of drought and extreme heat will lower farmers' earnings and could even increase the likelihood of violence. Burke et al. (2009) argue that climate change-induced summer heat will increase the risk of civil war in the sub-Saharan countryside. This prediction is based on estimating cross-county regressions using data for 1960–1995 in which they study the correlates of whether a country has had a civil war. They find that the probability of a civil war is higher in sub-Saharan countries when summer temperatures are warmer. One possible explanation for this finding is that as water becomes more scarce, livestock becomes threatened and nomadic people cross spatial boundaries in search of increasingly scarce inputs. In this case, the tragedy-of-the-commons logic predicts that violence is more likely to emerge. Whether rural violence is also exacerbated by extreme weather conditions in Asia remains an open question.

Agricultural research in Asia has measured the costs to farmers of prolonged drought. Chen, Wang, and Huang (2014) survey farmers in the People's Republic of China and find that many are taking proactive steps to protect themselves against drought. Specific strategies include changing agricultural production

³See https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

inputs and adjusting seeding or harvesting dates. In the Philippines, farmers are adapting through spatial diversification of fields and crops, varietal diversification, sharecropping (as opposed to fixed rental contracts), crop insurance, and weather insurance.

Income differentials between urbanites and inhabitants of rural areas create an incentive to urbanize.⁴ Climate change is likely to increase this urban premium. Based on data from Africa, Barrios, Bertinelli, and Strobl (2006) document the negative correlation between rainfall and urbanization. Some rural people may not be able to finance the fixed costs of moving. One field experiment in Bangladesh demonstrated that by providing subsidized transportation, rural families sent workers to the city to earn money that was remitted back to these families during the monsoon season (Bryan, Chowdury, and Mobarak 2014). This research has direct implications for climate change adaptation measures because it suggests that financing constraints are slowing down urbanization in Asia. If these constraints can be relaxed (either through small loans from villagers or through microfinance lending), then urban migration flows will accelerate. Household members who move to the cities will remit income back to the countryside, which will help protect farmers from income volatility associated with climate change (Townsend 1995). As farmers urbanize, total domestic farm production declines. In countries that have enacted domestic trade barriers to the international agricultural trade, urban food prices have risen (Glaeser 2014). The resultant higher prices also slow down the rate of rural-to-urban migration.

New migrants to a city have no incentive to internalize how their choices affect the city, but each has an incentive to consider what his wages, rent, employment opportunities, and quality of life will be like in each city. In Asian countries such as Bangladesh, Cambodia, and Thailand, a large share of the urban population lives in the largest cities. As discussed in Ades and Glaeser (1995), in South America the capital city is home to a large share of a country's urban population. If the central government offers special transfers to the capital city's residents, it creates an implicit subsidy to live in the megacity. Future research could explore how migration rates to the country's largest city are affected by political regimes and local fiscal generosity.

Past research has discussed the challenges of megacity growth in least developed countries (Henderson 2002, Hardoy and Satterwhaite 2014). For example, population growth increases population density in poorer areas of a city and economic history research has documented the positive correlation between infectious disease rates and local population density (Costa and Kahn 2015). Whether this correlation has been mitigated in today's poor urban areas in Asia

⁴Nguyen, Raabe, and Grote (2015) use panel data for 2,200 households from rural Viet Nam covering the period 2007–2010 and a tracking survey of 299 migrants from 2010. They find that employment-related migration is a livelihood support strategy for households exposed to agricultural and economic shocks.

remains an open question. Working with the authorities and civil society in poor Asian cities to estimate the correlation between urban density and local death rates over time would be a useful area of further study. Costa and Kahn (forthcoming) present data from the early 20th century in the United States (US) to document how urban sewer infrastructure investments attenuated this social cost of population density. Given that development institutions such as the Asian Development Bank (ADB) finance major urban infrastructure projects, reductions in urban death rates from infectious diseases offer an important outcome variable for measuring the social benefits of urban development projects.

If sanitary conditions suffer due to rising population density, it has direct implications for child mortality and child development in poor urban areas. In such a setting, there is greater risk of cholera epidemics quickly spreading (Albert et al. 1993). Islam and Azad (2008) argue that the urban–rural differential in childhood mortality rates has diminished in Bangladesh because of the reduced quality of life in urban slums. Their study demonstrates that housing conditions and access to safe drinking water and hygienic toilet facilities are the most important determinants of child survival in urban areas. Research on human capital acquisition and early health emphasizes the long-term consequences of early-life pollution exposure. Spears and Lamba (2016) document the effects on childhood cognitive achievement of early-life exposure to India’s Total Sanitation Campaign, which encouraged local governments to build and promote the use of inexpensive pit latrines. They find that the campaign led to 6-year olds who were exposed to messaging during their first year being more likely to recognize letters and simple numbers.

The inability to deliver clean water to poor people is partially a function of the actions of governments and individuals. Ashraf, Glaeser, and Ponzetto (2016) conclude that poorer Zambians choose not to pay for a connection to water and sewage systems since the government is unwilling to provide the subsidies needed to ensure universal connection to the system. They argue that there is a “last mile” externality problem of how to connect more households to water and sewage systems. The water pollution externality festers in this setting and children’s health is put at risk. Field experiments could test whether different subsidies to households for connecting to water and sewage systems induces them to change their behavior.

