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Urban Growth and Climate Change

Matthew E. Kahn

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Matthew E. Kahn

UCLA and NBER

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Author Contact Information:

UCLA
Institute of the Environment
La Kretz Hall, Suite 300
619 Charles E. Young Drive, East
Box 951496
Los Angeles, CA 90095
mkahn@ioe.ucla.edu
phone: 310-794-4904
fax: 310-825-9663

Abstract

Between 1950 and the year 2030, the share of the world's population who lives in cities is predicted to grow from 30% to 60%. This urbanization has consequences for the likelihood of climate change and for the social costs that climate change will impose on the world's quality of life. This paper examines how urbanization affects greenhouse gas production and it studies how urbanites in the developed and developing world will adapt to the challenges posed by climate change.

KEY WORDS: Global Externality, Tragedy of the Commons, Adaptation, Incidence, Cities, Global Warming

Introduction

Climate change is the leading environmental challenge we face. Climate scientists continue to investigate how much we must reduce global greenhouse gas (GHG) production to mitigate the impacts of climate change (Hansen et al. 2008). They measure the atmospheric concentration of carbon dioxide in parts per million (ppm). "Very roughly, stabilization at 500 ppm requires that emissions be held near the present level of 7 billion tons of carbon per year for the next 50 years, even though they are currently on course to more than double (Paccala and Socolow 2004)."

The fundamental challenge posed by climate change is that greenhouse gas emissions represent a global externality. No individual, firm or nation has an incentive to unilaterally reduce its emissions. Such an action would be costly and would only have a minor impact on reducing aggregate global greenhouse gas emissions. Given that the world's population roughly equals seven billion, global annual average per-capita carbon emissions would need to decline to one ton to achieve the aggregate goal described by Paccala and Socolow (2004). To put this target in perspective, if a person drives merely 2,130 miles per year using a vehicle whose fuel economy is 25 miles per gallon then this person would just exceed this target. Each person in the United States is currently producing eighteen tons of carbon dioxide per year.

Is city growth exacerbating this problem? Around the world, people are moving to cities. In 1950, 30 percent of the world's population lived in cities. In 2000 this fraction grew to 47 percent, and it is predicted to rise to 60 percent by 2030.[1] This paper melds insights from the urban and environmental economics to answer two main questions. First, does urban growth

[1] United Nations, "World Population Prospects: The 2004 Revision Population Database" (esa.un.org/unpp).

increase or decrease world greenhouse gas emissions? In the absence of explicit carbon incentives, how does city growth affect greenhouse gas production? Second, as climate change takes place, how will different cities in developed and developing nations cope and adapt?

Cities are the engine of capitalist growth. Over time, people move from rural areas to urban areas as they seek a higher standard of living. In cities, people earn higher incomes and thus have the financial resources to purchase more consumption products ranging from private transportation to larger homes. Urbanization increases the demand for residential and commercial electricity consumption. While urbanites produce more emissions per-capita than rural residents, they also choose to have fewer children. Urbanization also facilitates discovery and diffusion of new ideas. In the first section of the paper, I investigate how urban growth affects greenhouse gas production when there are no explicit carbon mitigation incentives and contrast this with the likely consequences of urban growth on GHG production in a world that adopts aggressive carbon pricing.

No matter how much we reduce the global stock of GHG emissions, we will experience some climate change. The second half of the paper focuses on urban adaptation to climate change. I examine how it will affect urban quality of life in different cities around the world. How will cities adapt to climate change? Which will gain and which will lose? As I will document below, climate change is predicted to have significant effects on major city average temperature and rainfall throughout the United States. The best models of future temperature and rainfall indicate that over the next 75 years, Southern California's cities such as Los Angeles will suffer a sharp reduction in climate amenity levels while a few cities in Florida will experience improvements in their climate amenity bundle due to climate change.

Climate change also poses a set of high risk, low probability events for cities (Weitzman 2008). Cities differ with respect to the levels of risk that they will face and their ability to handle these expected blows. Some coastal cities will experience more severe floods while other cities will suffer from worse heat waves. Given that cities differ with respect to the objective risk that climate change poses, what is the optimal role for the federal government in terms of paying for local public goods such as sea walls? Are moral hazard effects a significant concern? For example, could government investment in coastal protection increase the number of "victims" who locate in coastal areas as public investment crows out private self protection?

