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Density and Disasters

Economics of Urban Hazard Risk

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Abstract

Today, 370 million people live in cities in earthquake prone areas and 310 million in cities with high probability of tropical cyclones. By 2050, these numbers are likely to more than double. Mortality risk therefore is highly concentrated in many of the world's cities and economic risk even more so. This paper discusses what sets hazard risk in urban areas apart, provides estimates of valuation of hazard risk, and discusses implications for individual mitigation and public policy. The main conclusions are that urban agglomeration economies change the cost-benefit calculation of hazard mitigation, that good hazard management is first and foremost good general urban management, and that the public sector must perform better in generating and disseminating credible information on hazard risk in cities.

This paper—a product of the Finance, Economics, and Urban Development Department and the Environment and Energy Team, Development Research Group—is part of a larger effort in the department to examine the economics of hazard risks in urban areas. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at slall1@worldbank.org and udeichmann@worldbank.org.

Density and Disasters: Economics of Urban Hazard Risk[1]

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1. Introduction

How can public policy help manage risks from natural hazards in urban areas? The focus of this paper is on ex-ante preventive measures. People and firms are attracted to cities to benefit from economies of scale and agglomeration, reflected in higher wages and productivity. Institutions that govern the use and transfer of land facilitate higher economic densities and influence development in hazardous locations. Ensuring that urban public services are adequate and infrastructure well maintained can generate welfare gains to the local population while reducing their risk from day to day hazards. Large scale investments designed specifically for disaster mitigation need to consider economic efficiency as well as distributional effects. While institutional weakness and land market distortions may lead to the development of informal settlements in hazardous locations, disaster risk reduction strategies should not end up being disruptive for the livelihoods of poor people. What is required is a combination of carrots, such as improved plots in safer areas with affordable transport that links distant locations to jobs, and sticks, including enforcement of land use and zoning to discourage the spread of informal developments in risky locations.

The paper is organized in three sections. First, we discuss why a separate treatment of urban disaster risk is warranted (section 2). We argue that the benefits of economic density come with a higher concentration of people and assets at risk from natural hazards. And we discuss how geographic concentration changes the range of options and priorities for dealing with natural hazard risk – both for individuals and for public policy. In section 3, we provide an overview of existing empirical work as well as new findings to highlight how hazard risk is valued by firms and households. Our main finding is that if land markets work well, information on the location of natural hazards is priced into rents or home prices. However, many poor people are attracted by lower land prices in hazard prone locations thereby increasing the vulnerability of the poor. We then discuss appropriate policy priorities to mitigate disaster risk in cities in section 4. The challenges in developing countries are exacerbated due to (a) large scale informality in land markets where poor people locate in slums that are close to hazard sources; (b) rent controls that reduce private incentives to invest in mitigation; and (c) limited coverage of basic public services such as sewers and drains that amplify the negative impacts of small scale hazards. Section 5 summarizes the main conclusions.

2. Why disaster risk management in cities is different

Why treat urban disaster risk separately from disaster risk in general? Many of the concepts and lessons relevant to disaster risk reduction apply generally—in rural, peri-urban and urban areas. But some issues are specific to cities. Most importantly, as they increase in size, more and more people and assets will be exposed to natural hazards in dense urban areas. This density, of people and economic activity, not only changes the risk equation, it can also change the economics of disaster risk reduction strategies. This section summarizes what is special about disaster risk in cities. It then discusses the lessons learned from the 'new economic geography' literature—also reflected in the World Bank's 2009 World Development Report—in the context of natural hazards.

Disaster risk in cities is large and increasing

Global disaster damage statistics are not classified by urban versus rural location. We therefore have no concrete empirical evidence whether natural disasters have more severe impacts in urban compared to rural areas. This will depend on factors such as a country's overall urbanization rate, the type of natural disaster studied and the measure of damage considered. A drought or flood in a rural area may cause less direct damage than an urban earthquake or hurricane, but may have equally severe consequences on people's livelihoods. In the following paragraphs we discuss specific characteristics of hazard risk in urban areas. A core message is that in a rapidly urbanizing developing world, the growth of population and economic assets in cities will lead to a rapidly increasing concentration of hazard risk in urban areas.

Geography

The interplay of economic and physical geography is one major reason for high hazard risk in urban areas. Many cities have historically emerged at a location with good accessibility or favorable natural endowments such as a river crossing, a coastal location or fertile volcanic soils. Those geographic settings are often associated with an increased probability of hazard events—floods, cyclones and volcanoes. Agriculture in most of southern Italy, for example, is difficult due to poor soil quality. An exception is the area around Mount Vesuvius near the city of Naples where rich volcanic soils have been farmed for centuries despite the risk of new eruptions. Globally an estimated 9 percent of population lives within 100 km of a historically active volcano, with high concentrations in Southeast Asia (Indonesia, Philippines) and Central America (Small and Naumann 2001). Similarly, low elevation coastal zones, often exposed to cyclones and storm surges, cover 2 percent of the world's land area but contain 10 percent of the world's population and 13 percent of the world's urban population (McGranahan et al. 2007).

Land scarcity

Competition for land in urban areas is intense. City managers often exacerbate land scarcity by restricting high density development as further discussed later in this paper. The desire to live close to jobs and amenities means that even marginal city areas such as floodplains or steep slopes will be settled—often, though not always, by poor people. In Santo Domingo's largest slum, 45 percent of houses near a river flood when it rains (Fay et al. 2001, 2003). Housing prices reflect this risk with the poorest living in the lowest quality housing in the most at-risk areas. In cities such as Caracas or Rio de Janeiro, poor families occupy steeply sloped land prone to landslides. This sorting process, with low income households and squatters occupying the most hazardous urban land is not static. Detailed data for Cali, Colombia, show that localized hotspots of small scale disaster events change as inner-city neighborhoods gentrify, governments improve hazard management, and new informal settlements spring up at the periphery (ISDR 2009).

Externalities

Land scarcity leads to higher land prices and therefore, usually, to higher density occupation. Larger building sizes in cities can increase damages and loss of life in severe earthquakes especially where building codes are not enforced. The collapse of larger buildings in dense urban areas may also cause neighboring buildings to be damaged even if they are built to code.[2] These spillovers or externalities are absent in more sparsely populated rural areas where damages to smaller sized and dispersed dwellings will cause less or no collateral damage.

Exposure

The main reason why urban risk is large and increasing is the rise in exposure. Although urbanization statistics suffer from a lack of standard definitions of what should be considered 'urban', the assumption of half the world's population living in cities seems realistic. Urban populations are growing in practically all developing countries. About 40-60 percent of this growth can be attributed to natural growth, i.e., fertility of urban dwellers (Montgomery 2009). The remaining growth is due to urban expansion and migration, reducing the share of rural residents except where rural fertility is vastly larger.

The latest UN urban population estimates suggest that, globally, urban population exceeded rural population for the first time in 2008 (UN 2008). In less developed regions, this threshold is expected to be reached by 2019. This continuing urbanization process will lead to an increase of exposure of people and economic activity in hazard prone urban areas. Although we can only speculate about the global distribution of disaster damage in cities today and in the future, newly available geographically referenced data yield some estimates of urban exposure to natural hazards. A recent global hazard analysis generated a comprehensive database of hazard events during 1975-2007 from observed data and of event probabilities from geo-physical models (ISDR 2009). We combined this hazard information with city-specific population projections

[2] It should be noted that well-documented evidence for such externalities is quite scarce. Their importance is usually taken as given: "A building collapse may create externalities in the form of economic dislocations and other social costs in addition to the economic loss suffered by the owner. The owners may not have taken these consequences into account when evaluating specific mitigation measures. Consider the following example. A building toppling off its foundation after an earthquake could break a pipeline and cause a major fire, which would damage other homes that had not been affected by the earthquake in the first place. "Kuenreuther and Roth (1998). See also www.quakesmart.org/index.php?option=com_content&view=article&id=92&Itemid=209. But some experiences have been documented: "As shown by research on the Great Hanshin-Awaji Earthquake, including that conducted by the Architectural Institute of Japan, Architectural Institute of Japan (1997), houses with inferior earthquake-resistant quality triggered large negative externalities in the neighborhood. For example, broken fragile houses blocked transportation networks, thereby preventing effective fire fighting and, by severing lifelines, they made recovery more difficult." (Nakagawaa et al. 2007).

prepared for this report for 1970 to 2050. These population estimates are based on an economic-demographic model following Henderson and Wang (2007). Cities are included if their population exceeded 100,000 in a given year; there were about 3,700 such cities in 2000, for instance.

Overall, population in large cities exposed to cyclones is estimated to increase from 310 to 680 million between 2000 and 2050. These estimates assume that cyclone frequencies, severity and geographic distribution over this period will be similar to those between 1975 and 2007. Climate change will likely affect sea surface temperature and other factors determining cyclone patterns, but the precise nature of these effects is still vigorously debated in the scientific literature. It is unlikely, however, that cyclone risk will decrease significantly and an expected shift in the distribution of cyclones should not change urban exposure pattern significantly. As seismic activity is more stable over time, these caveats do not apply for earthquakes. Our estimates suggest that urban population exposed in areas with a significant probability of a major earthquake increases from 370 million in 2000 to 870 million in 2050. In both cases, this increase in urban hazard exposure is very likely not a net increase in urban exposure since some share of these additional urban residents will have come from rural areas exposed to the same or another hazard. In fact, increased hazard probabilities in coastal areas or drought risk may drive so-called environmental refugees into cities, possibly accelerating the concentration of disaster risk.[3]

The largest anticipated urban population exposed to cyclones is in South Asia where 246 million residents of large cities are estimated to live in areas affected by severe storms by 2050 (Figure 1). OECD countries and the East Asia and Pacific region each will have about 160 million urban residents exposed to cyclones. South Asia also experiences the second largest growth in urban cyclone exposure between 2000 and 2050 at about 2.6 percent per year, exceeded only by Sub-Saharan Africa's 3.5 percent.

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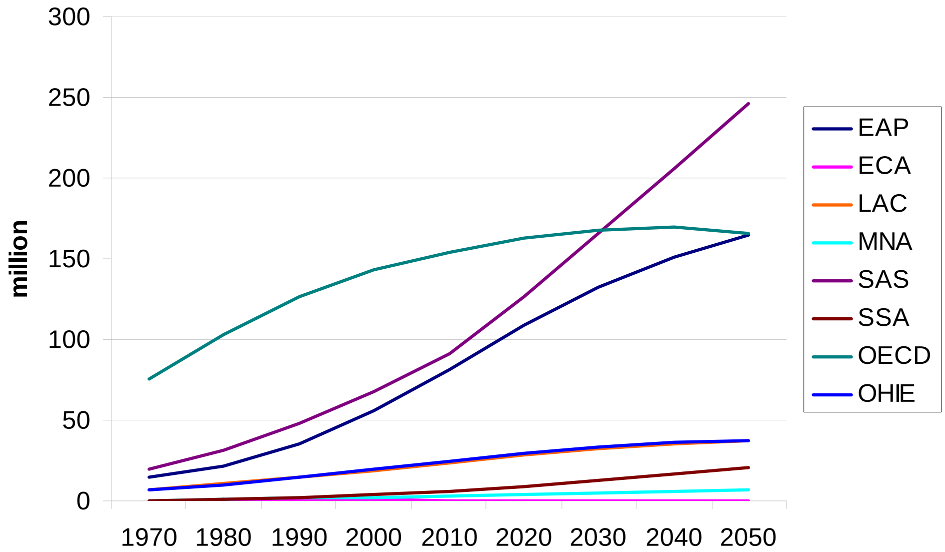
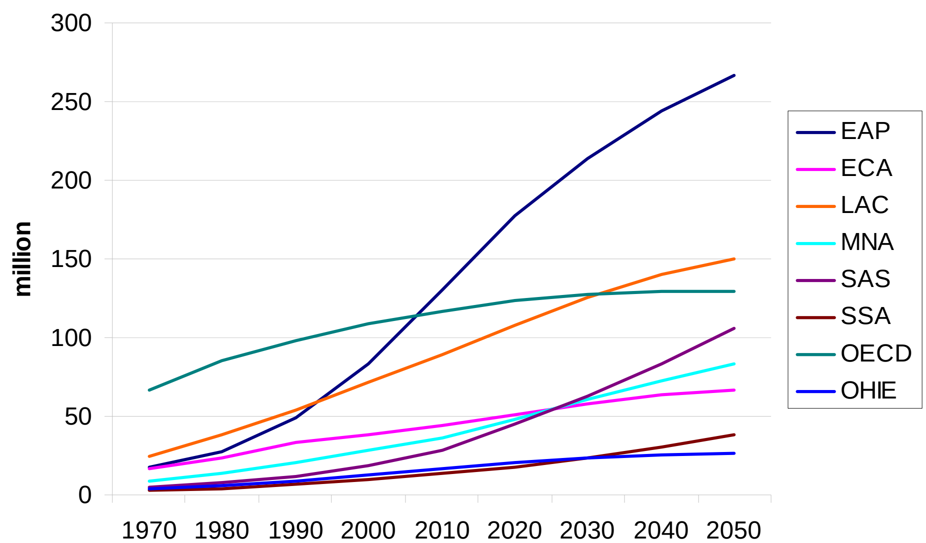
[3] There is some evidence of relocation due to environmental pressures to which climate change may be contributing. See, for instance, Barrios et al. (2003), "Refugees Join List of Climate-Change Issues " (www.nytimes.com/2009/05/29/world/29refugees.html?_r=1) and "China at cross-roads" (www.guardian.co.uk/world/2009/may/18/china-ecorefugees-farming). What proportion of environmental refugees might relocate to hazard-prone cities cannot be easily determined.