In many Asian countries, the urban poor live on land that they do not own. In Bangladesh, a large percentage of Dhaka’s residents live in informal settlements and face tenure insecurity since they live on government and private land (Ahmed 2007). This is a primary reason for the lack of government and donor fund allocations for communities living in these settlements. Evictions are common in this environment. If climate change accelerates urbanization, then it is likely that even more people will live illegally in such areas. Governments will face the question of whether they give ownership of land to informal settlers or continue to try and clear the land.

The decisions that governments make matter both in terms of income effects and with respect to the basic investments made by the people who live in these

areas. If informal settlers expect that they will have long-term property rights to the area where they live, then they will invest in improving it because they would be the residual claimants on any such improvements (Field 2005).

The absence of interventions to improve living conditions in slums will negatively affect children growing up in these neighborhoods. In the US, Chetty, Hendren, and Katz (2016) have documented the important long-term impacts on children of growing up in neighborhoods with higher quality of life indicators by assessing the results of the Move to Opportunity program. An extension of this research would be to implement similar Move to Opportunity experiments in Asia's slums to test how the role of location matters for children's human capital and health development. The key to such a research design is to randomly assign households to treatment and control groups, and to collect longitudinal data for both groups. Those in the treatment group would receive a voucher to pay for housing that would require them to move to a neighborhood with better quality of life indicators.

IV. Urban Income and Productivity

Climate change will increase the quantity and severity of heat waves in Asia. A new literature is emerging on the effects of heat on worker productivity (Heal and Park 2015). Those who work in nonair-conditioned buildings will face the greatest exposure from rising average temperatures. Poor people face challenges that richer people working and shopping in newer office buildings and malls do not face. Davis and Gertler (2015) have documented the increased global demand for air-conditioning, yet poor people still face budget challenges in buying and operating them.

A promising research topic in the new empirical microeconomic research studying how the productivity of different firms in different industries in Asia is affected by extreme heat. Graff-Zivin and Kahn (2016) present a heterogeneous firm model. Each firm within an industry has its own exogenous productivity parameter. There is a fixed cost to adopting air-conditioning and an additional operating cost for running it. Graff-Zivin and Kahn (2016) show that the most productive firms will adopt air-conditioning and insulate their workers from heat. Since these more productive firms produce the bulk of an industry's output, such optimal behavior insulates the economy. However, employees of the less productive firms are less likely to enjoy the amenity and productivity benefits of air-conditioning. This set of results merits testing using geocoded microdata on the productivity of Asian manufacturing firms over time.

A second urban productivity dimension was pointed out by Henderson, Storeygard, and Deichmann (2017) in their study on Africa. Among urbanites in African cities are middle men who collect agricultural output in one region and ship

it to another region. Therefore, the productivity of many African cities is positively correlated with nearby agricultural productivity. Such agricultural cities will suffer a recession if climate change reduces nearby farming output. To what extent many of Asia's cities fall into this same category remains an open question. Asia's cities will play a more important role in shielding poor people from income losses due to climate change shocks if the productivity of a city's industries is not positively correlated with income in the countryside.

V. Increased Natural Disaster Risk

The EM-DAT database provides information on long-term trends in deaths from natural disasters in Asia.⁵ During 1970–2016, roughly 20,000 people died in Asia on average in natural disasters each year. There were major natural disasters in 1970, 1976, 1991, 2004, and 2008. In the deadliest year, 1970, about 320,000 people died. Despite these peaks, there is not a clear upward trend in disaster deaths over this 46-year period. During a time of rapid population and per capita income growth, Asia has both grown richer and become more resilient in the face of natural disasters (Kahn 2005).

Between 1990 and 2007, 682 natural disasters occurred in South Asia, killing an estimated 400,000 people and affecting many more while causing severe economic damage. India, Bangladesh, and Afghanistan were the most affected countries in South Asia in terms of number of events. Bangladesh, India, and Pakistan suffered the most fatalities (Heltberg 2007).

Starting with the work of Kellenberg and Mobarak (2008), a recent literature has emerged arguing that natural disaster death counts are highest in poor countries that are urbanizing rather than in the poorest agricultural countries. The most vulnerable countries are those that are urbanizing but not rich enough to protect themselves through higher-quality infrastructure and housing. Rural areas are poor but spread out and thus diversified against spatial shocks. In contrast, poor cities are undiversified and can suffer greatly from natural disasters. Padli and Habibullah (2009) present additional evidence of the relationship between losses caused by natural disasters and economic development.

Coastal areas offer great amenity value. If richer people cluster in such areas, then the rich trade off living in a risky but beautiful place while being able to invest in self-protection technologies such as sturdy housing. Research based on data from India highlights that the most vulnerable people in the face of natural disasters are residents of slums and informal settlements who are often located in the most vulnerable locations (Revi 2008).

⁵See <http://www.emdat.be/>

Recent research using Google Images highlights how new big data techniques can be applied to Asia's cities to study the resilience of different places in the face of natural disasters. Naik et al. (2015) document that information embedded in Google Images proxies well for a location's income. This suggests that, even in the absence of local survey data, researchers can use these same techniques to analyze images of the same geographic area before and after natural disasters to provide a quantifiable measure of the extent of the damage and of rebuilding efforts. In this sense, big data offers a new low-cost strategy for collecting targeted data on who bears the costs of natural disasters. Another study by Masuya, Dewan, and Corner (2015) took an inventory of all buildings in Dhaka and combined this information with basic topography to identify the subset of buildings that face less flood risk. This subset of buildings offers potential safe havens for local residents during times of heavy floods. Such information is crucial in assessing a city's resilience and planning for how to adapt to disasters.