It is important to investigate how city residents expect to cope with climate change. Around the world, the median voter lives in a city. This paper's analysis is useful for understanding how voters in different cities form expectations concerning how climate change will affect their day to day life. Self interested voters are more likely to support aggressive carbon mitigation if they believe that they will significantly suffer under the business as usual scenario. Expectations of the incidence of climate change play a key role in determining whether voters prioritize climate change as an important policy issue.

Urban Growth's Impact on Greenhouse Gas Production

Total greenhouse gas emissions equal; income per-capita*population*greenhouse gas emissions per dollar of income. This accounting identity highlights the role that scale, and composition effects play in determining pollution production. This product can be calculated at any level of geographical aggregation ranging from a household to a city to a nation to the world. Given that the marginal damage caused by GHG production is independent of where it is produced, we ultimately care about the world's production of GHG emissions. This equation highlights the mitigation challenge. World population is growing and world per-capita income is growing more quickly than population growth.

How does city growth affect a nation's greenhouse gas production? Cities are the key engine of economic growth because they economize on the transportation cost of goods, workers and ideas (Glaeser 1998). Cities facilitate learning, and generation and diffusion of new ideas (Duranton and Puga 2001, Audretsch and Feldman 2004). Through encouraging specialization and facilitating trade, cities raise our per-capita income (Glaeser and Mare 2000).

Richer consumers spend more on goods and energy and a byproduct of this activity is more greenhouse gases. The income elasticity of the demand for energy is typically found to be between .8 and 1.1 (Nordhaus 1979, Gately and Huntington 2001). The aggregate consequences of income growth can be seen in Beijing, China. In 2001, there were 1.5 million vehicles in Beijing. By August 2008, its vehicle county had grown to 3.3 million. Prominent environmental writers such as Jared Diamond are deeply worried about the growth of the middle class in the developing world.

"Per capita consumption rates in China are still about 11 times below ours, but let's suppose they rise to our level. Let's also make things easy by imagining that nothing else happens to increase world consumption — that is, no other country increases its consumption, all national populations (including China's) remain unchanged and immigration ceases. China's catching up alone would roughly double world consumption rates. Oil consumption would increase by 106 percent, for instance, and world metal consumption by 94 percent.

If India as well as China were to catch up, world consumption rates would triple. If the whole developing world were suddenly to catch up, world rates would increase elevenfold. It would be as if the world population ballooned to 72 billion people (retaining present consumption rates)." (Diamond 2008).

While vehicles are the most salient example, we can expect to see sharp global increases in the consumption of electricity and residential durables ranging from ovens to refrigerators. Cross-national Environmental Kuznets Curve research (Schmalensee, Stoker and Judson 1998) has demonstrated that there is no "turning point" for per-capita carbon dioxide emissions as a function of national per-capita income. Using a spline approach for flexibly modeling the effects of real per-capita income, Schmalensee, Stoker and Judson (1998) use a national panel data set and include nation fixed effects in their specifications. They document that the marginal effect of real per-capita income on per-capita carbon dioxide emissions is always positive but the slope is steeper for poor nations than for richer nations.[2] Auffhammer and Carson (2008) create a panel data set for 30 Chinese provinces covering the years 1985 to 2004.[3] They find that a province/year's log of greenhouse gas emissions is an increasing and concave function of province/year log of per-capita income.

Greenhouse gas mitigation represents the ultimate global free rider problem. Unlike in the case of localized externalities such as urban air pollution or urban water pollution, local and national regulatory authorities have little incentive to regulate such emissions. Even for a nation

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[2] Future micro-econometric research should investigate why the marginal increase in GHG is a decreasing function of income. One possible explanation is co-benefits. Consider coal fired power plants. They emit both GHGs and local pollutants. If they reduce their greenhouse gas production, then local air quality also improves and the populace immediately enjoys improvements in public health.

[3] It is useful to contrast these results with other EKC studies (see Kahn 2006). For local pollutants such as lead, we know that emissions rise as nations grow richer due to scale effects of more driving using leaded gasoline. As nations grow richer, they enact regulations that lower pollution per mile of driving and lead emissions start to decline as a function of national income. Hilton and Levinson (1998) demonstrate for a cross-section of nations how both scale and technique effects vary as a function of national income. The early EKC literature argued that a per-capita income turning point exists such that for richer nations economic development is positively correlated with reduced pollution levels. More recent research has documented that this finding is not robust (Harbough, Levinson, and Wilson 2002).

such as the United States, the basic free rider logic holds. Sunstein (2007) argues that the fundamental problem is that China and the United States produce roughly 45% of the world's greenhouse gas emissions but that as climate change takes place, these two nations will suffer a much smaller percentage of its costs. If these nations expect to experience large losses from climate change, then they would have a private incentive to mitigate their emissions and to work co-operatively.