Figure 1: Population in large cities exposed to cyclones increases from 310 to 680 million between 2000 and 2050 (World Bank 2009)



Exposure to earthquakes in urban areas is expected to be largest in East Asia and the Pacific at 267 million in 2050 from 83 million in 2000 (Figure 2). Exposure is also high in Latin America and the Caribbean (150 million in 2050) and OECD countries (129 million in 2050). The fastest growth of exposure to earthquakes is expected to occur in South Asia (3.5 percent) followed by Sub-Saharan Africa (2.7 percent).

Figure 2: Population in large cities exposed to earthquakes increases from 370 to 870 million between 2000 and 2050 (World Bank 2009)



What applies to population, applies even more to economic assets and output. Cities are engines of growth and firms prefer to locate in urban centers with good access to labor markets, complementary inputs and customers. Increasing returns and specialization raise productivity to levels not achievable in rural areas. Each unit of area therefore generates far greater output and hosts a larger stock of economic assets. Estimates of GDP for cities are not widely available, except for a few countries and some of the larger world cities. These suggest that urban output per capita tends to be several times higher than in rural areas. This reflects the concentration and greater economic value of productive assets—as well as public infrastructure and private assets such as homes—in cities. Relative exposure of economic assets to natural hazards in cities will therefore be considerably higher than in rural areas.

These dynamics have profound implications for urban disaster risk profiles. With climate change, event probabilities may increase for hydro-meteorological hazards. Vulnerability—the characteristics of exposed assets or people that make them more or less likely to be damaged by a hazard event—may also increase initially as fast urban growth leads to rising slum populations in sub-standard housing. But the main driver of hazard risk in urban areas today and over the next few decades will simply be the greater accumulation of exposure, likely exceeding the contribution of climate change (e.g., ISDR 2009).

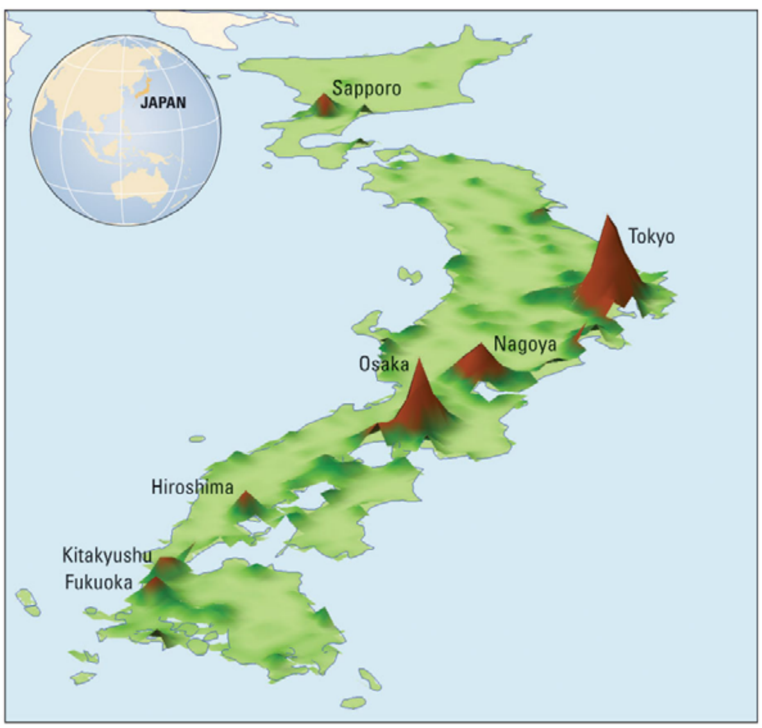
But some factors may reduce urban risk

In contrast to these factors that might increase risk, urban areas also have characteristics that mitigate possible hazard impacts. First, urbanization tends to be associated with increasing incomes and better education. These generally reduce damages from hazards (Kahn 2005, ISDR 2009). Loss of life is much lower in rich countries. Economic damages tend to be larger, but when measured as a share of exposed wealth, they are smaller than in poor countries. With higher incomes, better quality housing can be built, mitigation measures are more affordable and better institutions lead to enforcement of rules and regulations aimed at reducing vulnerability. Secondly, there are scale economies in risk mitigation. For example, risk control measures benefit more people, enforcement of standards is cheaper, and the cost of first responder services is shared by a larger population.

Economies of scale and agglomeration change the way people and firms respond to natural hazard risk

The defining characteristic of cities is the concentration of people and economic assets in a relatively small space. Globally, a conservative estimate of economic concentration or density suggests that half of worldwide GDP is produced in just 1.5 percent of the world's land, almost all of it in cities (World Bank 2008 /WDR09). This area is home to about a sixth of the world's population. The economic landscape in Japan shows tall mountains around Tokyo and Osaka (Figure 3). In fact, Tokyo -- the largest city in the world with 35 million people – has a quarter of Japan's population, packed into less than 4 percent of its land.

Figure 3: High economic densities around Tokyo and Osaka (GDP per sq. km)



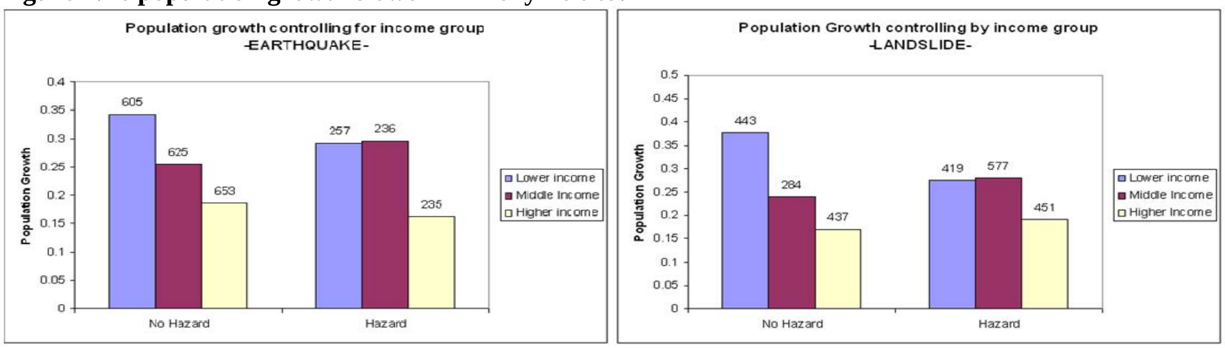
Source: World Development Report (2009) - Reshaping Economic Geography

When cities function efficiently, they attract firms in industries and services that value agglomeration economies. In fact, agglomeration economies are the reason that cities exist (Duranton and Puga, 2004). They can occur within a given sector, when firms in the same industry concentrate in a metropolitan area to enjoy access to specialized suppliers or expertise that could not be supported with lesser concentrations. Or they can occur across industries, as when firms from different industries benefit from collocating because the diversity of their skills and experiences encourages innovation. Agglomeration economies can be in consumption as well as production, as large cities attract residents because of the wider variety of restaurants, museums and other forms of entertainment. Empirical research confirms that agglomeration economies are substantial. Studies show, for example, that average productivity increases by 4 to 20 percent with each doubling of metropolitan population, and that the productivity effects are particularly pronounced in certain industries, among them some services (Rosenthal and Strange, 2004; Graham, 2006).

Agglomeration economies change how households and firms respond to natural hazard risk. People are unlikely to stay away from cities and urban residents do not tend to move out even when faced with significant hazard risk. If cities deliver economies of scale and agglomeration, the stakes of being physically close to economic density will be high enough for people not to be deterred by hazard risk. Risk mitigation (e.g., retrofitting buildings) and risk transfer (e.g., insurance) will be the main responses to risk. Mitigation is likely to have a positive benefit-cost ratio, and will be the mainstay of efforts in countries with weak information. In the longer term, as credible information on risk becomes available, the large market will be attractive for risk pooling through insurance.

But if cities are inefficient—either due to weak institutions or bad policies—the economic gains from agglomeration will be low, making these locations less attractive to households and business owners. In those cases, growth may slow down further in cities facing risk from natural hazards. Data from global cities with more than 100,000 people suggests that population growth between 1960 and 2000 is slower in low income country cities at risk from earthquakes—middle income and high income country cities do not exhibit any statistical change in growth rates (Figure 4). Similar patterns are found for landslide risk.

Figure 4: Is population growth slower in "risky" cities?



Data Source: Dilley et al. (2005)

In fact, land use regulations that try to manage city sizes and urban form often end up hurting the urban economy by artificially raising prices of land, and pushing many poor people to live in locations at risk from environmental hazards. Regulation of development densities is the main instrument used by city planners to manage city development. Cities try to achieve lower densities in several ways. One approach is imposing building-height limits. These limits are imposed via a restriction on a structure's floor-area ratio (FAR), which equals the total floor area in the building divided by the lot size. For example, a four-story building that covers half the lot area has an FAR of 2.0. A limit on FAR prevents the developer from constructing a tall building. Throughout the world, zoning regulations usually specify maximum FAR values in different parts of a city. But these FAR limits typically do not represent severe constraints on development, as they often roughly match the developer's preferred FAR value in a given location. In effect, FAR restrictions often "follow the market," providing a way for city planners to ensure that the character of development does not greatly diverge from the norm in a given area.

However, in Mumbai planners went against the grain of markets. FARs were introduced in 1964 and set at 4.5. Rather than raising the allowable density over time to accommodate urban growth, planners in Mumbai went the other way lowering the index to 1.3 in 1991. These regulations hold Mumbai's buildings to only between a fifth and a tenth of the number of floors allowed in major cities in other countries. The city's topography should exhibit a high-density pattern similar to that in Hong Kong, China, but it is instead mostly a low-rise city. Space consumption averages 4 m^2 – one-third the level in Shanghai and less than one-fifth of that in Moscow. People still keep coming to Mumbai, but face skyrocketing housing prices and rapid slum formation.

Evidence from developed and developing countries show that land use regulations designed to manage city size and guide urban form often end up hurting economic fortunes of towns and cities. By getting in the way of the urban area's capacity to accommodate people and firms, place-specific regulations can lower productivity and artificially increase the price of urban land and housing services. And by increasing the scarcity of land (and housing) in the formal sector, these regulations encourage informal development—often in locations at risk from natural hazards.