Finally, if climate change causes heat waves and drought, this will increase the likelihood of severe fires in the countryside. Much of Singapore's air pollution is caused by fires in Indonesia. Such cross-boundary pollution represents a classic externality. Whether neighboring Asian countries will increase their cooperation to find solutions to reduce the likelihood of these events remains an important policy issue and research topic. One might argue that the richer downwind victims can pay the upstream polluter money to encourage pollution mitigation steps. Whether transaction costs limit these gains to trade remains an open question that will become more important as climate change increases the quantity and severity of these fires.

VI. Government Investment in Adaptation and Population Protection

As poor people face increased risk from climate shocks, will local governments increase their efforts to supply public goods such as reliable water and electricity, and safe infrastructure? For Asia's poorest countries, there are several related questions concerning governance. First, do some mayors worry that a consequence of protecting poor neighborhoods is that even more poor people will move to the area? Feler and Henderson (2011) observed that mayors of some Brazilian cities choose not to connect housing in poor areas to the water system because they anticipate that such connections would accelerate the migration of the poor to these areas.⁶ Also, can cities finance such investments?

⁶Revi (2008) argues that the Government of India and the country's elite have been ambivalent about accepting the centrality of the poor in the process of urban development and economic growth as the imperative of delivering adequate services (water, sanitation, solid waste, drainage, power) and equitable access to land and housing to the bulk of city residents is still a matter of contention.

VII. Macro-Quantitative Predictions of Expected Damage from Climate Change

The previous section highlighted several microeconomic scenarios focused on how climate change impacts an economy. Facing data limitations, much of the climate economics literature works with country-level panel data.

Lee, Villaruel, and Gaspar (2016) estimate large negative effects for climate change-induced higher temperatures on Asia's future economic growth. These results build on the findings of Burke, Hsiang, and Miguel (2015), who estimate a version of the following equation:

$$GNP\ Growth_{jt} = B_1 * Climate_{jt} + B_2 * X_{jt} + U_{jt} \quad (1)$$

Using data for 168 countries for 1960–2014, Lee, Villaruel, and Gaspar (2016) posit that if the world warms by 3.9 degrees Celsius by the year 2100 then, based on the estimate of equation (1), this will lead to per capita income losses as high as 10% for countries in developing Asia, with India and Indonesia's losses predicted to be larger than the losses for the rest of the region. Such country-specific predictions are very useful because they highlight the possible impacts of continuing under a business-as-usual scenario. With regard to climate change mitigation investments, the marginal benefits will likely be greatest in countries where the loss of life and economic opportunity is expected to be most impacted by climate change.

VIII. Pathways to Lower Cost Adaptation

An optimist can point to Singapore and the US as offering different pathways through which urbanized countries of vastly different size can adapt to the climate change challenges enumerated above. Richer Asian cities such as Singapore have an edge in adapting because of their widespread adoption of air-conditioning and their ability to finance expensive engineering strategies such as importing sand and elevating flood-prone structures. Those cities that can maintain and improve the quality of life during a time of increased risk will attract more jobs and develop higher levels of human capital.

The Menu of Cities

In the spatial economics literature, cities differ with respect to their locational characteristics. Some cities feature cold winters, while others feature mountains. Real estate prices and rents adjust across cities so that those with better quality of life have higher rents and lower wages as compensation differential for living there (Rosen 2002). Climate change affects a city's attributes. For example, a city that has enjoyed a temperate summer climate may now be much warmer during summer

months. In the typical urban economics model, a city's attributes are all common knowledge. When considering the urban consequences of climate change, a city's future attributes should be thought of as a random vector. For example, we do not know exactly what challenges Singapore will face in the year 2025 resulting from higher temperatures and/or rising sea levels. We can form expectations of these random variables, but we know that we do not know these future outcomes.

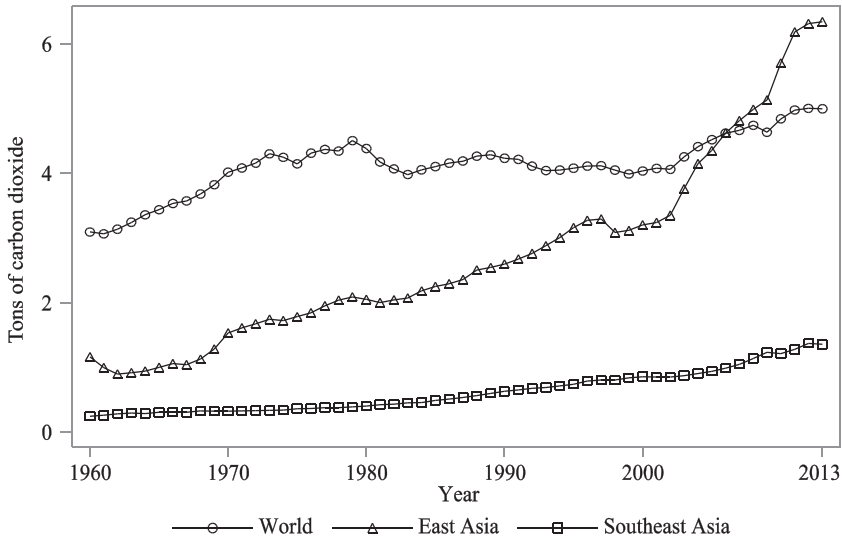
Facing uncertainty about how the quality of life will evolve in different cities, the theory of option value suggests it is important that Asia's urban poor have as many possible destinations to move as possible. Such a menu of cities protects individuals and creates competition. Every city and country features locations of "higher ground" that are ostensibly more protected from the impacts of climate change. Advances in spatial mapping software can pinpoint such areas. If cities change their land use patterns to allow for higher densities in such areas, then adaptation is promoted.