This logic has not slowed states such as California from unilaterally pursuing climate change mitigation regulation. In 2006, Governor Arnold Schwarzenegger signed the California Global Warming Solutions Act of 2006 (AB 32). This law commits California to reduce its greenhouse gas emissions 80% below its 1990 levels by 2050. The California Air Resources Board is the regulatory agency charged with meeting this goal. It has proposed a bundle of regulations including; increasing commercial and residential building energy efficiency, forcing electric utilities to supply power with an ever growing share of power generated by renewable energy sources and making utilities participate in a cap and trade market. California is only responsible for 5.9% of the nation's greenhouse gases despite the fact that roughly 18% of the nation lives in California.[4] The United States is responsible for 25% of the world's greenhouse gas emissions. Holding the rest of the world's greenhouse gas emissions constant, an 80% reduction in California's emissions today would reduce the United States' emissions by 1.18% and the world's emissions by .3%. This arithmetic highlights that unilateral action yields small aggregate effects.

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[4] This fact is based on data from Vulcan project based at Purdue University (http://www.purdue.edu/eas/carbon/vulcan/research.html).

Urbanization does trigger two offsetting forces. Urbanization slows national population growth through changing fertility patterns.[5] This can offset some of the GHG produced due to the urban productivity effect. Women have numerous employment opportunities in cities. This encourages women to marry later and delay having their first child. Anticipating that they will live in an urban area with labor market opportunities gives school age women a greater incentive to invest in their human capital. Given that cities raise women's wages and offer a thick local labor market, women have greater opportunities outside the home. This raises the opportunity cost of having children. Urban land is more expensive than rural land and this also provides an incentive for smaller household sizes. Urbanization also facilitates idea generation and diffusion. Proximity enhances the ability of firms to exchange ideas and be cognizant of important new knowledge (Audretsch and Feldman 2004).

Urban Adaptation to Carbon Pricing

The adoption of a credible carbon trading market, or a carbon tax would incentivize polluters to change their behavior. These policies would induce innovation to reduce greenhouse gas emissions per dollar of output (Stern 2008, Metcalf 2008). Despite the fundamental free rider problem, regional carbon trading agreements have been implemented in Europe (see Ellerman and Buchner 2007 and Kruger, Oates and Pizer 2007) and in North American's East Coast (http://www.rggi.org/home) and West Coast (see http://www.westernclimateinitiative.org/Index.cfm).

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[5] For a sociologist's perspective the causal role of urbanization in explaining differential rural/urban fertility see the work of Michael White (2005).

If the U.S participated in a national cap and trade system, how would cities adapt?[6] Cities differ with respect to their marginal contribution to greenhouse gas production. Glaeser and Kahn (2008) document that the marginal social cost of moving a household from a high GHG city such as Houston to a low GHG city such as San Francisco is roughly $600 per year.[7] Relative to a "green city" such as San Francisco, Houston's humid summer climate requires much more electricity consumption for air conditioning. Houston's cheaper housing encourages households to buy more housing and this increases their energy consumption. Houston's low population density and spread out employment means that people rely on the private vehicle for transportation and few use public transit. Houston's electricity is generated by dirtier power plants than San Francisco's electricity. A majority of California's power is produced by natural gas fired power plants rather than dirtier coal fired power plants. Glaeser and Kahn's (2008) study quantifies cross-city differences at a point in time, the year 2000. It remains an open question how this ranking of cities would change in the presence of a carbon tax and how these city rankings compare in developing countries such as China and India. The baseline carbon production differentials between cities such as San Francisco and Houston indicate that the adoption of carbon pricing would be capitalized into local land prices and wages. All else equal, San Francisco's rents would rise relative to Houston's.

The durability of residential and commercial buildings introduces differential effects from carbon pricing in booming cities versus declining cities. Consider growing cities in the

[6] Metcalf (2008) bases his analysis on a starting tax of $15 per ton of carbon dioxide. This rises over time such that it equals $50 in year 2005 dollars by the year 2050. This is a much smaller number than Stern's (2008) estimate of a marginal social damage cost of $85 per ton of carbon dioxide.