3. The valuation and distribution of disaster risk in cities

Valuation

Evidence from empirical research is ambiguous about the extent to which natural disaster risk is priced into property values. Much of the empirical evidence is based on estimation of hedonic models, where land and housing prices reflect the value of a property's physical characteristics (such as size), as well as the characteristics of its neighborhood and the services and amenities available in the area (Lancaster 1966; Rosen 1974). The idea that the present value of a property is the sum of benefits derived from it is formally described as capitalization. These models have been used extensively to study variation in housing prices and location decisions. For example, the bid-rent models of Alonso (1964), Muth (1969) and others were based on the observation that land values decline with distance from (monocentric) city centers, as the cost of commuting increases, and that this variation is reflected in the price of housing. Similarly, one can examine how the value of land or a property changes (decreases) in locations that are at risk from natural disasters.

Information on the location and source of risk should be capitalized in home prices. In Istanbul property values in 2000 were found to be lower near the fault lines in the Sea of Marmara compared to those further away (Onder et al. 2004). In contrast, proximity to the fault line had no impact on property values when data from 1995 were used for the analysis. Presumably, information on distance from fault lines influenced property values as households became more conscious of hazard risk only after the Kocaeli earthquake in 1999.

Similarly in the United States, flood zone disclosure is mandatory in some areas of North Carolina, so buyers are aware of flood risk before buying a property. Using a hedonic property price model, Bin et al. (2008) find that the property market reflects geographic differentials in flood risk, reducing property values on average by 7.3%. The market capitalizes risk as flood insurance premiums equal the discount in property values. Bin and Polasky (2004) also examine the effect on property values in North Carolina of Hurricane Floyd (September 1999), which affected two million people and damaged property worth 6 billion dollars. Most properties did not have flood insurance before the hurricane but the event increased the awareness of flood hazards and houses located on the floodplain faced a price reduction from 4% to 12%. However, price reductions were greater than the capitalized value of insurance premiums suggesting the existence of non-insurable costs associated with flooding.[4]

There are two common concerns regarding conventional hedonic approaches discussed earlier. The first concern regards the imposition of a functional form, which can result in specification bias. The fact that theory does not suggest specific functional forms for outcome equations suggests that imposing one may require strong assumptions. The second issue is that conventional regression identification strategies often compare apples to oranges, as there is considerable heterogeneity in the underlying variables used in the analysis. To address these problems, we utilize a micro level database of 800,000 buildings in the city of Bogotá to examine if hazard risk was reflected in land values.

For our analysis we match properties (without using functional form restrictions) on a range of characteristics based on available data. These include quality of construction, use of property (residential, commercial or industrial), and distance from the city center. In principle, the only difference among matched properties is their level of hazard risk.

[4] The reduction of the property values on average was $7,460 and the increase in premiums for flood insurance was $6,880.

Our main interest is in identifying if property values in riskier areas are lower, thereby capitalizing "dis-amenities" from potential risk. We consider two approaches for comparing property prices. First, we group properties into deciles of seismic risk, and compare prices for matched properties in two adjacent deciles. For example, comparable properties in the riskiest decile are valued 7114 pesos less than properties in the next riskiest decile (see comparisons between the 9th and 10th decile in Table 1). Similarly we see lower property values in locations with higher risk for most deciles of seismic risk.

Table 1: Propensity score matching results

10th decile: most risky neighborhoods. 1st decile: least risky neighborhoods

Propensity Score Values	Treated	Controls	Difference in property values	Standard Errors
9th vs. 10th decile	107,864.21	114,981.45	(7,117.24)	438.65
8th vs. 9th decile	123,985.18	124,605.55	(620.37)	292.96
7th vs. 8th decile	135,456.52	183,383.70	(47,927.18)	561.85
6th vs. 7th decile	183,383.70	177,011.83	6,371.87	683.37
5th vs. 6th decile	194,592.08	207,884.16	(13,292.08)	755.68
4th vs. 5th decile	207,884.16	189,487.95	18,396.21	663.00
3rd vs. 4th decile	193,627.91	234,565.17	(40,937.26)	2,166.93
2nd vs. 3rd decile	232,855.67	188,860.65	43,995.02	2,043.64
1st vs. 2nd decile	188,860.65	193,513.79	(4,653.14)	454.74

Source: estimates for this paper.

Second, we identify ten neighborhoods facing the highest seismic risk, and examine if property prices are significantly higher in locations that are further away (Figure 5 shows where these neighborhoods are located). These include La Picota Oriental, San Juan Bautista and La Arbolada Sur. Estimates in Table 2 confirm that difference between properties in the riskiest neighborhoods and others locations increase with distance. For instance, property values per unit of construction are higher by 13,434 pesos in locations closest to the riskiest neighborhoods, and the difference increases to 28,265 pesos for locations in the 20th-204th percentile of distance. For the furthest 20 percentile, the difference is 124,533 pesos. Details on the econometric work can be found in Atuesta et al. (forthcoming).

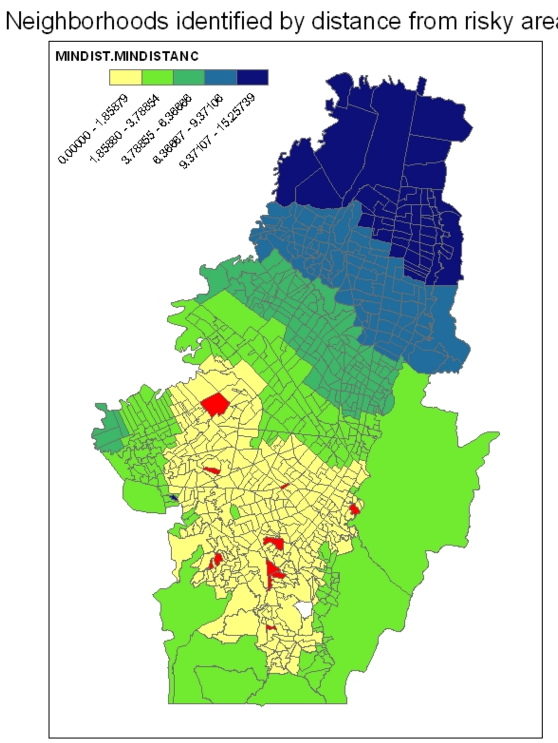
Table 2: Property prices are lower in locations with high earthquake risk: Bogotá

Treatment group: 10 most risky neighborhoods. Quintiles calculated based on distance to these neighborhoods.

Comparison group	Treated	Controls	Difference	Standard Errors
1st quintile vs. 10 risky neighb.	101,684.48	115,118.53	(13,434.06)	818.11
2nd quintile vs. 10 risky neighb.	101,684.48	129,949.62	(28,265.14)	917.95
3rd quintile vs 10 risky neighb.	101,684.48	128,633.04	(26,948.56)	1,027.02
4th quintile vs 10 risky neighb.	101,684.48	192,346.51	(90,662.03)	893.52
5th quintile vs 10 risky neighb.	101,684.48	226,237.97	(124,553.49)	1,120.82

Source: estimates for this paper.

Figure 5: Neighborhoods at highest risk from earthquakes: Bogotá



Data Source: Cadastre, Bogotá

Investors actively trade-off disaster risk with gains from economic density. In addition to the city or location specific analysis, we examine how investors value risk from natural disasters. Data from a recently compiled dataset of a sample of global cities provides some insights. Gomez-Ibañez and Ruiz Nuñez (2006) constructed a dataset of central business district office rents for 155 cities around the world in 2005 to identify cities where rents seem elevated or depressed by poor land use or infrastructure policies. Their dataset also includes information on many factors that determine the supply and demand for central office space such as construction wage rates, steel and cement prices, geographic constraints, metropolitan populations and incomes.

We link this information to the natural disasters hotspot dataset (Dilley et al. 2005), and examine if city demand – as reflected in office rents, is sensitive to risk from natural disasters. Gomez-Ibañez and Ruiz Nuñez (2006) focus on offices in the primary business district, which they define as the district having the highest density of employment; a very large, if not the largest, concentration of offices; and the highest rents in the metropolitan area. As we are interested in the tradeoff between economic density and disaster risk, using the central business district works well for our analysis.

Table 3: Natural Hazards and City Demand

Dependent variable (log rent)	1	2	3	4	5	6
Vacancy rates (2007)	-0.0291***	-0.0284***	-0.0273***	-0.0320***	-0.0309***	-0.0319***
(urban demand)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Urban density (logs)	0.193***	0.478***	0.477***	0.470***	0.484***	0.473***
(agglomeration)	(0.06)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)
Urban Population (logs)	0.066	0.128**	0.193***	0.211***	0.223***	0.215***
(scale effects)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Construction wages (logs)		0.339***	0.251***	0.256***	0.277***	0.261***
(developer costs)		(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Average low temperature			-0.0129***	-0.0128***	-0.0123***	-0.0127***
(geography)			(0.00)	(0.00)	(0.00)	(0.00)
Pollution concentration			-0.00244	-0.00236	-0.00217	-0.00231
(environment disamenity)			(0.00)	(0.00)	(0.00)	(0.00)
City in earthquake zone				-0.322***		-0.256
(hazard var)				(0.09)		(0.18)
City earthquake severity					-0.0596***	-0.0152
(hazard var)					(0.02)	(0.04)
Constant	4.657***	1.855	2.692*	2.747*	2.302	2.636*
	(0.48)	(1.61)	(1.55)	(1.47)	(1.49)	(1.50)
Observations	122	119	119	119	119	119
R-squared	0.304	0.513	0.57	0.616	0.61	0.617
*** p<0.01, ** p<0.05, * p<0.1						
Standard errors in parentheses						

Source: Estimates produced for this paper

Estimates from regression analysis of office rents are presented in Table 3. These estimates should be considered as indicators of correlation—not precise magnitudes of causal relationships. The first three columns report results of estimating how office rents reflect city demand and supply. Vacancy rates have a negative effect, reflecting lower city demand, while urban density has a positive effect – reflecting economies of agglomeration. Construction wages have a positive effect on rents as construction labor accounts for about half the non-land costs of constructing an office building. Surprisingly, pollution concentration is not associated with office rents.

In column 4, a variable on earthquake risk (whether the city is in an earthquake zone) is introduced into the regression. We find that being in an earthquake zone has a negative effect on office building rents – reflecting lower demand for a city. Similarly, earthquake severity (column 5) also has a negative effect on city demand. These estimates suggest that business owners trade off agglomeration economies with seismic risk in making investment choices across cities. Similar regressions for floods and cyclones did not generate statistically significant estimates.

Private investment in mitigation is capitalized into property values. Just as natural disaster risk reduces property values, investments in mitigation such as earthquake proofing structures are likely to be recovered through increases in property prices. Nakagawa et al. (2007) use a 1998 hazard map of the Tokyo Metropolitan Area to examine the extent to which housing rents reflect earthquake risk as well as earthquake-resistant materials used in construction. The study exploits the fact that the Building Standard Law was amended in 1981 to enhance the earthquake-resistant quality of buildings, and that a building constructed after 1981 needed to conform to the new standard of earthquake-resistant quality. The authors find that the rent of houses built prior to 1981 is discounted more substantially in risky areas than that of houses built after 1981. In Tehran, Willis and Asgary (1997) interview real estate agents to examine the capitalization of investments in Earthquake Risk Reduction Measures (ERRMs) on property values and assess if home buyers are willing to pay for ERRMs incorporated into a house. The estimates suggest significant price differences between earthquake-resistant and nonresistant houses, across all districts in the city – however, the limited adoption of ERMMs in Tehran may be due to limited public information of earthquake risks.

Spatial distribution of hazard risk

There is heterogeneity in how households respond to information on risk. When facing risk from natural disasters, people can move out of harm's way; they can self-protect by building structures less vulnerable to damage; or they can insure. Empirical research on how people and housing markets responded to Hurricane Andrew -- one of the largest natural disasters to affect the United States, shows that the economic capacity of households explains most the differences in how different groups respond to the hurricane damage (Kerry Smith et al. 2006). In 2000, households with annual incomes over USD 150,000 were the only group likely to be attracted to areas with a comparable "type" of household—i.e. to areas where the same income level households lived in 1990.