In countries with dozens of cities, the potential to migrate to another city creates an insurance policy protecting mobile urbanites from location-specific shocks. Owners of real estate in these shocked cities would therefore be affected. Those cities whose quality of life suffers due to some combination of heat waves and rising sea levels will experience falling real estate prices and outward migration. Anticipating this Ricardian effect provides incentives for local authorities to invest in resilience protection in their area.

The US features hundreds of geographically spread-out cities. Within such a system of cities, people and firms can "vote with their feet" by moving to a new location. This competition to attract and retain skilled workers provides local leaders and land owners with an incentive to be proactive in protecting their city from emerging threats. Fuller and Romer (2014, 11) write about replacing the Millennium Development Goals: "Perhaps we could replace [them] with a single goal: every family can choose from several cities that compete to attract them as permanent residents." This quote highlights a testable Tiebout hypothesis. The ability to move helps a population adapt by providing a menu of substitution possibilities. Is it the case that adaptation costs are lower in Asian countries that feature more cities to choose from?

Development institutions can play a key role in helping countries identify the geographic areas facing the least objective risk from climate change. These will be geographic areas featuring higher ground, cooler climates, and less flood risk. A benevolent planner would allow greater housing density in these areas because they have an adaptation edge. The housing supply literature in both India and the US have highlighted the role that land use regulations play in limiting new development (Glaeser, Gyourko, and Saks 2005; Bertaud and Brueckner 2005). New research on the unintended consequences of land use regulations that inhibit climate change adaptation would be very valuable.

Figure 1. Per Capita Carbon Dioxide Emissions



Source: World Bank. World Development Indicators. <http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators>

IX. Economic Development as an Adaptation Strategy

Economic development is a primary strategy for adapting to climate change and urbanization fuels economic development. While economic development is associated with rising greenhouse gas emissions (Figure 1), in the absence of a global tax on the pollution externality, each country’s best response to adapt to the challenges of climate change is to accelerate its own economic growth. A richer country has more resources for individuals to self-protect and for the government to provide public goods. The urban population will also increasingly demand air-conditioning to offset exposure to extreme heat. Over the course of the 20th century, people in the US enjoyed a sharply reduced rate of deaths caused by extreme heat because of the increased adoption of air-conditioning (Barreca et al. 2016). In the developing world in the 21st century, the demand for air-conditioning is soaring (Davis and Gertler 2015). If the electricity used to operate these air conditioners is generated by fossil fuels, the increased demand will contribute to carbon emissions and the associated adaptation challenges, though researchers are not in agreement as to the magnitude of this effect.

The entire world faces adaptation challenges, which is fueling adaptation innovation. Just as Acemoglu and Linn (2004) argued that the expanding market power of an aging baby boomer generation created incentives for drug companies to target innovation for this cohort. Therefore, firms can also be expected to target

innovation to help produce climate change adaptation products. Furthermore, a growing share of Asian urbanites will be able to afford them.⁷ In this sense, a richer Asia fuels greater adaptation through private goods such as more energy-efficient air-conditioning.

Given that climate change is likely to increase the incidence and risk of flooding, Asia's urbanites will demand higher-quality housing. Richer people have greater access to safer housing in better locations, healthier food, transportation, and good hospitals. Such quality-of-life investments pay off in terms of survival. As discussed above, Google Images can be used to see if a city's resilience in the face of natural disasters is increasing as it grows richer over time.

Furthermore, ADB could create new household-level consumption databases that resemble the World Bank's Living Standards Measurement Survey. ADB has conducted its own Living Standards Measurement Survey in Bhutan.⁸ Such a survey could be used to measure household durable goods ownership, such as air-conditioning and refrigeration, and its electricity consumption. Ideally, such data would include retrospective measures of household illness over the previous year.

Economic development and human capital acquisition go hand in hand. Forward-looking farmers will recognize that their children will likely need to urbanize. Becker and Lewis' (1974) theory of fertility predicts that households expecting to urbanize will have fewer children and invest more in human capital. Shah and Steinberg (2013) document that, based on an opportunity cost argument, a positive outcome of weather shocks is greater household-level educational investment. If children cannot work in farming due to severe weather or pollution, then it is cheaper for them to go to school. This effect will be amplified if the parents expect that the children will move to a city that features a higher return to cognitive skills. Embedding climate change into a Roy model of educational choice and sectoral choice is a promising future research topic.

Anticipating the unintended consequences of location-based investments is also necessary. Many infrastructure investments attract individuals to live in certain geographic locations. For example, an investment in a dam can encourage more people to live in a flood plain. Such public investment in infrastructure can crowd out private self-protection measures as individuals move to places that are increasingly at risk due to climate change. Boustan, Kahn, and Rhode (2012) study this phenomenon in the US. Whether infrastructure investments have had this effect in Asia is another promising research topic. Put simply, many public investments are meant to stimulate local economic growth, but do such investments encourage people to live in objectively riskier areas? Does public investment crowd out private self-protection?