[7] These findings are based on a $43 per ton of carbon dioxide marginal social cost.

West such as Las Vegas and Phoenix. As these cities grow, new residential and commercial buildings will be constructed. Facing a carbon tax, real estate developers will have incentives to build buildings whose marginal energy consumption is less than the incumbent capital stock's average. Contrast such growing cities with shrinking cities such as Buffalo and Detroit. In such cold weather, low amenity cities, there is little new construction. In the face of carbon pricing, there are two possible outcomes. One possibility is that carbon pricing will accelerate the scrappage of older energy inefficient buildings. This logic is similar to the claim of how higher gas prices affect the scrappage rate of used SUVs and Hummers. This is especially likely in cities whose power is generated by coal fired power plants. Whether real estate owners in declining cities will make significant investments in retrofitting existing buildings to improve their energy efficiency is an open question. The dim prospects of obtaining a high resale price for the asset would be traded off against the short term present discounted value of electricity expenditure savings. In a booming city, the real estate owner who chooses to retrofit an existing building gains the short run electricity expenditure savings and will gain from the capitalization effect upon selling the asset. The present discounted value of these two terms will be compared to the cost today of retrofitting the building. Such retrofit costs are unlikely to vary across cities.

Within cities, carbon pricing will encourage densification and living closer to the city center. How large could these effects be? The 1970s OPEC oil shocks provided one "natural experiment". Urban economists do not believe that this increase in the price of gasoline pushed many people to live in the center cities. Instead, people responded by purchasing smaller more fuel efficient vehicles. Today, urban economists are celebrating the high quality of life in consumer center cities (Glaeser, Kolko and Saiz 2000). Recent reductions in crime have dramatically improved center city quality of life (Levitt 2004). Reyes (2007) predicts that crime rates will continue to decline.[8] Street safety and high gas prices both encourage people to live in new urbanist walking communities. Weak urban public schools appear to be the last hurdle discouraging adults with young children from living in center cities.

Carbon pricing would encourage electric utilities to rely less on coal fired power. Based on year 2004 data from the EPA's EGRID database, the average emissions factor for coal fired power plants is 50% higher than the average emissions factor non-coal fired power plants.[9] States in regions such as the South East feature high average emitting power plants. In the presence of carbon pricing, these electric utilities would have a strong incentive to change the composition of their power generation and to green their techniques. A health benefit of these efforts is that local air pollution would decline. A co-benefit of taxing carbon dioxide is that ambient pollution from coal fired power plants would fall. Major cities close to coal fired power plants would enjoy an improvement in local ambient air quality as these plants cleaned up their emissions.

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[8] She argues that urban lead exposure is a key determinant of crime. In a nutshell, she argues that in the 1950s, more and more households were buying cars and driving them around their new suburban homes. Back then, cars used leaded gasoline. While no individual car driver intended to pollute the air, an unintended consequence of rising leaded gasoline consumption was elevated lead levels. This created public health problems as exposed children suffered from IQ loss and were more prone to attention deficit disorder. The criminology literature has documented that these two factors increase a person's likelihood of becoming a criminal. Kids born in the 1950s were exposed to elevated lead levels and 18 years later when they were young adults (in the early 1970s), urban crime levels increase. Now, the story has a happy ending. In the early 1970s, the U.S Environmental Protection Agency started its regulatory efforts. The introduction of the catalytic converter as an emissions control device meant that new vehicles could not run on leaded gasoline anymore. Vehicles built after 1972 used unleaded gasoline. Starting in the mid-1970s as more and more of the vehicle fleet no longer used leaded gasoline, ambient lead emissions declined. Kids born after 1972 were exposed to less ambient lead. As these kids become adults (starting in the early 1990s), they committed fewer crimes relative to earlier cohorts.

[9] See http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

Policy makers such as the California Air Resources Board, the agency responsible for meeting the goals set in AB32, have voiced tremendous optimism that carbon pricing will actually offer a "free lunch" as households and firms will experience a net reduction in the present discounted value of their electricity expenditures.[10] Such environmental regulators are implicitly embracing a behavioral economics viewpoint that in the absence of carbon pricing and carbon regulation that households and firms would simply satisfice rather than ruthlessly minimize their electricity expenditures. This claim, which appears to be a close cousin of the Porter Hypothesis, merits further research to test whether real world consumers and firms need regulatory mandates to push them to make energy efficiency investments that have negative net costs.