As property prices in the worst affected areas reduced the most, low income households responded by moving into low-rent housing being offered in these locations. On the other hand, middle income households moved away to avoid risk, and the wealthy, for whom insurance and self-protection was the most affordable, did not change where they lived.

Poor people "sort" into low rent locations – which are often at higher risk to natural hazards. The problem is particularly acute in developing countries where there is a divide between the formal and informal markets for land. While formal developments may respect land use regulations, informal settlements are often located in hazard prone locations, such as on hill slopes, close to river banks, or near open drains and sewers. In Dhaka for example, informal settlements are developing across the metropolitan area, with many residents lacking basic public services and in locations at risk from flooding. In fact, most informal settlements do not have access to a public toilet within 100 meters, and 7,600 households in 44 slums live within 50m of the river (World Bank 2005, Dhaka Urban Poverty Assessment).

For the city of Bogotá, we use the same database discussed earlier to examine if poor people are at greater risk from natural hazards – particularly earthquakes. By collecting data on the location of properties, income levels of households, and linking this to information on hazard risk, we find evidence that poor people face disproportionately high burden of hazard risk, as they sort into high density low rent properties, which are located in higher risk locations. Figure 6 shows the distribution of seismic risk on the left panel and residential location of the poor households in Bogotá.[5] In comparison, Figure 7 shows the spatial distribution of the richest twenty percent of the city's households. From these maps, it becomes clear that poor households are located in areas with higher earthquake risk, which are towards the western and southern parts of the city. On average the city's poor live in locations that have twice the seismic risk compared to where rich households live.

[5] We include households who fall in the lowest twenty percentile of the city's income distribution.

Figure 6: Bogotá -- poor people face higher risk from earthquakes

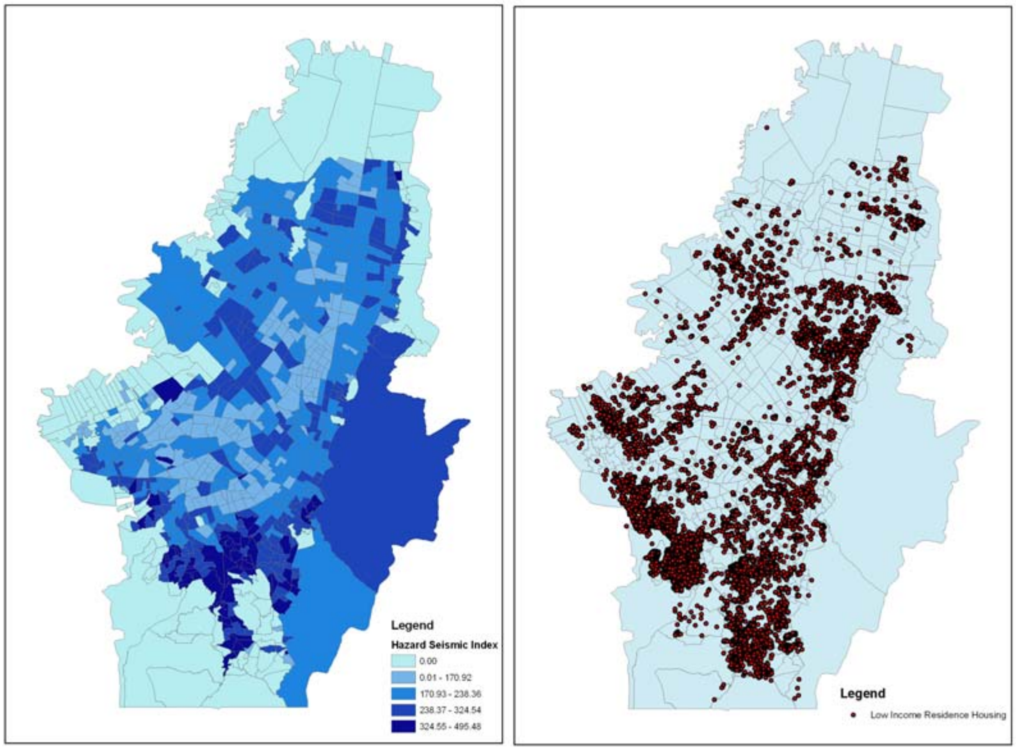
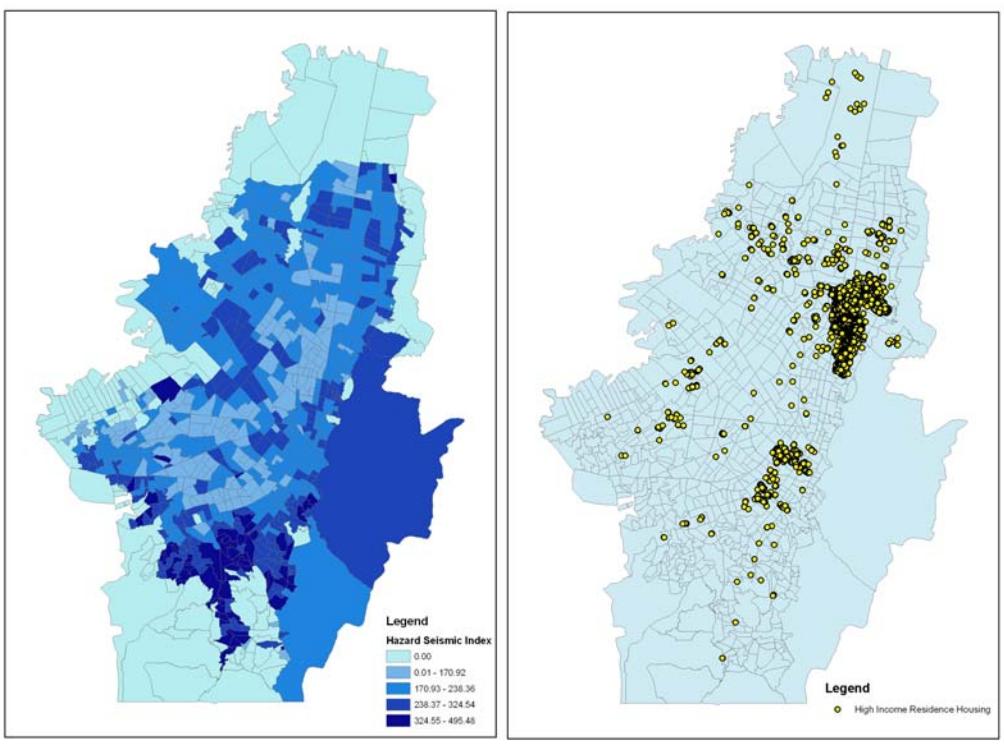


Figure 7: Bogotá – rich people sort in lower risk locations



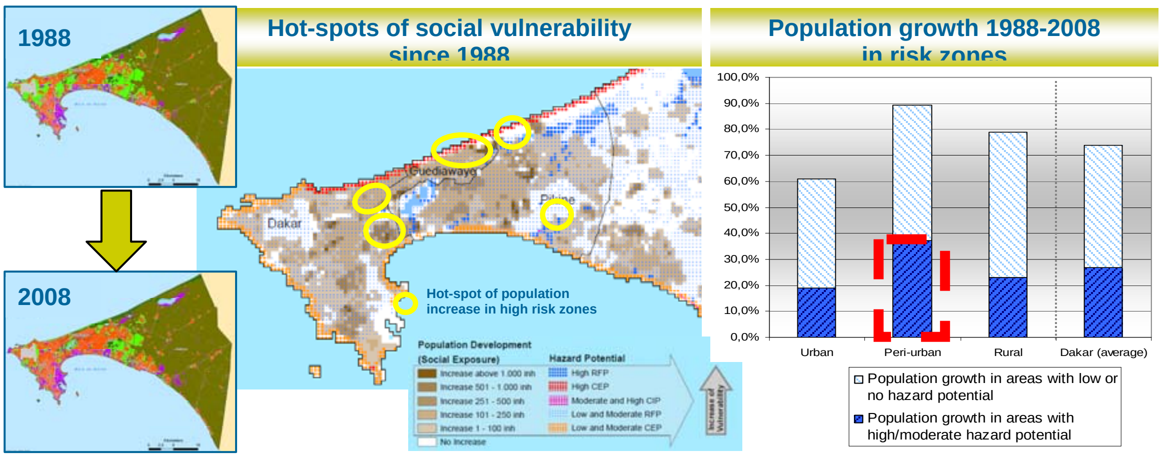
Source: Cadastre data from the city of Bogotá

Our empirical analysis highlights that households and businesses value the dis-amentiy of natural hazard risk in deciding where to locate as reflected in a negative capitalization of hazard risk in property values. We find that earthquake risk has a negative association with land values. We also examined if people living in areas at risk from natural hazards (earthquakes, landslides, and floods) invested in improving building quality when they were close to centers of economic activity. The underlying intuition is that the net benefits from investing in mitigation have a higher pay-off when the value of assets at risk is higher. To examine this hypothesis, we examined the spatial patterns of investments in structural upgrades and compliance with building standards among low income residents. Regression analysis shows that compliance with building codes is higher and quality of construction better in dwellings close to the city's economic center. This is indicative that individual investment in mitigation increases with economic density as people have more to lose with disruptions due to natural hazard events.

Residents of informal settlements trade-off housing services and environmental safety to be physically integrated in the labor market. Evidence from Pune, India tells us that poor households prefer to live close to their work place – thus, living in centrally located slums allows slum dwellers to access jobs. Many of these slums are located on riverbanks that are prone to flooding or on hillsides. These residents are also willing to pay a premium to live in areas that are composed of households sharing their language, religion, level of educational attainment and average length of tenure in the neighborhood – community structure and social capital are very important. An assessment of the welfare impact of relocating slum dwellers from their current locations to less desirable peripheral locations shows that relative to no intervention (allowing slum dwellers to be in their current location, with the same service levels and housing conditions), upgrading services in situ is the only policy intervention examined which increases welfare of these slum dwellers. Moving to alternate locations is welfare reducing – showing that slum dwellers are willing to put up with the threat of poor housing and environmental conditions to be physically integrated in the labor market (Lall et al. 2008).

The challenges of informal development in hazardous locations get severe when local governments do not have the administrative capacity to enforce land use codes or monitor the development of new settlements. In Dakar, for example, the fastest population growth in the metropolitan region over the last 20 years happened in peri-urban expansion areas and 40% of the population growth in these peri-urban areas occurred on high-risk lands, a percentage that almost doubled that in rural and urban areas (Figure 8).[6] The physical vulnerability and risk in peri-urban areas are compounded by weak institutional capacity than in traditionally urban or rural areas.

Figure 8: Weak administrative capacity and increasing hazard risk in peri-urban areas: Case of Dakar



Source: Wang and Montoliu (2009)

Why are peri-urban areas more vulnerable? Human settlements in peri-urban areas in developing countries are exposed to greater risks due to the following factors: (a) settlements are often unplanned due to lack of planning standards and land-use plans; (b) lack adequate infrastructure; (c) weak property rights; (d). located in precarious areas; and (e) weak institutional structures at the local level. However, as illustrated by the case of Dakar, peri-urban areas are one of the fastest growing areas as they provide cheap and readily available land for settlement. In fact, Pelling (2003) argues that the peripheries of expanding cities tend to grow more rapidly compared to central business districts. In

[6] Satellite data were used to map: (a) the pace and direction of growth of the metropolitan area of Dakar over the past 20 years into the surrounding rural areas; (b) potential disaster hotspots resulting from models predicting the impact of selected types of disaster (e.g. flood, coastal surge/erosion); and (c) population density and the nature of build tissue in the metropolitan region and beyond, to distinguish dense urban from peri-urban and rural growth.

mega-cities, annual growth rates of peripheral population tend to reach around 10-20 percent compared to central business districts.

4. Implications for public policy

Hazard management is a task both for the public sector and for private households and firms.