⁷See <http://www.scidev.net/global/disasters/news/amphibious-houses-float-out-of-trouble-in-bangladesh.html>

⁸See <https://www.adb.org/publications/bhutan-living-standards-survey-2012>

X. The Smartphone Era

Many Asian urbanites have cell phones and therefore real-time access to information about emerging threats. The Indian Ocean tsunami of 2004 would have caused fewer deaths if cell phone penetration had been as high as it is today.⁹ Jensen (2007) offers an optimistic vision for the role that information technology plays in spreading real-time information. Cell phone technology allows for both the diffusion of information and for big data firms to quickly accumulate information. Asian governments can work with these firms to understand more about the geographic distribution of the population. Research analyzing the content of social media tweets can also reveal real-time information about the concerns of the public (Baylis 2015).

XI. Urban Political Economy of Adaptation

Given that climate change directly impacts city quality of life, one surprising fact is that many leaders from around the world appear to devote more effort to seeing their city become a low-carbon city rather than a resilient city. To an economist, greater effort being devoted to mitigation rather than adaptation is surprising. With the former, there is a free-rider problem. Each city only contributes a small amount of the world's total emissions; even if a city's emissions are reduced to zero, its efforts will make no real difference in mitigating climate change. Therefore, self-interest should drive adaptation efforts. Climate change can be perceived as a medium-term threat that will intensify after today's leaders are no longer in power. It remains an open question whether elected officials are rewarded for tackling medium-term challenges. If real estate markets are forward looking, then current prices should reflect future threats. If a city develops a reputation for having a declining quality of life, then it will have more trouble attracting and retaining skilled workers. The threat of a brain drain (and lost tourism receipts) should incentivize local leaders to act.

Local leaders are more likely to pursue the adaptation agenda if key voting blocs support action on these issues. Research documenting the positive correlation between education and the quality of governance suggests that as educational attainment rises in Asia's cities government will increasingly seek to deliver on public goods (La Porta et al. 1999; Botero, Ponce, and Shleifer 2012). One microfoundation for this finding is presented by Besley and Burgess (2002) based on their work in India. They argue that in Indian states with higher rates of literacy the local news does a better job investigating officials, who are more likely to deliver public goods since the principal-agent problem is attenuated.

⁹See <http://www.scidev.net/asia-pacific/disasters/opinion/how-the-2004-tsunami-is-changing-disaster-response.html>

If good governance and education go hand in hand, then this highlights another payoff from human capital investments. Banerjee et al. (2011) provide additional evidence by conducting field experiments on officials' accountability and voter behavior in India. They find that "[v]oters demonstrated sophistication in how they use report card information to judge performance and qualifications—they used their knowledge on incidence of public good spending in slums to evaluate jurisdiction-level information on public good spending by the incumbent and used challenger qualifications as a yardstick to judge incumbent qualifications" (Banerjee et al. 2011, 3).

Financing climate resilience investments will continue to be a major issue in Asia. Cutler and Miller (2006) provide an optimistic example from the US. In the 1920s, American cities faced major infectious disease risk because of polluted water. They document that when American cities could issue municipal bonds, that access to capital allowed them to construct water treatment facilities that sharply improved the local quality of life by lowering the infectious disease rate. Development institutions can play a key role in helping cities issue municipal bonds by providing default guarantees. Field experiments could be run in which the interest rate that cities can borrow at is changed at random to estimate a mayor's demand for climate-resilient infrastructure.

Urban areas provide basic public goods such as water and electricity. Climate change may make both increasingly scarce. Standard economic logic argues that prices for publicly provided goods such as water and electricity should reflect scarcity. If climate change induces droughts and heat waves, then prices for water and electricity should rise as these public goods become more scarce. Politicians often limit such pricing flexibility in an attempt to protect the poor. Evidence from the US documents that residential electricity consumers respond to critical peak pricing by reducing their consumption (Wolak 2011). If Asia's water and electricity utilities are willing to allow the price of water and electricity to reflect scarcity, it would help these cities adapt by encouraging the adoption of more energy- and water-efficient appliances and practices. The benefit of introducing such dynamic pricing is that fewer power blackouts would occur in summer and scarce water resources would be more efficiently allocated. Development institutions could use incentives to encourage cities to pilot dynamic pricing and income transfer programs so that they can afford their old energy and water bundles at new prices.

Macro Evidence of Adaptation

What will be the evidence supporting either the pessimistic or the optimistic view that adaptation progress is taking place? Consider a new version of equation (1) in which the effects of climate on economic growth vary over time. If extreme heat had a large negative effect on growth in the past but this effect is shrinking toward zero over time, then there is evidence of adaptation. In addition to studying

economic growth dynamics, researchers can study other macro indicators such as annual death tolls from natural disasters. In this case, the key explanatory variable would be the quantity and severity of disasters suffered by a country each year. The adaptation test would be whether the death toll from a disaster of the same type and intensity is shrinking over time.

If a population can self-protect from emerging threats using affordable technologies and real-time information, and if local governments can do a better job protecting urban residents from risk, then the historical relationship between risk and negative outcomes can be attenuated. This is a new version of the “Lucas critique,” which argues that as governments change the rules of the game, economic agents reoptimize and past relationships between consumption and income no longer hold (Lucas 1976). In the case of climate adaptation, Mother Nature changes the rules of the game and economic actors change their decision making to reduce their risk exposure. Forward-looking households and firms should be making investments to become more nimble in the face of increased exposure to heat, drought, and climate volatility. The net effect should be that B_1 in equation (1) shrinks toward zero over time.