Urban Adaptation to Climate Change in the United States

Even if we could reduce our greenhouse gas emissions to zero from now on, we will experience the consequences of climate change. Relative to a rural agricultural world economy, will we suffer less because we live in cities? Is an urban household insulated from the effects of climate change relative to rural households? Urban households live an indoor life where one's productivity is not a function of outdoor climate. In contrast, farmers know that the quantity and quality of their output is directly related to climate.

Climate change will shift the distribution of temperature and rainfall by different amounts in different locations. Given that urbanites value quality of life, it is important to consider which cities in the United States will be net "winners" and "losers" from changes in climate amenity

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[10] http://www.arb.ca.gov/cc/scopingplan/document/economic_appendix1.pdf

bundle. Quality of life is a key determinant of which cities attract the skilled. There are more highly skilled people living in San Francisco than Detroit. This must be due to selective migration rather than any inherent productivity effect from living in San Francisco. High quality of life "consumer cities" will attract the skilled and experience economic growth (Shapiro 2006, Glaeser and Gottlieb 2006, Glaeser, Kolko and Saiz 2000).

But this raises the issue, what determines a city's quality of life? Admirers of San Francisco would point to its temperate climate, low pollution levels, amenity beauty and low crime levels as major attractors. For a city such as San Francisco, climate change will shift its average monthly climate, and rainfall. This in turn will expose the population to greater air pollution levels because pollutants such as ozone that reaches its highest levels in the summer heat.

Given the predictability of these changes to climate, compensating differentials theory predicts that cities that are now exposed to cooler winters and warmer summers will experience declining home prices and rising wages (Blomquist, Berger and Hoen 1988, Gyourko and Tracy 1991). This logic is based on a open city model where households can vote with their feet and migrate across cities. If migration costs are zero, spatially tied attributes such as climate will be capitalized into wages and rents such that the marginal household is indifferent between living in "nice" cities and low quality of life cities. Climate change is likely to change this spatial equilibrium.

To investigate the possible size of these effects, I use county level data from the year 2000 Census of Population and Housing. I estimate some simple hedonic home price regressions. The dependent variable is the county's average home price. I control for no explanatory variables except for a vector of county climate variables.[11] This climate data is used in work see Deschenes and Greenstone 2007a, 2007b. In these regressions, the key explanatory variables are a county's county's 1968 to 2000 average temperature in January and July and the county's 1968 to 2000 average rainfall in January and July. Table One reports two OLS regressions based on equation (1). I estimate these models with and without state fixed effects.

$$\text{Home Price}_{jlt} = \alpha + \beta^{*}\text{Climate}_{jlt} + \varepsilon_{jlt} \qquad (1)$$

I take the OLS estimates of β and use these as index weights. These index weights represent the marginal valuation of winter and summer temperature and rainfall in the year 2000.

Climate researchers have developed two different models of climate change's predicted effects for future temperature and rainfall by month by county. These two models are called the CCSM Model and the H3A1FI Model (see Deschenes and Greenstone (2007a, 2007b) for more details about these models). These models yield county level predictions over average temperature and rainfall by month between 2070 and 2099. I average the two sets of county level predictions and use the average January and July predictions for rainfall and temperature. Define this vector of future county climate conditions as $\text{Climate}_{jlfuture}$ and define the historical county climate conditions as Climate_{jlpast}. I then calculate for each county j, the predicted climate change index (measured in dollars) = $\beta^{*}(\text{Climate}_{jlfuture} - \text{Climate}_{jlpast})$ (2)

The estimate of β is based on estimates of equation (1) reported in Table One's column (2) I calculate this dollar climate hedonic index for each county and then aggregate this to the metropolitan area level using the county's year 2000 population level as the weight. Intuitively,

[11] All of the climate data was generously provided by Olivier Deschenes.

this index, measured in dollars, represents the expected dollar gain in metropolitan area quality of life due to climate change. Positive values of this index indicate metropolitan area's whose climate quality of life is expected to improve due to climate change and negative values indicate expected climate quality of life losses. In Table Two, I report the names climate index change for all 53 metropolitan areas that have more than 1 million people in the year 2000. As a Los Angeles home owner, I am struck by the last row of the matrix. Los Angeles is the major metropolitan area that will suffer the largest climate amenity loss due to climate change. A look at the raw data reveals the issue. During the historical time period, Los Angeles was blessed with an average August temperature of 75 degrees. The climate change models are predicting that this area's mean temperature will rise to 90 degrees by the late 21st century.