For the public sector in cities, this includes ensuring the safety of municipal buildings and public urban infrastructure, encouraging and supporting private sector hazard risk reduction, and developing first response capacity. A considerable share of hazard risk stems from relatively small but frequent events which cause localized damage and few injuries or deaths (Bull-Kamanga et al. 2003). For instance, an analysis of detailed records of 126 thousand hazard events in Latin America showed that more than 99 percent of reported events caused less than 50 deaths or 500 destroyed houses (ISDR 2009). In aggregate, these accounted for 16.3 percent of total hazard related mortality and 51.3 percent of housing damage. The probability of larger events may or may not be predictable. For instance, a city may be in an earthquake risk zone, but the location specific ground shaking probabilities are not known. *Individual* dwelling unit level mitigation is therefore necessary everywhere in the general area of high earthquake probability. For other hazard types like landslides and floods, potential risk areas can be more easily delineated. Households in the risk zone have limited options for protecting against these hazards individually. But some form of large, *collective* risk mitigation is sometimes feasible, such as levees or slope stabilization measures. The following paragraphs discuss the role of public policies in supporting individual versus collective hazard risk reduction.

Good urban management goes a long way towards reducing urban hazard risk, especially the small-scale, under-the-radar-screen events.

Natural disasters are the man-made consequences of geo-physical hazard events. This applies for large as much as for small-scale hazards. But smaller disasters can be more easily avoided. Good routine urban management already reduces disaster risk considerably. By mainstreaming hazard risk reduction in everyday urban planning and management, negative consequences can be avoided early on. For instance, floods in developing country cities are often the consequence of insufficient maintenance of drainage systems. In South Asia, monsoon rains encounter drainage ditches that are used as garbage dumps, losing their function to transport runoff away from settlements. For example, Mumbai spends about 1 billion rupees ($25 million) per year on preparing for the monsoon rains. Yet, the 2005 monsoon caused 300 deaths.[7] Unchecked urban development that leaves too little porous green space further increases runoff and flood risk.

Besides hazard-proofing urban infrastructure investments and improving service provision such as garbage collection, land use planning is another core task of city government that has an influence on hazard risk. For hazard risk reduction the main objective is to prevent development of hazard prone land. In fast growing cities land for new development is scarce. Poor people often cannot afford transport charges and need to locate close to city centers to have access to labor markets. They often end up on the least desirable land such as flood plains or steep and unstable slopes. To reduce settlement of these areas cities need to use a combination of regulation and incentives. Zoning enforcement must attempt to prevent settlement of the most risky areas. This is not easy since informal settlements can spring up overnight and once established are difficult to relocate.[8] To absorb a growing population while excluding risk-prone areas, cities need to ensure a supply of suitable land for new development. As these areas will be further from economic opportunities, land development must be accompanied by affordable transport services.

These problems are not easily addressed. However, there are several cities that have started to institutionalize disaster risk within their local policies. Table 4 provides a snapshot of policies from Bogotá, Metro Manila, Istanbul and Seoul. It is clear that there is no single template for disaster risk management. Table 4 illustrates that there are different models of disaster risk management and the experience varies across countries.

[7] http://uk.reuters.com/article/homepageCrisis/idUKBOM301508._CH_.242020080528
[8] To prevent settlement of steep lands in Bogotá, the city government establishes communal facilities in those areas such as public parks or cemeteries. Local residents then help prevent settlement as they benefit from these amenities. (Francis Ghesquieres – pers.comm.).

It is evident that a key ingredient is the existence of strong institutional capacity at the local level.

In any case, most developing country cities are severely resource and capacity constrained, and they face a backlog of public investment while dealing with continued population growth in part through an influx of new residents. Yet, these cities will invest billions of dollars over the next years in public infrastructure and services as many of them will double in size over the next three decades. Mainstreaming risk reduction in urban planning and management will help reduce risk and at a lower cost compared to ex-post mitigation.

Table 4: Experiences of selected cities on Disaster Risk Management (Source: http://www.emi-megacities.org/megaknow)

City	No. of Local Governments under Jurisdiction	Legislation for Disaster Risk Management (DRM)	Key elements of Disaster Risk Management (DRM)	Stakeholder Involvement	Experience
Bogotá, Colombia	20 localities	Established in 1987. DRM is governed by the District System for Emergency Prevention and Attention (SPDAE).	- A national plan for prevention and attention of disasters has been prepared which was incorporated in the territorial and land-use plans (POT) for Bogotá Metropolitan area in 1998. - In 1995, a resettlement plan was been initiated for informal settlements residing in high-risk zones to relocate households to safer areas.	Strategic alliances between institutions, academia and private enterprises	The city has made concerted efforts to ensure households avoid locating in precarious areas. However, efforts are weak in adjacent municipalities like Soacha, where technical capacities are limited.
Istanbul, Turkey	N/A	Since 1999, legal reforms in the country provided metropolitan cities greater jurisdictional authority over land and buildings.	-Metropolitan Municipality of Istanbul established AKOM, a 24/7 state of the art disaster coordination system. -Municipalities increased authority over building construction supervision and compulsory earthquake insurance laws	N/A	Bureaucracy, weak enforcement of norms and standards and limited involvement of local governments
Metro Manila, Philippines	17 Local Government Units (LGUs)	Apex Organization - Metro Manila Disaster Coordinating Council. All LGUs have their own Disaster Coordinating Councils.	-Each LGU prepares its own comprehensive land use plan which is submitted to Housing and Land use Regulation Board for ratification.	N/A	DRM is focused on response.
Seoul , South Korea	25 Self Governing Districts (Gu)	2001 Comprehensive Earthquake Prevention Plan	- Requires existing building to be tested against seismic activity based on earthquake resistant design standards from 1999 to 2005.	2001 action plan involving Seoul Red Cross and incorporates a public-private partnership for local earthquake management plan	N/A

For individual-level risk reduction, a core task for cities is to provide the information for land, housing and insurance markets to operate efficiently.

Consider the city government's role in supporting these activities. A core task of the urban public sector is simply to coordinate the production and wide dissemination of credible information on disaster risk. Such information is often produced by private firms as well, but selective disclosure creates information asymmetries that put households at a disadvantage. Data on hazard probabilities and vulnerability of structures and people feed into comprehensive risk assessments. These should be considered a public good, accessible to all. [9] Such information then allows residents to make informed location choices, enables markets to price hazard risk appropriately, provides the basis for the emergence of private insurance markets, and it serves as a sound basis for transparent zoning decisions and other land use restrictions.

Disaster risk varies across space, so information on hazard event probabilities, exposure and vulnerability needs to be collected and disseminated spatially. New technologies, such as satellite images with a resolution high enough to replace far more expensive air photos and global positioning systems that facilitate field data collection, have made it easier and cheaper to collect geographic data. Easy-to-use geographic data browsers (such as Google Earth) make spatial data available to everyone. Most importantly, while hazard mapping has been performed for many decades, new technologies allow constant updating of information at relatively low cost. Making these technologies accessible to cities—not only the largest, but also smaller and medium sized cities with limited local capacity—should be a priority for national governments and donors.

For large-scale collective hazard risk reduction investments, the costs and benefits depend in large part on the dynamics of the urban economy.

The above portfolio is something cities *should* do to support risk reduction. The decision to invest in larger protective infrastructure is more complex. For instance, if parts of a city are at risk of flooding from river overflows or storm surges, large scale infrastructure

[9] Robert J. Murnane, "New Directions in Catastrophe Risk Models", Baseline Management, October 9, 2007. Risk modeling companies typically use proprietary models and require non-disclosure agreements with licensees.

investments in dams or levees can reduce that risk. Such investments raise several important questions.

Do the benefits justify the costs? Investments in large scale infrastructure compete with other demands for scarce resources in developing country cities. The cost-benefit calculation largely depends on the value of land. In dynamically growing cities, where land is scarce, large scale investments to make land habitable or reduce significant risk may well be justified. An analogy is large-scale land reclamation in cities such as Hong Kong, China; Singapore; or around the urban core of the Netherlands. Limited alternative expansion options in the vicinity of high economic density raise the value of land significantly. This shifts the cost-benefit ratio in favor of large protective investments. A strict test is whether a developer would, in principle, be willing to pay a price for the reclaimed or protected land that reflects the cost of the intervention.

The viability of large scale disaster mitigation infrastructure will be very different in cities with a stagnant economy and little or no population growth. Today this is largely a phenomenon of mature economies with demographic decline or strong geographic shifts in economic and population centers (Pallagst 2008). Examples are the former socialist countries in Europe but also parts of Scandinavia and the Mediterranean countries, as well as the old industrial core of the US Midwest. Over time, given demographic trends in many middle income countries, “shrinking cities” may also emerge in some of today’s emerging economies, for instance in East Asia.

The best known example in a natural disaster context is New Orleans. Public investments in the wake of Hurricane Katrina have sparked a vigorous debate on the role of large scale protective investments to encourage the rebuilding of New Orleans within the pre-Katrina city limits. It is estimated that $200 billion of federal money will be used to rebuild the city. Some have argued for providing residents of areas behind massive flood control infrastructure with checks or vouchers, and let them make their own decisions about how to spend that money—including the decision about where to locate, or relocate (Glaeser 2005). The choice is between spending $100 billion dollars on infrastructure for city residents vs. giving each residents a check for more than $200,000 – in a place where annual per capita income is less than $20,000. From an urban economics perspective, it may therefore not be the best use of scarce funds to invest in rebuilding large scale protective infrastructure in New Orleans, a city in decline that reached its peak of economic importance in 1840.[10]

What are the distributional impacts? Large scale protective infrastructure will turn undesirable land—often the only space available for the poor—into coveted real estate. Development of this land may well displace poor residents who will have no place to go but other risk-prone parts of a city or places that are far from economic opportunity. These displacements need to be anticipated by requiring set-asides for low income households, designing proper compensation mechanisms, socially responsible resettlement schemes, or alternative housing options with good accessibility to jobs and services. Planning protective infrastructure must therefore be embedded in broader urban development planning. The costs of mitigating distributional impacts need to be considered in the overall cost benefit analysis. This may shift the balance in favor of more traditional risk reduction strategies such as early warning or mitigation at the individual level.

Will the investment be climate-proof? Engineering designs for hazard resistant structures typically follow a risk based approach. For instance, according to the American Society of Civil engineers, in the United States major dams are designed so that the probability of a failure causing more than a thousand fatalities is less than once every 100,000 to 1 million years. Estimating these risks is difficult especially where the geophysical baseline information is limited. Furthermore, the level of risk may not be static. With climate change, flood or storm surge return periods may shorten considerably during the life span of long-lived infrastructure. What was once a 1 in 500 year event (or a one in ten chance every 50 years), may become a 1 in 200 year event. Making structures climate resilient requires designs with a high margin of safety. Storm surge protection in the Netherlands is designed to withstand events with a 10,000 year return period. This increases costs significantly. But the alternative is to face higher than expected risks after protective investments have encouraged people and firms to move into harm's way.

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[10] The Civil War and the relative decline of water-based transportation relative to rail caused the city to lose ground, relative to Northern cities, through much of the Nineteenth century. New Orleans' population peaked at 627,000 residents in 1960 and began to decline following Hurricane Betsy in 1965 to 485,000 residents in 2000. (Glaeser 2005).

Do alternative mitigation strategies exist? Some hazard risk is made more severe by human interference in natural systems in the vicinity of urban areas. Increased urban flooding—for instance in South and Southeast Asia—is often attributed to deforestation in upper watersheds. But many scientists believe that the conversion of wetlands to urban use has contributed significantly to more frequent floods (Bonell and Bruiinzeel 2004). Draining wetlands reduces the absorption capacity of soils, removing the natural buffer function of these areas. Restoring the ability of the land to regulate water flow may often be a more cost effective risk reduction strategy with additional ecological benefits.

Large scale protective infrastructure may sometimes be justified on economic grounds where land is scarce and valuable, financial resources are available, no lower cost options exist and environmental impacts can be minimized. But, as the discussion in the previous paragraphs showed, the bar should be set fairly high.