The Need for More Microdata

To rigorously test the claim that Asia’s poor are increasingly able to adapt to climate change requires new longitudinal data that track a large number of people and their well-being over time. Such geocoded data will allow a test to see how extreme heat, pollution, and natural disasters affect different socioeconomic groups in different countries. Key outcome indicators such as weight, well-being, morbidity, and mortality can be tracked over time.

As new data on urbanites is needed, Google Earth and other remote sensing technologies can be used to understand how physical places are evolving over time. Where are new structures in a city being built? How tall are they? When natural disasters occur, how damaged are they?

In this age of big data, it is possible to fine-tune investments based on local data to better focus on areas that are at greater risk. In Chicago, the local government has been working with engineers and data scientists to install 500 information-gathering nodes throughout the city. By measuring data on air quality, climate, and traffic, this sensor network will provide useful real-time information. The city will post the data in an open format to allow concerned citizens, the media, and researchers to have real-time access.¹⁰ Such information holds urban leaders accountable if clear evidence emerges that certain neighborhoods and groups of

¹⁰See <https://ci.uchicago.edu/press-releases/chicago-becomes-first-city-launch-array-things>

citizens are suffering significant reductions in their quality of life due to climate change.¹¹

Even if poor Asian governments do not have the capacity to collect data, social media companies such as Facebook, Google, and Twitter can track such data. As discussed above, Google Images offers an easy tracking tool to judge whether areas quickly recover after disasters. From an adaptation perspective, a key question is to study whether current efforts incorporate more resilient capital so that the next shock will cause less damage. Such data would allow for a test of whether location-based shocks are having smaller impacts on the quality of life over time.

XII. Conclusions

Climate change can have enormous social costs for poor Asian cities. This paper has adopted a microeconomic perspective to investigate the mechanisms at play. The megacity nightmare is congestion, pollution, poverty, and infectious disease. This paper has investigated how climate change is likely to affect each of these. The economic approach to studying climate change adaptation recasts individuals and firms as forward looking, optimizing agents who seek to achieve their goals in the face of new threats. In this setting, climate change has direct effects on the quality of life, the labor supply, locational choice, and household demand for self-protection products. Unfortunately, the poor have the fewest affordable options.

Throughout this paper, many research designs have been discussed that could inform policy making in the context of Asian climate change adaptation. A major role of economic research in this context is to identify cost-effective strategies for improving the quality of life of the poor.

This paper has focused on Asian cities' adaptation prospects. I have not discussed the carbon footprint of individual cities. (For an example of such benchmarking in the People's Republic of China, see Glaeser and Kahn 2010.) Many of the world's major cities are seeking to demonstrate that they are low-carbon cities as they promote green technology, public transit, and power generated by renewables.

The carbon footprint benchmarking literature raises the question of how to create an analogous adaptation index to identify which cities are the best at adapting. One metric would be to compare natural disaster death rates across cities. Another metric could be resilience: what is the loss in a city's capital stock when a major shock occurs? Development institutions can play a beneficial role in benchmarking these outcomes to allow for cross-city comparisons and for time series comparisons for an individual city.

¹¹See <http://www1.nyc.gov/311/about-311.page> and <http://www1.nyc.gov/311/about-311.page>

References*

- Acemoglu, Daron, and Joshua Linn. 2004. "Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry." *Quarterly Journal of Economics* 119 (3): 1049–90.
- Ades, Alberto F., and Edward L. Glaeser. 1995. "Trade and Circuses: Explaining Urban Giants." *Quarterly Journal of Economics* 110 (1): 195–227.
- Ahmed, K. Iftekhar. 2007. "Urban Poor Housing in Bangladesh and the Potential Role of ACHR." Bangkok: Asian Coalition for Housing Rights.
- Albert, Manuel John, Mohammed Ansaruzzaman, Pradip Kumar Bardhan, Abu Syed Faruque, Shah Mohamed Faruque, Mohammad Islam, Dilip Mahalanabis, R. Bradley Sack, M. Abdus Salam, Abul Kasem Siddique, Mohammad Yunus, and Khalequ Zaman. 1993. "Large Epidemic of Cholera-Like Disease in Bangladesh Caused by *Vibrio Cholerae* 0139 Synonym Bengal." *The Lancet* 342 (8868): 387–90.
- Ashraf, Nava, Edward L. Glaeser, and Giacomo A. M. Ponzetto. 2016. "Infrastructure and Development Infrastructure, Incentives, and Institutions." *The American Economic Review* 106 (5): 77–82.
- Banerjee, Abhijit V., Selvan Kumar, Rhojini Pande, and Felix Su. 2011. "Do Informed Voters Make Better Choices? Experimental Evidence from Urban India." Unpublished.
- Banks, Nicola, Manoj Roy, and David Hulme. 2011. "Neglecting the Urban Poor in Bangladesh: Research, Policy, and Action in the Context of Climate Change." *Environment and Urbanization* 23 (2): 487–502.
- Barrios, Salvador, Luisito Bertinelli, and Eric Strobl. 2006. "Climatic Change and Rural–Urban Migration: The Case of Sub-Saharan Africa." *Journal of Urban Economics* 60 (3): 357–71.
- Barreca, Alan, Karen Clay, Olivier Deschenes, Michael Greenstone, and Joseph S. Shapiro. 2016. "Adapting to Climate Change: The Remarkable Decline in the US Temperature–Mortality Relationship over the 20th Century." *Journal of Political Economy* 124 (1): 105–59.
- Baylis, Patrick. 2015. "Temperature and Temperament: Evidence from a Billion Tweets." Energy Institute at Haas Working Paper.
- Becker, Gary S., and H. Gregg Lewis. 1974. "On the Interaction between Quantity and Quality of Children." *Journal of Political Economy* 81 (2): S279–S288.
- Bertaud, Alain, and Jan K. Brueckner. 2005. "Analyzing Building-Height Restrictions: Predicted Impacts and Welfare Costs." *Regional Science and Urban Economics* 35 (2): 109–25.
- Besley, Timothy, and Robin Burgess. 2002. "The Political Economy of Government Responsiveness: Theory and Evidence from India." *The Quarterly Journal of Economics* 117 (4): 1415–51.
- Botero, Juan, Alejandro Ponce, and Andrei Shleifer. 2012. "Education and the Quality of Government." NBER Working Paper No. 18119.
- Boustan, Leah Platt, Matthew E. Kahn, and Paul W. Rhode. 2012. "Moving to Higher Ground: Migration Response to Natural Disasters in the Early Twentieth Century." *The American Economic Review* 102 (3): 23–44.
- Bryan, Gharad, Shyamal Chowdhury, and Ahmed Mushfiq Mobarak. 2014. "Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh." *Econometrica* 82 (5): 1671–748.