Climate change will have a differential impact on major city quality of life. Table Two highlights that all of the cities in Southern California are expected to suffer a sharp climate amenity loss due to climate change. In contrast, cities in Florida will actually experience an improvement in their climate bundle as winter temperatures increase (an amenity) and summer average temperatures rise relatively little. Only five major U.S metropolitan areas are expected to experience an improvement in their climate bundle due to climate change. Relative real estate prices will adjust to reflect these underlying changes in climate amenities. These effects could be quite large. The average home price in the year 2000 for Los Angeles County is $286,632.8, thus the predicted amenity decline of $145,496 reported in Table Two represents over a 50% decline! The climate models are predicting that Los Angeles will have a similar climate amenity bundle as Jacksonville, Florida by the year 2070.

Climate is just one dimension of risks that cities face due to climate change. Warmer summer temperatures will raise urban ozone smog levels and this will reverse some of the recent gains in big city smog progress (www.epa.gov/airtrends). Cities also differ with respect to whether they are located on a coast and thus at risk for flooding. All over the United States, people are moving to the coasts (Rapapport and Sachs 2000). As population moves to coastal areas and more construction in coastal areas, assets at risk? Pielke and co-authors (2000, 2008) have documented that population locational trends have put more people and capital at risk to be destroyed by floods and hurricanes.

If certain coastal cities now face increased risk of flooding due to climate change, think of New Orleans; are these low probability events salient enough and large enough to be capitalized into the cross-city hedonic wage and real estate gradients? Risk perception plays a key role in determining the incidence of the amenity dynamics induced by climate change. If safer more pleasant cities do not command a real estate premium, then land owners in such cities are not enjoying the rents from this dimension of city quality. Conversely, if at risk cities feature a sharp capitalization effect then this could affect population sorting. Such cities would be more likely to attract the poor and risk lovers.

We know that government interventions can help cities self protect against shocks posed by climate change. While government cannot change the weather, engineering investments such as improved levees helps to reduce the risks posed by storms. In the presence of Knightian Uncertainty, how do we estimate the expected present discounted value of the benefits we gain from making such engineering investments versus delaying such an investment? Weitzman (2008) sketches some very scary right tail low probability events associated with climate change.

Government investment in city protection can have important implications for the spatial distribution of capital and human capital across a nation. Kousky, Luttmer and Zechauser (2006) offer a very useful framework. They model the non-cooperative investments of the private sector and a government who both recognize that their investments are complements. For example, suppose that the private sector must decide whether to make an irreversible investment in a new hotel. The government must decide whether to invest in sea walls that reduce the probability of climate change induced flood. If the private investor believes that the government will build the sea wall then the expected benefits of building the hotel go up. Symmetrically, if the government believes that the hotel will be built then there are more physical assets that are protected by a sea wall. After all, it wouldn't make sense to build a Sea Wall if nobody lives in the city. There is an implicit moral hazard problem here. If people and capital that would have self-protected and located in a "safe city" such as St. Louis now locate in New Orleans because they trust that government will invest and protect them, then the government's activism will crowd out self protection and more people will be at risk from the climate change shock. If the sea walls have a positive probability of crumbling due to Mother Nature's blows, then the ex-post costs of government activism can be large.

In terms of political economy, place based politicians in at risk areas (i.e New Orleans) such as Mayors and Congressional Representatives have a strong incentives to attract resources to build up their city (Glaeser and Gottlieb 2008). They will lobby for federal financing of local public goods such as sea walls. After all, major public transit infrastructure projects such as urban subway systems receive subsidies of up to 80%. The Boston Big Dig is a famous example. Do such investments encourage efficiency or do they breed moral hazard effects as more people move to coastal areas because they feel safe due to government investments? If significant federal resources are used to provide local public goods for specific cities, then this will be a redistribution from tax payers in safe cities to tax payers in at risk areas. This raises efficiency and equity issues.

An interesting, but potentially costly, game of "chicken" could arise. Suppose that cities such as New Orleans want improved sea Walls but want the Federal Government to pay for it. They have an incentive to delay constructing such capital intensive projects. Thus, in the short run they face more climate risk because they are not prepared. An alternative financing approach would be to tax local land owners. In an economy with low cross-city migration costs, urban land owners bear the incidence of improvements in public goods.