How public policy can encourage individual level risk mitigation

How can public policies help in reducing hazard risk while not disrupting livelihoods of the urban poor? Building capacity in local planning institutions will help limit development in hazard prone areas. But these preventive measures are unlikely to work by themselves. Rather, public policies should try to encourage private investment in hazard risk mitigation without imposing severe constraints on livelihood strategies of residents. Three policies can be of particular relevance here.

Deregulating land markets: In many countries, excessive land regulations have led to shortages in formal land supply in safe areas and driven up prices, making it difficult for many households to enter the formal land market. As discussed earlier, the most pernicious and frequently used land use regulations are restrictions on building heights, which result in highly restrictive markets that lead to inefficient use of land as well as adverse equity consequences. These restrictions increase the geographic size of a city; raise the cost of housing in the city, and price poor people out of the formal land and housing market. This leaves informal and often hazard-prone areas as their only option close to economic opportunities.

A second land-use intervention is the *regulation of development densities*, which similarly reduces housing supply on suitable land. One approach is a minimum lot-size restriction, which limits densities in areas with detached houses by requiring that each structure be surrounded by an ample land area. In 1979 the Federal government in Brazil established the basic legislation at the national level (Federal Law 6766) for developing, approving and registering urban land subdivisions. Among these parameters were a minimum lot size of 125 m², with a minimum frontage of 5 m, and a compulsory donation of 35% of development area for public uses and open spaces.[11] This effectively zoned many poor people out of the formal land and housing market.

Property rights. The literature on property rights provides three primary justifications for titling (Brasselle et al., 2002). First, the "assurance effect", argues that a title will provide households with secure tenure, and thus households will be more likely to invest in their dwelling once the fear that others will benefit from their improvements by seizing their property has been reduced (Jimenez, 1984; Brasselle et al., 2002). Second, the "collateralization effect" argues that a title will provide a household with the ability to use one's property as collateral, and thus provide households with easier access to credit markets (Feder et al., 1988; Besley, 1995; Feder and Nishio, 1999; De Soto, 2000; Brasselle et al., 2002). Third, the "realizability effect" argues that being given a title will lower the transaction costs of transferring one's property to others (Besley, 1995; Brasselle et al., 2002). Overall, households will be more willing to invest in improvements, including hazard mitigation, if they are assured to reap the long term benefits while living in their dwelling and through increased home values.

Titling programs however face numerous institutional constraints. These include limited down marketing of general and housing specific finance. Lenders are unwilling to provide loans as most residents of informal settlements also work in the informal sector and do not have regular incomes, which make it difficult to assess their repayment capacity. Further, property titles are often disputed, which makes it difficult to use them as collateral. In addition to institutional constraints, the demand for titling may vary

[11] Lall, Wang and DaMata (2007)

across households and individuals, as the better educated and better informed may see the intrinsic value of having a property title for economic investments.

In the Indian state of Madhya Pradesh, the government has implemented slum regularization programs where slum dwellers have been provided with titles, called *pattas*. On average, slum dwellers with titles spend about twice as much on home maintenance and upgrading housing quality compared to other slum dwellers (Lall et al. 2006). In addition to the influence of tenure security on private investment, property rights are likely to be associated with a higher degree of community participation (Lall et al. 2004). Tenure security provides incentives for individuals to invest in the community because the gains from improvements in services can be capitalized in the value of the home. Slum households with titles are more likely to participate in community based service provision—37.5% of the survey respondents with titles participate in community service provision, compared to 28.9% for households without titles. Similarly, in Ecuador, Lanjouw and Levy (2001) show that households with a stronger claim to their property are significantly more likely to participate in activities to improve the community.

Why is risk often not priced into home values and mitigation often not done?[12]

As discussed in preceding sections, the evidence from hedonic analysis of risk mitigation in housing markets is mixed. There is some evidence that known hazard risk and vulnerable building quality lower housing prices. Yet, even in high-risk cities and neighborhoods, mitigation efforts are often scarce.[13] Economic and behavioral reasons provide some possible explanations.

[12] The discussion of the principal-agent problem and possible solutions to it is based on Adhvaryu and Deichmann (2009).

[13] Dr. Richard Sharpe (Earthquake Engineering New Zealand) reported on work in Istanbul. Many areas with highest potential ground acceleration in the likely event of a future earthquake are occupied by five-floor apartment buildings. Inspection of a sample of these buildings suggests that most would not be able to withstand a major earthquake (51% were at high risk, 28% at very high risk). Building collapse will likely lead to high mortality. Yet, structural retrofitting of these buildings is extremely rare at costs of external retrofitting solutions of 19% of reconstruction costs. (R. Sharpe, Presentation at the World Bank, 22 September 2008.).

Limited mitigation in private buildings may be related to housing ownership in cities. In rural areas, most people live in dwelling units owned by the household. The person responsible for the strength of the structure is also the person bearing the consequences if the structure fails. In urban areas, many apartment buildings are owned by landlords who do not live in them, so the person responsible for the structural integrity of the building is not at major risk to be injured or killed when the structure collapses. The relationship between landlords and tenants of residential buildings in urban areas exhibits the properties of the well-known *principal-agent* (PA) problem in information economics. Not only are the objective functions of the two parties different from each other, but their information sets are likely very different as well. Below, we examine how these differences may contribute to the lack of retrofitting of urban residential buildings in developing countries, followed by a discussion of possible policies to increase private mitigation.

Since landlords often live away from the buildings they own, their incentives to retrofit are different from the incentives of their tenants. For the landlord, the consequences of poor construction or lack of retrofitting are related primarily to infrastructure damage. The potential cost of human life, or destruction of tenants' property, may not be incorporated fully in the landlord's investment decision when he does not live in the residential structure himself and when—as is common in developing countries—there is little likelihood of criminal prosecution for negligence in construction or maintenance. Traditional cost-benefit analysis for retrofitting investment, which does not incorporate the expected loss of tenants' lives, show that potential building damages alone are typically not sufficient to justify investment on the part of building owners (Ghesquiere et al. 2006).

The expectation of government aid in the event of a natural disaster further dampens the perceived benefits of retrofitting for the landlord (OECD 2004). Also, studies have shown that house owners may be making decisions based not on an expected utility model but rather using simplified heuristics that do not fully incorporate the probability of disaster, even when it is perfectly observed (Kunreuther and Kleffner 1992). Finally, there is often a high level of mistrust between home owners and contractors, who may provide sub-standard building services. Without independent assessment whether the retrofitting solution is adequate and cost-effective, landlords may not want to risk scarce capital.

Further, in many urban areas of developing countries, building code regulation and enforcement is inadequate, if they exist at all. This lack of regulation, often combined with widespread corruption, diminish the potential legal consequences for the landlord, while making it harder for tenants to pursue legal action. Disasters are often seen as "acts of God," and only gross negligence is prosecuted; in countries where legal institutions are weak, prosecution in any instance may not be feasible (Jain 2005).

On the other hand, the benefits from retrofitting may be high for tenants, since retrofitting enables them to avoid loss of life and destruction of property. Why do tenants then not directly finance, or otherwise initiate, retrofitting in their places of residence? There are several possible answers to this question. The simplest explanation is that individuals are not fully aware of hazard risk which is a function both of the probability of a hazard event such as an earthquake and the vulnerability of their dwelling units. This risk can vary significantly even within a given neighborhood of an earthquake-prone city (Nakagawa et al. 2007). In addition to this concern, the behavioral economics literature shows that especially for the case of very low-probability events like large-scale earthquakes, probabilities are often not accurately assessed, and that individuals adhere to a "selective fatalism," choosing often to downscale the importance or likelihood of events over which they perceive having little or no control (Sunstein 1998). Thus, the costs of a disastrous earthquake may not be accurately perceived and incorporated as a result of this selective reckoning of risk.

Since the benefit of infrastructure investment for risk mitigation is likely to accrue benefits only in the long term on average, individuals' subjective discount rates over time also play a potentially important role in evaluating the costs and benefits of such investment (Kenny 2009). Recent research from development economics (Oster 2005, 2009) implies that because of the multitude of risks often faced by individuals in resource-poor countries, discount rates are likely to be higher than in the developed world, thus creating a high opportunity cost of investments that yield payoffs only in the long-run or not at all.

But even where the risk is generally known, there are a number of possible reasons for tenants' complacency. First, financial constraints, including low liquidity and low access to credit, can be significant barriers to investment. Access to credit is particularly low where owner-residents or landlords have only *de facto*, not *de jure* tenancy such that they cannot use their dwelling as collateral. Second, tenants often do not have the legal authority to make changes to their building's structure. Third, appropriate retrofitting procedures involve structural changes to the entire residential structure, not to individual apartments. Anbarci et al. (2005), for example, have shown that collective action problems like the decision of a building's tenants to invest in retrofitting technology are exacerbated by inequality: heterogeneous agents bargaining for collective action may not be able to agree on an adequate distribution of costs, inducing a non-cooperative equilibrium in which each individual self-insures or does not insure at all (depending on the income level).

Policy options to increase private mitigation efforts

Strengthening building codes and effective enforcement have reduced the number of vulnerable dwelling units in countries such as Japan or the United States. Interestingly, high insurance coverage—typically absent in low income countries—can reduce the incentives to implement loss reduction measures (Kunreuther and Kleffner 1992). Insurance covers the loss of property, but earthquakes and other hazards can also cause high mortality. Governments therefore frequently mandate the implementation of cost effective mitigation; insurance premiums should then reflect the lower risk. But in environments with weak institutions and enforcement, regulation by itself is not sufficient.

Policy intervention is aimed at aligning the objectives of tenants and landlords, and expanding and generating overlap of information sets across the two parties. Under the PA framework, policies toward a solution to the problem of retrofitting differ in the degree of government intervention in markets and incentives. We begin with the least interventionist policy, which is information disclosure. Disaster risk is often imperfectly observed and incorporated into cost-benefit analyses by both tenants and landlords; information campaigns must therefore be directed towards both parties. This information has two components: hazard probability and building vulnerability. First, tenants must be made aware of the risks of living in buildings close to active fault lines and on vulnerable soils. This requires investment in geological surveys and seismic monitoring technology and dissemination of the resulting information as a public good. Secondly, and more complicated, is the assessment of building quality. This requires an engineering assessment of each structure. This is costly, so the question is whether the landlord or the government should cover the cost. A compromise is where an initial public engineering inspection yields a simple vulnerability score. If the score is below a certain threshold, the building owner is required to obtain a more thorough inspection that proves the buildings integrity.[14]

Adequate hazard risk information would increase awareness of the probability of disaster, as well as potentially mitigate the problem of selective fatalism discussed earlier by enabling tenants to realize that the choice of residential housing can mitigate the extent of earthquake risk they face. Since price is often the most easily processed signal of underlying quality, public disclosure of idiosyncratic earthquake risk could also generate a rental market with an informative price gradient (Brookshire et al. 1985).

Providing information to landlords may boost the chances of retrofitting, as well. Landlords may revise their cost-benefit calculations based on more precise probabilities of earthquake risk. However, if the revised (accurate) probability does not change the outcome of this calculation, the public disclosure of the fact that building owners decide to build in relatively high-risk areas or that they do not retrofit buildings in those areas appropriately, could spur the development of a social cost on such negligence in the form of public shaming. This added cost further boosts the probability of undertaking appropriate disaster mitigation investments. Such strategies have been implemented successfully in the control of industrial pollution through public disclosure of emission levels of firms using a simple rating system (Wheeler 2000). The driving forces behind these efforts have been national environmental agencies as well as non-governmental organizations.

[14] New Zealand, a country with high seismic activity, uses this approach.

The previous discussion applies where the information sets of both landlord and tenant are limited. Another important source of inefficiency through PA interaction is informational asymmetry. In particular, it is plausible that landlords have more information than their tenants about the extent of disaster risk and of the safety of their buildings' construction. Landlords have no incentive to reveal this information to tenants, since even landlords who own marginally risky buildings do not stand to benefit from alerting potential tenants.

Policy intervention in this case should be aimed at reducing the extent of asymmetry by making the same information available to both parties. One idea along these lines is to introduce monitoring agreements into rental contracts, although the effectiveness of such agreements would need to be proven in practice. Information on how dangerous a particular building is, both in its location and its construction can be made available to potential tenants through such agreements, enabling them to judge the extent of retrofitting or sound construction accurately. Mandating such agreements would exert pressure on landlords, through the market mechanism, to engage in retrofitting investment. The cost of monitoring—hiring trained engineers to survey and test the construction of buildings—can be borne by some combination of the government, landlords, and tenants.

The final strategy we discuss is direct support to landlords to engage in retrofitting investment, for instance in the form of subsidized credit or tax breaks, or direct penalties for not doing so. This policy involves significantly more government intervention than public disclosure mandates or information campaigns. Policymaking in this arena can benefit from a large literature in economics that discusses optimal contracting methods for different types of principal-agent interaction. For example, Hiriart and Martimort (2006) show that in the context of regulation of environmentally risky firms, mandating an extension of liability for environmental risk to stakeholders (principals) in endogenously formed contracts can be welfare-improving for both parties. The concept of extended liability could potentially be brought over to the landlord-tenant relationship in the disaster mitigation case: if landlords were held liable for the mortality consequences of earthquake disasters that affect their tenants, their cost-benefit calculations would likely change dramatically.

Laffont (1994) similarly advocates the use of optimal contracts for regulation based on the particular type of PA problem. Of interest are contracts that include auctioning of incentives to landlords (which would make for efficient use of government funds), and optimal dynamic contracting under limited commitment, under which the specified contract changes as the landlords investment actions are revealed from period to period. Finally, Gawande and Bohara (2005), who examine law enforcement of oil spills involving US flag tank vessels, find that the optimal contract is a mixture of ex ante incentives and ex post penalties. This carrot-and-stick brand of contracting could be beneficial in the disaster mitigation case as well. Giving landlords monetary incentives to retrofit, and threatening penalties in the case they have not, could be an effective combination.

Using incentives or penalties to align retrofitting objectives may be most appropriate for the construction of new urban residential buildings, and may prove important, given that the urban population in developing countries is expected to grow dramatically in the next quarter century. The demand for new residential buildings in urban areas is likely to be directly proportional to this population growth, and so the opportunity to intervene before construction is ripe. Some form of direct support during this period, paired with public disclosure agreements of the sort discussed above, could provide significant monetary and non-pecuniary incentives to landlords to construct buildings capable of withstanding the earthquake risks they face. As with all types of subsidies for hazard risk reduction, however, these need to be carefully designed to avoid moral hazard that can reduce incentives for autonomous risk reduction efforts or encourage building in areas of clearly delineated high risk—as is often the case with subsidized risk transfer such as flood insurance.

Urban public finance implications

Financing local infrastructure and public services is challenging in most developing country cities. In addition, planning for and financing infrastructure to reduce vulnerability to hazards that may only affect certain parts of a city become particularly challenging as user charges are often not adequate for cost recovery. From an efficiency perspective, a simple, yet often forgotten economic principle—the Henry George

Theorem, named after a 19th century American political economist and activist—can be used to help cities finance public goods and infrastructure. The basic Henry George principle: city governments should implement a land-value tax that provides the incentive to develop land to its highest value and enhance economic density.

The success of Taiwan, Hong Kong, and Singapore in becoming major commercial centers is in large part because much of their public finance is based on taxing land values (Peterson 2008). Hong Kong's revenues came mainly from selling land leases, with low taxes on trade and commerce. Johannesburg and Sydney have levied real estate taxes on land values only. Some cities in Pennsylvania have had a two-rate system, where land values are taxed at a rate higher than the tax on improvements. Property taxation is widely used in developed countries (it represents up to 30% of local revenues in European countries). Ad valorem property tax on residential and business property is a neutral tax that would provide incentives for cities to accept new residents, as well as help finance urban services. The tax on business property will cause firms to consider more carefully the opportunities for economy in land and space utilization. It will also align more closely the services provided to commercial and industrial property with the costs of providing these services.

The higher the economic density, the easier it should be for taxes to be raised to finance infrastructure and public services. However, political economy considerations have limited the extent to which cities have been able to implement land based taxes. Politicians dislike property taxes and let valuable land be bought and sold without paying taxes; land bought for speculation is left idle; income taxes are paid to the central government but very few cities use piggy back systems to tap into this source (Peterson and Annez 2007).

Provided that cash-flows are stable and predictable, cities can leverage their own taxes and access credit sources to finance infrastructure. Municipal Bonds are used to finance local capital expenditures in a number of cities, especially in the US and Canada. They allow city residents to raise revenues for lumpy investments, while still facing the costs of the capital assets they acquire. The success of municipal bonds depends on the discipline of the local authorities. Bondholders must be paid as their claims come due, and if cities fail to do so (the raiding of the bond accounts) national governments may feel compelled to make good on the bonds. This problem has plagued local finance in Latin America and explains the relatively underdeveloped local credit markets in countries such as Brazil and Mexico.

It is unusual that smaller cities issue their own bonds, but they can join forces with other cities through specific funds and shared operations. Municipal Development Funds in place in many countries (e.g. India, South Africa, and Brazil) have been very useful to provide credit to intermediate cities and help leverage their own budget resources.

Another option to “unlock” urban land values—is by selling public lands to capture the gains in value created by investment in infrastructure projects (Peterson 2008). Land-based financing techniques are playing an increasingly important role in financing urban infrastructure in developing countries. They complement other capital financing approaches, such as local government borrowing, and can provide price signals that make the urban land market more efficient.

There are at least two important challenges in designing instruments to finance infrastructure specifically designed to reduce natural hazard risk. First, paying back debt raised to finance long term and lumpy investments for hazard mitigation may take resources away from routine maintenance and basic service delivery, introducing a development–disaster mitigation tradeoff. The problem is exacerbated when information on the location and frequency of hazards is not accurately known – and resources may end up being spent on unproductive activities.

Second, who should bear the burden of paying for hazard mitigation infrastructure – owners of capital who have assets at risk, or households who worry about loss of limb or life? And should localities directly in harm’s way foot most of the bill, or should financial instruments also tap neighboring localities which are likely to experience beneficial spillovers? Answers to these questions are not straightforward. Assessments of the distributional impacts of hazard risk – across groups or people or neighboring jurisdictions are scarce in developing countries. Distributional concerns are likely to emerge if financing instruments do not differentiate between land uses and location specific (dis)amenities.

5. Summary

Exposure to natural hazard risk in urban areas is large and increasing, largely driven by economic opportunities in cities.

The population in large cities exposed to cyclones is estimated to rise from 310 to 680 million between 2000 and 2050. And the urban population exposed in areas with significant probability of major earthquakes will increase from 370 million to 870 million over the same time period.[15] Even in the most hazard-prone cities, disaster risk is unlikely to reduce population growth, because the economic premium due to agglomeration economies and the amenity value of large cities dominate the location decisions of firms and people (World Bank 2008). Public policies aimed at slowing down the growth of hazard-prone cities are unlikely to succeed. On the other hand, reducing urban hazard risk through large scale mitigation infrastructure must carefully consider the dynamics of city demand. Building large protective infrastructure may make sense in rapidly urbanizing places that are attracting skilled workers and private investment, where land is scarce, and fiscal capacity is sufficient. They may not be justified where they protect stagnant or declining areas, as some have suggested is the case in New Orleans (Glaeser 2005). This applies to ex-ante investments as much as to the decision to rebuild. Sometimes, rather than "build back better"[16] the preferred strategy is "better build elsewhere."

The cope-mitigate-transfer framework of risk management also applies to different types and sizes of cities in a country's urban system.

All cities are not equal. We expect that city characteristics will influence the nature of response to disaster risk. So the priority policies will also be different for "successful", large and rapidly growing cities compared to smaller towns and cities in lagging regions.

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[15] No estimates are currently available for flood risk. Global hazard distributions data focus on large rural floods, while a large share of flood damage in cities comes from localized floods often caused by inadequate drainage infrastructure.

[16] See, e.g., Kennedy et al. 2008.

Table 5: Typology of cities

	Cope/ Move	Mitigate	Insure
Advanced Urbanizers “Superstars”	X	√	√
Secondary cities / Intermediate	√	√	X (information failures, market size)
Market towns /incipient urbanization	√	X (does not justify costs)	X

In the policy framework presented in Table 5, for the largest and most dynamic cities we expect that the benefits from agglomeration economies outweigh greater risk, especially when the probabilities are relatively small for any reasonable time period (as in the case of earthquake risk). The stakes are too high for people to be deterred. So people are unlikely to move or stay away. As a result, moving to alternate locations in response to disaster risk is less likely, especially in developing countries with high primacy. Risk mitigation (e.g., retrofitting buildings) and risk transfer (e.g., insurance) will be the main responses. Mitigation is likely to have a positive benefit-cost ratio, and will be the mainstay of efforts in countries with weak information. In the longer term,—as credible information on risk becomes available—the large market will be attractive for risk pooling through insurance.

For secondary or intermediate cities, the options are a bit less clear. People are more likely to move to more dynamic cities or to invest in mitigation. But in many cases, the cost benefit analysis is unlikely to generate long term positive yields from mitigation efforts. Insurance is less likely an option because information failures and the smaller city size mean that there is no transparent and large enough market.

For smaller cities (market towns, incipient urbanizers), moving is the only available response to reduce risk. Significant investment in mitigation is unlikely to be cost-effective and insurance markets will not extend to the smallest towns.

Hazard risk reduction in cities requires, first and foremost, good general urban management.

Hazard management in cities needs to be seen as an integral part of urban planning and management, not as a separate activity. Urban disasters are frequently the consequence of poor urban management. Three aspects are particularly important: First, hazard proofing new urban infrastructure should be standard procedure, but is frequently ignored. This includes implementing structural engineering standards for public buildings, but also sizing of drainage systems for peak events, or developing steeply sloped land without increasing the probability of landslides.

Second, maintenance of infrastructure and good basic service provision reduce the impacts of hazard events and prevent further indirect damages.[17] In most developing country cities, public services such as water, sanitation, sewerage, lighting, and health services are underprovided. Poor service delivery not only has adverse direct effects on household welfare, it can also convert everyday hazards into disasters (Bull-Kamanga et al. 2003). For instance, where drainage networks are poorly maintained, even moderate floods can cause deaths from waterborne diseases and cross contamination between water and sewer lines. Where roads on steep terrain are not kept in good condition, they can increase erosion and landslide risk. These "institutional" efforts of achieving minimum standards in service delivery should form the bedrock of hazard risk reduction strategies.

Third, land use management, in particular zoning, needs to prevent settlement of the most hazardous areas. Poor people often bear a disproportionate burden of hazard risk because land scarcity forces them to "sort" into informal settlements or low rent dwellings in hazard prone areas such as flood plains or steeply sloped land. For instance, in New Orleans: "*After [Hurricane] Betsy [in 1965] highlighted the differentials of flood risk, the middle classes moved away from the eastern part of the city and the lowest lying districts became increasingly unimproved rental properties - the preserve of low income and elderly residents.*"[18] While enforcement of zoning laws may limit development in

[17] The poor record on infrastructure maintenance has been highlighted by Estache and Fay 2007, among many others. At 4 percent of GDP, estimates of required maintenance expenditures equal those required for new infrastructure investment

[18] "Climate Change, Insurance and Development", Presentation by Robert Muir-Wood of Risk Management Solutions, Inc., World Bank, December 3, 2008.

hazardous locations, it can cut poor people off from labor market opportunities by forcing them onto cheaper land far from the city center. Complementary demand side policies such as reforming land use regulations for higher density growth, rent vouchers or improving access to housing finance can help informal sector residents move into better quality dwellings. Investments in affordable transport integrate lower cost residential areas and expand a city's economic reach—creating a larger integrated labor market. With good transport services, households do not need to locate in informal settlements in hazard-prone parts of the city. Local governments must develop the capacity to balance the need for flexible land use management with the enforcement of zoning and building standards.

Collection and public disclosure of credible information on the source and location of hazards helps people and businesses make better choices on where to live and where to invest.

Generating and disseminating hazard information is perhaps the least distortionary urban hazard management policy. Where credible information on the distribution of geophysical hazard risk and the vulnerability of structures exists, empirical evidence suggests that hazard risk is capitalized into prices for residential properties and office space. Informed residents can choose between risk transfer through insurance (where it is available), investing in mitigation *in situ* such as retrofitting houses to comply with building codes, or moving to less risky locations. Places close to economic density (within and across cities) will likely see market induced self discipline where individuals comply with building codes to lower physical harm and disruption in businesses from natural disasters. In places far from economic density, where land values are low, people are more likely to move towards lower risk locations. Credible and public information also provides a basis for the emergence of efficient private insurance markets—where risk assessments are generated by the insurer and not disclosed, information asymmetries put residents at a disadvantage. Finally, public risk information serves as a sound basis for transparent and least distortionary zoning decisions and other land use restrictions. Unfortunately, encouraging data sharing, even when data generation was funded with public resources, is not a trivial task. Public agencies often see data as a strategic or marketable asset rather than as a public good whose wide and inexpensive distribution increases overall welfare.

Public policies should facilitate the development of market based instruments for better managing disaster risk, provide the right regulatory environment, and selectively intervene where clearly defined social and environmental externalities exist. Common institutions that allocate property rights, manage land use, monitor zoning compliance, and disseminate credible information on hazard risk are fundamental building blocks for balancing gains from economic density with risk from natural hazards.

References

Adhvaryu, Achyuta and Uwe Deichmann (2009), Information economics aspects of risk reduction in urban settings, Development Research Group, World Bank, processed.

Alonso, W. (1964), *Location and Land Use*. Harvard University Press, Cambridge, MA

Anbarci, Nejat, Monica Escaleras and Charles Register (2005), Earthquake fatalities: the interaction of nature and political economy, *Journal of Public Economics*, 89: 1907-1933.

Atuesta, Laura, Uwe Deichmann, Somik V. Lall, and Luis Yamin (forthcoming). Is hazard risk capitalized into housing prices? Evidence from Bogotá. World Bank, processed.

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, 357-371.

Bin, O., J. Brown Kruse, and C.E. Landry (2008), “Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market,” *Journal of Risk and Insurance*, 75, 1: 63-82.

Bin, Okmyung and Stephen Polasky (2004), “Effects of flood hazards on property values: Evidence before and after hurricane”, *Land Economics*, 80 4: 490-500.

Bonell, M. and L.A. Bruijnzeel (2004), *Forests, water and people in the humid tropics*, Cambridge University Press, Cambridge, UK.

Brookshire, David, Mark Thayer, John Tschirhart and William Schulze (1985) “A Test of the Expected Utility Model: Evidence from Earthquake Risks, *Journal of Political Economy*, vol. 93, no. 2: 369-389.

Da Mata, D., U. Deichmann, J.V. Henderson, S.V. Lall, and H Wang (2007). “Determinants of city growth in Brazil.” *Journal of Urban Economics*, 62, 2.

Dilley, Maxx, Robert S. Chen, Uwe Deichmann, Art L. Lerner-Lam, and Margaret Arnold (2005), *Natural disaster hotspots: A global risk analysis*, World Bank and Columbia University, Washington, DC

Escaleras, Monica, Nejat Anbarci and Charles Register (2007), Public sector corruption and major earthquakes: a potentially deadly interaction, *Public Choice*, vol. 123, no. 1: 209-230.

Estache, Antonio and Marianne Fay (2007), Current debates on infrastructure policy, Paper Prepared for the Growth Commission, The World Bank, Washington DC.

Fay, Marianne, Francis Ghesquiere and Tova Solo (2003), Natural disasters and the urban poor, *En Breve*, October 2003 No. 32, Latin America and Caribbean Region, World Bank.

Fay, Marianne, J. Luis Guasch, Rosanna Nitti and Soumya Chattopadhyay (2001), The anatomy of a slum – The Ozama barrios in Santo Domingo, mimeo., Latin America and Caribbean Region, World Bank.

Gawande, Kishore and Alok Bohara (2005) Agency Problems in Law Enforcement: Theory and Application to the U.S. Coast Guard, *Management Science*, vol. 51, no. 11: 1593-1609.

Ghesquiere, Francis, Luis Jamin and Olivier Mahul (2006), Earthquake Vulnerability Reduction Program in Columbia: A Probabilistic Cost-benefit Analysis, World Bank Policy Research Working Paper 3939.

Glaeser, Edward L. (2005), Should the Government Rebuild New Orleans, or Just Give Residents Checks?, *Economists' Voice*, 2, 4 (Sept. 2005)

Gomez-Ibañez, J. and F. Ruiz Nuñez (2006), Inefficient Cities. Mimeo.

Greenstone, Michael and Justin Ghallager (2008), Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program, *Quarterly Journal of Economics*, vol. 123, no. 3: 951-1003.

Hallstrom, D.G. and V. K. Smith (2005), Market responses to hurricanes, *Journal of Environmental Economics and Management*, 50: 541-561

Henderson, J. Vernon and Hyoung Gun Wang (2007), Urbanization and city growth: The role of institutions, *Regional Science and Urban Economics*, 37, 3:283-313.

Hiriart, Yolande and David Martimort (2006), The Benefits of Extended Liability, *RAND Journal of Economics*, vol. 37, no. 3: 562-582.

International Energy Agency (2007), *Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency*. ISBN: 978-92-64-03884-4. URL available: http://www.iea.org/textbase/nppdf/free/2007/mind_the_gap.pdf

ISDR (2009), Global Assessment Report, need full reference

Jain, Sudhir (2005), The Indian Earthquake Problem, *Current Science*, vol. 89, no. 9: 1464-1466.

Kahn, Matthew E. (2005), The death toll from natural disasters: the role of income, geography and institutions, *Review of Economics and Statistics*, 87(2), 271-284.

Kennedy, Jim, Ashmore, Joseph, Babister, Elizabeth and Kelman, Ilan, (2008), The Meaning of Build Back Better: Evidence from Post-Tsunami Aceh and Sri Lanka. *Journal of Contingencies and Crisis Management*, 16, 1, 24-36.

Kenny, Charles (2009), Why Do People Die in Earthquakes? The Costs, Benefits and Institutions of Disaster Risk in Developing Countries, World Bank Policy Research working paper #4823. URL available: http://go.worldbank.org/63LLVVJ990 .

Kerry Smith, V. Jared C. Carbone , Jaren C. Pope, Daniel G. Hallstrom and Michael E. Darden (2006, Adjusting to natural disasters, *Journal of Risk and Uncertainty* 33:37–54.

Kunreuther, Howard and Anne E. Kleffner (1992), Should earthquake mitigation measures be voluntary or required? *Journal of Regulatory Economics*, 4, 321-333.

Kunreuther, Howard and Richard J. Roth (1998),Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States, Joseph Henry Press.

Kunreuther, Howard and Anne Kleffner (1992), Should Earthquake Mitigation Measures Be Voluntary or Required?" *Journal of Regulatory Economics*, vol. 4: 321-333.

Laffont, David. 1994 (The New Economics of Regulation Ten Years After, *Econometrica*, vol. 62, no. 3: 507-537.

Laffont, Jean-Jacques and David Martimort (2002), *The Theory of Incentives: The Principal-Agent Model.* Princeton University Press, Princeton.

Lall, Somik V. and Uwe Deichmann (2006), "Fiscal and distributional implications of property tax reforms in Indian cities" *Economic and Political Weekly*, July 22, 2006, pp 3209-3220.

Lall, Somik V., A. Suri and Uwe Deichmann (2006), Household savings and residential mobility in informal settlements in Bhopal India, *Urban Studies*, 43, 7, 1-15

Lall, Somik, Uwe Deichmann, Mattias Lundberg and Nazmul Chaudhury (2004), Tenure, diversity, and commitment: Community participation for urban service provision, *Journal of Development Studies*, 40, 3:1-26

Lall, Somik V., Mattias Lundberg, and Zmarak Shalizi (2008), "Implications of alternate policies on welfare of slum dwellers: Evidence from Pune, India." *Journal of Urban Economics*, 63, 56-73.

Lancaster, K.J. (1966), A new approach to consumer theory, *Journal of Political Economy* 74, 132–157.

McGranahan, Gordon, Deborah Balk and Bridget Anderson (2007), The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones, *Environment and Urbanization*, 19, 1: 17-37.

Montgomery, Mark R. (2009), Book review of World Development Report 2009: Reshaping Economic Geography, *Population and Development Review*, 35, 1:197-208.

Muth, R.F. (1969), *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. University of Chicago Press, Chicago.

Nakagawa, Masayuki, Makoto Saito and Hisaka Yamaga (2007), Earthquake risk and housing rents: evidence from the Tokyo Metropolitan Area, *Regional Science and Urban Economics*, vol. 37: 87-99.

OECD (2004), *Large scale disasters - lessons learned*, Organisation for Economic Co-operation and Development, Paris.

Onder, Zeynep, Vedia Dokmeci, and Berna Keskin (2004), The Impact of Public Perception of Earthquake Risk on Istanbul's Housing Market. *Journal of Real Estate Literature*. 12, 2.

Organization for Economic Co-operation and Development (2008), Costs of Inaction on Environmental Policy Challenges: Summary Report, ENV/EPOC(2007)17/REV2. URL available: http://www.oecd.org/dataoecd/60/45/40501169.pdf

Oster, Emily (2005), Sexually Transmitted Infections, Sexual Behavior and the HIV/AIDS Epidemic, *Quarterly Journal of Economics*, vol. 120, no. 2: 467-515.

Oster, Emily (2009), HIV and Sexual Behavior Change: Why Not Africa?" NBER Working Paper #13049. URL available: http://home.uchicago.edu/~eoster/hivbehavior.pdf

Pallagst, Karina (2008), Shrinking Cities. Planning Challenges from an International Perspective, in *Cities Growing Smaller*, Cleveland Urban Design Collaborative, Kent State University, pp. 7-16.

Pelling, M.,H Reid, D Satterthwaite, J Songsore, K Westgate and A Yitambe, L Bull-Kamanga, K Diagne, A Lavell, E Leon, F Lerise, H MacGregor, A Maskrey, M Meshack, (2003), From everyday hazards to disasters: the accumulation of risk in urban areas, *Environment and Urbanization*, 15, 3:193-204.

Pelling, M (2003), The Vulnerability of Cities –Natural Disasters and Urban Resilience. Easthscan.

Peterson, George (2008), Unlocking Land Values to Finance Urban Infrastructure. Trends and Policy Options 7, PPIAF/ World Bank.

Rosen, S. (1974), "Hedonic prices and implicit markets: product differentiation in pure competition". *Journal of Political Economy* 82 (1), 34–55.

Small, Christopher and Terry Naumann (2001), The global distribution of human population and recent volcanism, *Global Environmental Change Part B: Environmental Hazards*, 3, 3-4:93-109.

Sunstein, Cass (1998), Selective Fatalism, *Journal of Legal Studies*, vol. XXVII: 799-823.

UN (2008), World Urbanization Prospects 2007 Revision, United Nations Population Division, New York.

Wang. Hyoung and Marisela Montoliu (2009), Peri urban expansion in Dakar. World Bank. Processed.

Wheeler, David (2000), Greening industry: New roles for communities, markets, and governments, World Bank Policy Research Report, Oxford University Press.

Willis, Kenneth and Ali Asgary (1997), The Impact of Earthquake Risk on Housing Markets: Evidence from Tehran Real Estate Agents, *Journal of Housing Research*, vol. 8, no. 1: 125-136.

Winston, Clifford (2008). The Efficacy of Information Policy: A Review of Archon Fung, Mary Graham, and David Weil's *Full Disclosure: The Perils and Promise of Transparency*, *Journal of Economic Literature*, vol. 46, no. 3: 707-717.

World Bank (2008), World Development Report 2009. Reshaping Economic Geography. World Bank, Washington, D.C.

World Bank (2009), Current and future estimates of exposure to natural hazards in the world's large cities, Background analysis for the Economics of Disaster Risk Reduction report, Washington, D.C.