*The Asian Development Bank recognizes "China" as the People's Republic of China and "Vietnam" as Viet Nam."

- Burke, Marshall, Solomon M. Hsiang, and Edward Miguel. 2015. "Global Non-Linear Effect of Temperature on Economic Production." *Nature* 527 (7577): 235–39.
- Burke, Marshall B., Edward Miguel, Shanker Satyanath, John A. Dykema, and David B. Lobell. 2009. "Warming Increases the Risk of Civil War in Africa." *Proceedings of the National Academy of Sciences* 106 (49): 20670–74.
- Chen, Huang, Jinxia Wang, and Jikun Huang. 2014. "Policy Support, Social Capital, and Farmers' Adaptation to Drought in China." *Global Environmental Change* 24: 193–202.
- Chetty, Raj, Nathaniel Hendren, and Lawrence F. Katz. 2016. "The Effects of Exposure to Better Neighborhoods on Children: New Evidence from the Moving to Opportunity Experiment." *The American Economic Review* 106 (4): 855–902.
- Costa, Dora L., and Matthew E. Kahn. 2015. "Declining Mortality Inequality within Cities during the Health Transition." *The American Economic Review* 105 (5): 564–69.
- _____. Forthcoming. "Death and the Media: Asymmetries in Infectious Disease Reporting during the Health Transition." *Economica*.
- Cutler, David M., and Grant Miller. 2006. "Water, Water Everywhere: Municipal Finance and Water Supply in American Cities." In *Corruption and Reform: Lessons from America's Economic History*, 153–84. Chicago: University of Chicago Press.
- Davis, Lucas W., and Paul J. Gertler. 2015. "Contribution of Air Conditioning Adoption to Future Energy Use under Global Warming." *Proceedings of the National Academy of Sciences* 112 (19): 5962–67.
- Feler, Leo, and J. Vernon Henderson. 2011. "Exclusionary Policies in Urban Development: Under-Servicing Migrant Households in Brazilian Cities." *Journal of Urban Economics* 69 (3): 253–72.
- Field, Erica. 2005. "Property Rights and Investment in Urban Slums." *Journal of the European Economic Association* 3 (2–3): 279–90.
- Fuller, Brandon, and Paul Romer. 2014. "Urbanization as Opportunity." World Bank Policy Research Working Paper 6874.
- Glaeser, Edward L. 1998. "Are Cities Dying?" *The Journal of Economic Perspectives* 12 (2): 139–60.
- _____. 2014. "A World of Cities: The Causes and Consequences of Urbanization in Poorer Countries." *Journal of the European Economic Association* 12 (5): 1154–99.
- Glaeser Edward L., and Matthew E. Kahn. 2010. "The Greenness of Cities: Carbon Dioxide Emissions and Urban Development." *Journal of Urban Economics* 67 (3): 404–18.
- Glaeser, Edward L., Joseph Gyourko, and Raven Saks. 2005. "Why is Manhattan So Expensive? Regulation and the Rise in Housing Prices." *Journal of Law and Economics* 48 (2): 331–69.
- Graff-Zivin, Joshua, and Matthew E. Kahn. 2016. "Industrial Productivity in a Hotter World: The Aggregate Implications of Heterogeneous Firm Investment in Air Conditioning." NBER Working Paper No. 22962.
- Hardoy, Jorge E., and David Satterthwaite. 2014. "Environmental Problems of Third World Cities: A Global Issue Ignored?" In *Cities of the Global South Reader*, edited by Faranak Miraftab and Neema Kudva, 155–59. Routledge.
- Heal, Geoffrey, and Jisung Park. 2015. "Goldilocks Economies? Temperature Stress and the Direct Impacts of Climate Change." NBER Working Paper No. 21119.
- Heltberg, Rasmus. 2007. "Helping South Asia Cope Better with Natural Disasters: The Role of Social Protection." *Development Policy Review* 25 (6): 681–98.
- Henderson, J. Vernon. 2002. "Urban Primacy, External Costs, and Quality of Life." *Resource and Energy Economics* 24 (1–2): 95–106.