Cities at risk to suffer from climate change can use public policies and market incentives to reduce ex-ante risk taking and reduce the costs of adaptation. Cities can use zoning laws to discourage high density development in at risk areas. If property insurance prices reflect actuarial risk, then this would discourage building in flood zones and fire zones. The frequency and severity of such events are likely to increase due to climate change. Insurance is a regulated market. While economists might support price discrimination such that at risk areas feature higher insurance premiums, citizens might complain that this is "price gouging". The government may have to provide insurance policies to the public if for profit firms do not believe that they can earn profit in the face of regulation (Ross, Mills and Hecht 2007). If governments do not allow the insurance industry to engage in price discrimination, then the ex-post costs of adaptation will be higher.

Utility maximization and minimizing the cost of adaptation can be compatible objectives if the population perceives the probability of "bad states of the world" and places a high utility cost of damage in those states. In this case, real estate prices will be low in areas that face greater risk. This would induce sorting such that risk lovers and the poor would live in the risky cities. If the public is unaware about the actuarial risk, then this provides a paternalistic justification for government to invest in public self-protection. An open question is whether voters will view such investments as "good" or do they need to be woken up by salient events such as a Hurricane Katrina before they are willing to support costly self protection investment? The answer partially hinges on whether voters believe the climate scientists. If the public views scientists as "alarmists" who have been wrong about past predictions, then the government may under-invest in self protection and the public will also under-invest in private self-protection as they under-estimate the true threat posed by climate change.

Adaptation in Cities in Developing Nations

LDC cities face two additional adaptation challenges; rural to urban migration accelerated by climate change and the increased disease risk, pollution exposure and natural disaster risk that informal urban squatters face. This section sketches the likely consequences of these patterns and suggests a research agenda.

Rural to Urban Migration

In developing nations, there are many more people living in rural areas. Many of these people may move to nearby cities if the income they earn from farming declines due to climate change. Barrios, Bertinelli and Strobl (2006) document that climatic change, as proxied by rainfall, has acted to change urbanization in sub-Saharan Africa but not elsewhere in the developing world. Moreover, this link has become stronger since decolonization, which is likely due to the often simultaneous lifting of legislation prohibiting the free internal movement of native Africans. In a Harris-Todaro expected utility framework, climate change provides a push from farming areas as previously profitable areas experience a reduction in profitability. An active agricultural economics literature has examined how farmer profitability varies as a function of climate (see the work of Robert Mendelsohn and co-authors). One optimistic claim is that farmers suffer less from climate variability than they did in the past. The simplest static expected income calculation comparison would yield a locational decision rule stating that a farmer should move to the city if:

Profits farming <= (probability find job)*urban wage – migration cost - urban rent (3)

In the short term, climate change will lower the left side of this equation and this encourages urbanization. In the medium term, such migration may have general equilibrium effects. As farmers urbanize, this will lower equilibrium urban wages and raise urban rents. These changes in factor prices will slow down migration.

Climate change poses a set of risks to the urban poor. Heat waves, exposure to high levels of urban smog, and climate related events such as floods and mudslides all threaten this vulnerable group.[12] In the developing world, city governments are not providing high quality services. Comparative research has documented that governance quality is worse in poorer nations (LaPorta et. al. 1998). If local governments do not have the revenue to provide basic services of clean water and sanitation for a growing urban population, then climate change induced "environmental refugees" can help to unintentionally trigger local urban quality of life challenges. In such nations, the urban poor face the greatest risks from climate change induced

[12] In recent work, I have documented that richer nations suffer fewer deaths from natural disasters than poorer nations (see Kahn 2005). I argued that income is associated with a higher quality capital stock, better functioning government and greater medical resources to treat those affected by natural disasters.

events such as heat waves and flooding.   Relative to richer households, they have less access to medical services and household durables to offset climate exposure (i.e air conditioning, refrigeration). Facing the land price gradient, the poor choose to live in the lowest quality, least desirable parts of the city where rents are low. The inability of the poor to defend themselves from climate change matters because it is likely to be the case that local governments in developing countries do not have financial resources to provide public goods to protect the local population. Such governments are also likely to be unresponsive to the needs of informal squatters who are unlikely to vote.

International research continues to investigate which cities are the "hot spots" of climate risk. A recent OECD 130 city study states;

"Around half of the total population exposure to coastal flooding caused by storm surge and damage from high winds is contained in just ten cities today. Mumbai has the highest number of people exposed to coastal flooding. But by 2070, Kolkata (Calcutta) will be the most vulnerable, with the exposed population expected to increase over seven times to more than 14 million people. Over the coming decades, the unprecedented growth and development of the Asian mega-cities will be a key factor in driving the increase in coastal flood risk globally. In terms of population exposure, Kolkata is closely followed by Mumbai, Dhaka, Guangzhou, Ho Chi Minh City, Shanghai, Bangkok and Rangoon (Myanmar). Miami is in ninth place and would be the only top ten city in a currently developed country, while Hai Phong in Vietnam is ranked tenth." (Nicholls et. al. 2008).

Conclusion

Relatively little economic research has focused on cities and climate change. This paper has argued that the role of cities in causing climate change and the impact that climate change will have on different types of cities represents a first order issue at the intersection of environmental and urban economics. After all, urban growth fuels income growth. As people around the world achieve the "American Dream" an unintended consequence is increased per-capita greenhouse gas production. Such scale effects unleashed by capitalism suggest that city growth is causing climate change. But, city growth also helps to slow population growth and accelerate technological innovation and diffusion. In a world without explicit carbon pricing, the net effect of urbanization is GHG growth. This paper has offered a set of conjectures for how cities will be affected by the introduction of carbon pricing. The investigation of such incentive pricing in both developed and LDC cities represents an important topic for future research.

This paper has also examined how city quality of life will be affected by climate change. Adaptation to climate change can take place both at the individual level, city level and national level. Strategic interactions between these three responses merit future research. Under plausible scenarios, government ex-ante investments in self protection (i.e sea walls) will crowd out self protection of private individuals and firms.

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Table One: Cross County Hedonic Home Pricing Year 2000

	beta	s.e	beta	s.e
January Rainfall	2505.673	1204.089	7034.378	1708.237
January Temperature	2617.485	184.416	7012.093	419.856
July Rainfall	-8507.113	972.033	-5034.146	2893.371
July Temperature	-7741.370	424.782	-7025.780	618.182
Constant	679761.600	28355.990	441076.800	44025.490
Observations	3105		3105	
R2	.251		.483	
Fixe d Effects	None		State	
Regressions weighted by county year 2000 population. See equation (1) in the text. The unit of analysis is a county. The dependent variable is the average home price in the county.				

Table Two: Predicted Change in the Climate Bundle Amenity 2000 to 2080

Metropolitan Area Name	MSA Code	Predicted Change in the MSA's Climate Index from 2000 to 2080 (year 2000 $)
Fort Lauderdale, FL	2680	38913.48
West Palm Beach, Fl	8960	34358.72
Tampa, FL	8280	27542.09
Norfolk, VA	5720	21624.44
Orlando	5960	15879.6
Hartford	3283	-5067.189
New Haven	5483	-12266.24
Boston	1123	-16803.7
Jacksonville, FL	3600	-18986.64
Minneapolis	5120	-21334.24
NYC	5600	-21355.8
Milwaukee	5080	-28892.5
San Jose	7400	-31635.96
Baltimore	720	-33275.3
Washington DC	8840	-34419.88
Rochester, NY	6840	-36364.92
Detroit	2160	-37356.33
Las Vegas	4120	-38679.09
Philadelphia	6160	-39917.8
Buffalo	1280	-43900.47
Cleveland	1680	-45217.91
New Orleans	5560	-47465.01

Chicago	1600	-47769.67
Columbus	1840	-48837.98
Pittsburgh	6280	-53391.64
Indianapolis	3480	-54721.8
Houston	3360	-58271
San Antonio	7240	-60333.15
Cincinnati	1640	-60681.93
Portland	6440	-62760.29
Phoenix	6200	-63563.88
Raleigh	6640	-65944.21
Greensborough	3120	-66471.52
Austin	640	-68135.39
San Francisco	7360	-68516.25
Charlotte	1520	-71330.45
Salt Lake City	7160	-72405.72
Kansas City	3760	-72549.86
Louisville	4520	-73309.2
St. Louis	7040	-73818.52
Atlanta	520	-76884.83
Fort Worth	2800	-79363.66
Sacramento	6920	-79485.88
Oklahoma City	5880	-81095.09
Dallas	1920	-81155.93
Nashville	5360	-81571.36
Seattle	7600	-82830.23
Denver	2080	-84623.28

Memphis	4920	-92587.66
San Diego	7320	-126400.1
Riverside	6780	-126562.1
Orange County	5945	-127265.2
Los Angeles	4480	-145496

See Equation (2) in the text.