- Henderson, J. Vernon, Adam Storeygard, and Uwe Deichmann. 2017. "Has Climate Change Driven Urbanization in Africa." *Journal of Development Economics* 124: 60–82.
- Islam, M. Mazharul, and Kazi Azad. 2008. "Rural–Urban Migration and Child Survival in Urban Bangladesh: Are the Urban Migrants and Poor Disadvantaged?" *Journal of Biosocial Science* 40 (1): 83–96.
- Jensen, Robert. 2007. "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector." *The Quarterly Journal of Economics* 122 (3): 879–924.
- Jones, Charles I., and Peter J. Klenow. 2016. "Beyond GDP? Welfare across Countries and Time." *American Economic Review* 106 (9): 2426–57.
- Kahn, Matthew E. 2005. "The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions." *Review of Economics and Statistics* 87 (2): 271–84.
- Kellenberg, Derek, and Ahmed Mobarak. 2008. "Does Rising Income Increase or Decrease Damage Risk from Natural Disasters?" *Journal of Urban Economics* 63 (3): 788–802.
- La Porta, Rafael, Florencio Lopez de Silanes, Andrei Shleifer, and Robert Vishny. 1999. "The Quality of Government." *Journal of Law, Economics, and Organization* 15 (1): 222–79.
- Lee, Minsoo, Mai Lin Villaruel, and Raymond Gaspar. 2016. "Effects of Temperature Shocks on Economic Growth and Welfare in Asia." ADB Economics Working Paper Series No. 501.
- Lucas, Robert E. 1976. "Econometric Policy Evaluation: A Critique." In *Carnegie-Rochester Conference Series on Public Policy Volume 1*, 19–46. Amsterdam: North-Holland.
- Masuya, Akiko, Ashraf Dewan, and Robert J. Corner. 2015. "Population Evacuation: Evaluating Spatial Distribution of Flood Shelters and Vulnerable Residential Units in Dhaka with Geographic Information Systems." *Natural Hazards* 78 (3): 1859–82.
- Naik, Nikhil, Scott D. Kominers, Ramesh Raskar, Edward L. Glaeser, and Cesar A. Hidalgo. 2015. "Do People Shape Cities or Do Cities Shape People? The Co-Evolution of Physical, Social, and Economic Change in Five Major US Cities." NBER Working Paper No. 21620.
- Nguyen, Loc Duc, Katharina Raabe, and Ulrike Grote. 2015. "Rural–Urban Migration, Household Vulnerability, and Welfare in Vietnam." *World Development* 31 (71): 79–93.
- Padli, Jaharudin, and Muzafar Shah Habibullah. 2009. "Natural Disaster Death and Socioeconomic Factors in Selected Asian Countries: A Panel Analysis." *Asian Social Science* 5 (4): 65–71.
- Pillai, Poonam, Bradford Ryan Philips, Priya Shyamsundar, Kazi Ahmed, and Limin Wang. 2010. *Climate Risks and Adaptation in Asian Coastal Megacities: A Synthesis Report*. Washington, DC: World Bank. <http://documents.worldbank.org/curated/en/2010/09/12886839/climate-risks-adaptation-asiancoastal-megacities-synthesis-report>
- Revi, Aromar. 2008. "Climate Change Risk: An Adaptation and Mitigation Agenda for Indian Cities." *Environment and Urbanization* 20 (1): 207–29.
- Rosen, Sherwin. 2002. "Markets and Diversity." *The American Economic Review* 92 (1): 1–15.
- Shah, Manisha, and Bryce Millett Steinberg. 2013. "Drought of Opportunities: Contemporaneous and Long Term Impacts of Rainfall Shocks on Human Capital." NBER Working Paper No. 19140.
- Spears, Dean, and Sneha Lamba. 2016. "Effects of Early-Life Exposure to Sanitation on Childhood Cognitive Skills: Evidence from India's Total Sanitation Campaign." *Journal of Human Resources* 51 (2): 298–327.
- Stiglitz, Joseph E., Amartya Sen, and Jean-Paul Fitoussi. 2010. *Mismeasuring our Lives: Why GDP Doesn't Add Up*. New York: The New Press.

- Tolley, George S. 1974. "The Welfare Economics of City Bigness." *Journal of Urban Economics* 1 (3): 324–45.
- Townsend, Robert M. 1995. "Consumption Insurance: An Evaluation of Risk-Bearing Systems in Low-Income Economies." *The Journal of Economic Perspectives* 9 (3): 83–102.
- Weitzman, Martin L. 2009. "On Modeling and Interpreting the Economics of Catastrophic Climate Change." *The Review of Economics and Statistics* 91 (1): 1–9.
- Westphal, Michael, Gordon Hughes, and Jörn Brömmelhörster, eds. 2015. *Economics of Climate Change in East Asia*. Manila: Asian Development Bank.
- Wolak, Frank A. 2011. "Do Residential Customers Respond to Hourly Prices? Evidence from a Dynamic Pricing Experiment." *The American Economic Review* 101 (3): 83–87.
- World Bank. World Development Indicators. <http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators>