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Does Urbanization Indeed Increase Disaster Damages? - Lessons from Gyeonggi Province, South Korea

Choong-Ik Choi

도시화가 자연재해를 늘리는가? - 경기도 사례를 중심으로

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국 문 요 약

본 연구는 도시화가 도시의 자연재해에 어떤 영향을 미쳤는지에 대해 패널모형을 통해 실증분석하고 있다. 연구의 문제의식은 도시화가 지역의 환경변화를 통해 도시의 기후변화에 따른 자연재해 취약성을 더욱 높일 수 있음에 착안한다. 본 연구의 분석틀은 도시재해 피해에 영향을 미치는 요소들에 대한 개념화에서 출발한다. 도시화는 토지이용과 인구밀도 두 가지 관점에서 조작적으로 정의되었으며 도시재해 피해를 늘리는 중요변수들을 위주로 모델링되었다. 본 연구의 분석결과는 도시화가 도시의 자연재해 피해를 반드시 증가시키지는 않으며 오히려 적절히 관리될 경우 피해를 줄일 수도 있는 것으로 나타났다. 도시화는 자연재해 피해를 늘리기도 하지만 동시에 저감시킬 수 있는 가능성을 가지고 있음을 확인하였으며, 이를 토대로 향후 기후변화에 대응하는 바람직한 적응정책(adaptation policy)의 방향을 제시하고 있다.

주제어 도시화, 지역환경정책, 도시적 토지이용, 기후변화, 적응정책

Abstract

This study empirically investigates whether urbanization triggers urban disaster damages in the metropolitan areas of Korea by applying panel data analysis. Issues are approached with respect to the perspective that increased natural disaster damages are closely related with urbanization. This paper describes the conceptual framework of disaster management to understand the factors that determine urban disaster damages in Korea. This study used a simplified model with some key factors for analysis, because flood damage factors in urban areas are too diverse, and a full understanding of every cause is not feasible. The results indicate that urbanization does not necessarily lead to increasing urban disaster damages and if properly managed, urbanization can actually reduce urban disaster damage.

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The vulnerability of disaster damages can be reduced by urban land use controls, even if the population density increases. Planned urbanization with proper land use regulations will be able to help cities become less vulnerable to urban disasters, which can be useful in making an adaptation policy to climate change.

Keywords Urbanization, Regional Environmental Policy, Urban Land Use, Climate Change, Adaptation Policy

Ⅰ. INTRODUCTION

The majority of enormous disaster damages areconcentrated in the developed world and there have been many global examples of the drive for socio-economic development inducing new disasters. In recent decades, the upward global trend in natural disaster damage has been primarily driven by the increase in the number of reported hydro-meteorological disasters, which are the main contributors to this pattern (UNDP, 2004; ISDR, 2007).

Hurricane Katrina attacked the states of Louisiana and Mississippi, in 2005. Property losses were estimated at $96 billion (recited in Col, 2007). Katrina was recorded as the worst natural disaster in US history. Similar mega-disasters in the world are likely to occur in the not-too-distant future. Climate change is expected to exacerbate current stresses on water-related disasters as urbanization proceeds, including population growth and land use changes (IPCC, 2007; Landy, 2008). On a regional scale, urbanization strongly affects regional environmental change, which eventually may make cities more vulnerable to urban disasters.

Similarly, Korea has also suffered from some catastrophes. The amount of property damage caused by two typhoons in 2002, Rammasun and Rusa was over $6 billion. The destruction caused by Maemi in 2003 cost the nation nearly $5 billion and represented almost 8 % of the nation's 2003 GDP.

Korea has two key characteristics in its urban disasters. First, Korea has experienced rapid urbanization since the 1970s. Drastic population growth and regional environmental changes made cities more vulnerable to threats from natural disasters. Second, urban development has accompanied environmental destruction such as deforestation. At the end of 2007 over 90 % of the Korean population now resides in urban areas. Most cities in Korea have been suffering from sprawling development that has encroached on forest. This has made Korean cities vulnerable to urban disasters, increased human casualties, property loss, and severe ecological damages.

This research illuminates the relationship of natural disasters with urbanization as the key factor in regional environmental changes. How can human development increase natural disaster vulnerability? What is the best policy to make cities and regions resilient to urban disasters? Prior to formulating an effective disaster management plan, the relationship between urbanization and urban disaster damages deserves more attention. This paper empirically investigates what factors have created conditions for urban disasters in metropolitan areas in Korea.

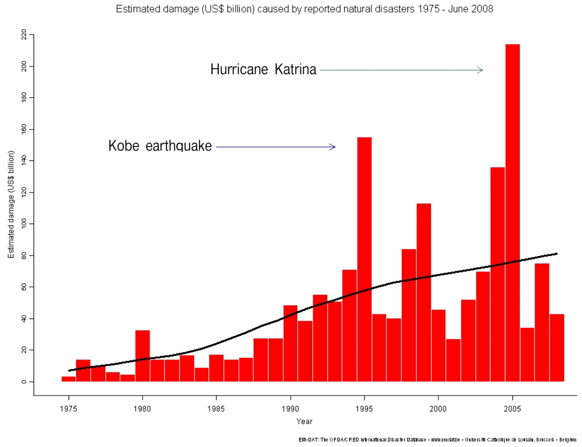
The research pinpoints the factors that determine urban disaster damage and scrutinizes how urbanization makes cities more vulnerable to disaster damage. Furthermore, this study attempts to offer research-based recommendations that outline a broad strategy to improve current regional environmental policy for natural hazard risk reduction.

Ⅱ. URBAN DISASTER DAMAGE

1. Study Area

Figure 1 shows the trend in natural disasters in relation to economic damage. This upward trend is driven by the increase in hydro-meteorological disasters (Figure 2). Approximately 196 million people in more than 90 countries were annually exposed to catastrophic flooding (UN, 2004). Flooding is one of the most common worldwide natural disasters and many studies have been carried out to reveal the causes.

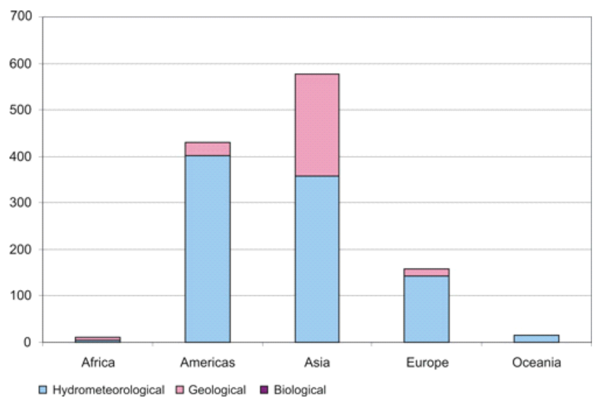
Figure 1 Estimated Damage Caused by Reported Natural Disasters (1975–2008)



Source: EM-DAT (The OFDA/CRED International Disaster Database-www.emdat.be).

Urban disaster damages have steadily increased since the 1970s in Korea (Figure 3). Hydro-meteorological disasters were the major source of economic damages and make up 90% of all natural disaster damages in Korea. Many measures have been taken to reduce economic damages by natural disasters. In particular, structural measures mainly used to keep flood hazards away from people and property are engineering methods such as levees, dikes, dams and pumps, etc.

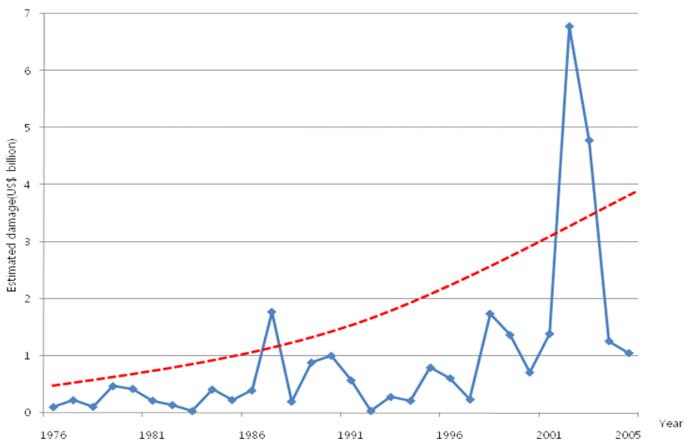
Figure 2 Total Amount of Reported Economic Damage by Continent and Disaster Origin(2005 US$ billion, 1991–2005)



Source: EM-DAT (The OFDA/CRED International Disaster Database-www.emdat.be).

Flood damage has increased over the years and under these circumstances it is crucial to identify factors determining flood damage prior to formulating an urban disaster management policy. There are many restrictions and limitations in investigating all the factors affecting urban disaster damage because of its complex and diverse causes and it is important to develop a simplified model with key factors that identify the overall mechanism of flooding, which is dominant in urban areas.

Figure 3 Trend in Natural Disasters in Korea (1976–2005)



The term “natural” has frequently been disputed because the events are not simply hazards or disasters without human involvement (Alexander, 2002). In this article, a natural disaster is defined as the effect of a natural hazard (e.g. flood, tornado, volcano eruption, earthquake, or landslide) that affects the environment, and leads to financial, environmental or human losses. In this paper, “the term natural disaster damages of Korea” generally means flood damages, because water-related disasters such as floods make up 90% of all natural disaster damages in Korea. There are few, if any, other natural disaster damages in Korea. According to statistics from the past 10 years for natural disaster damages (1998-2007), the ratio of flood disasters to all the natural disasters is 89.3% (Koh et al., 2010).

2. What Factors Worsen Disaster Damages in Urban Areas?

There have been a number of attempts to analyze disaster damages by combining socio-economic factors with meteorological factors. Some studies show that the increase in disaster damage is connected with meteorological factors (Choi, 2004; Smith, 1993; Changnon, 1980; IPCC, 2007). Simultaneously, it has also been demonstrated that disaster damage is the product of human interaction with nature. Moreover, the cities of the world are threatened by climate change, which may give rise to the big changes in precipitation patterns and increase flooding risks in many ways (Huq et al., 2007).

It is the consensus of disaster specialists that the increase in disaster hazards should be considered as a mixed phenomenon that has been affected by both meteorological and natural factors, as well as by socio-economic factors (Pielke and Downton, 2000 Changnon et al., 2000; Choi, 2004). In particular, social and economic factors are particularly important for cities recovering from disasters (McEntire et al., 2002).

Kerwin and Verrengia (1997) claim that population growth and urban developments are the main causes of increased disaster damages. Furthermore, Labaton (1993) points out that misdirected laws and policies increase natural disaster damage rather than decreasing it. Additionally, Labaton maintains that ineffective flood management measures have served to exacerbate flood damage. Sanderson (2000) approaches this issue from the perspective that urbanization factors matter in a disaster management. He maintains that cities are dangerous places for poor people even though the rich and the poor live together in cities. Poor urban residents are likely to dwell in risky land on the edges of ravines and in flood-prone areas like that. This means that urbanization drives poor people into the worst quality areas and consequently increases financial damages in the city.

Past studies show that urban disaster damage is a phenomenon resulting from complex interactions between natural factors such as weather and geography, socio-economic factors such as population growth, and physical factors such as land use. An integrative framework is needed for formulating a disaster-preventive policy (McEntire et al., 2002; Pielke and Downton, 2000; Changnon et al., 2000).

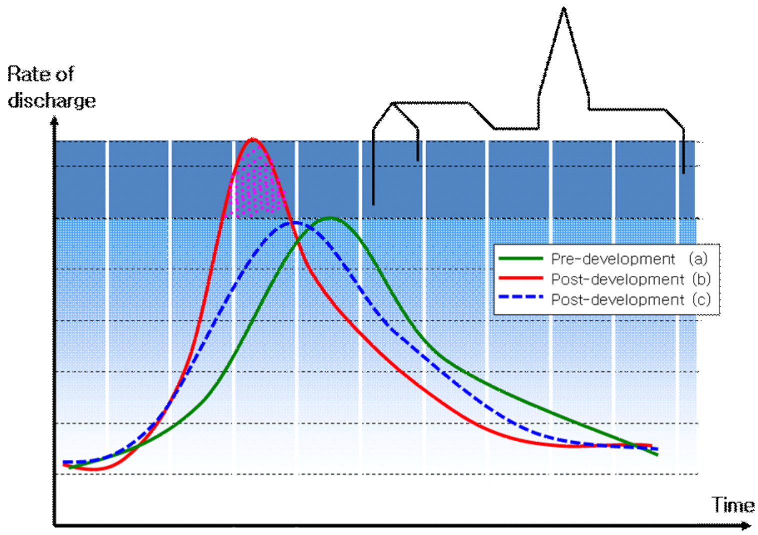
3. Urbanization and Vulnerability

The main characteristic of a city is density. Capital assets, population, and functions are focused on limited area, which may make cities more vulnerable to urban disaster damages. It is natural that urbanization, which means concentration of population and increased land use, worsens urban disaster vulnerability. There are few places and economic systems that are not affected by urbanization. Today cities are better described as hotspots of disaster risk as a result of high population density, crowded living conditions, and the placing of residential areas near hazardous floodplains (Pelling, 2007).

It is crucial to understand the relationship between urbanization and disaster vulnerability when identifying the factors that determine urban disaster damage. To effectively conduct empirical analysis, this study considers urban areas as a contrasting concept to rural areas and makes an operational definition of urbanization as a phenomenon that is marked by an increase of urban land use areas and population density. Population leads to changes in land use but land use also has a decisive impact on population. A detailed analysis of this dynamic relationship is needed to understand the major causes of natural disasters. There have been many related research studies with different conclusions about how these two factors affect disaster damage (Choi, 2004).

Choi (2004) and Changnonet al. (2000) maintain that the increase of population along with economic development has accelerated urbanization that has resulted in low-height areas near rivers to be densely populated. It is claimed that this population growth in flood-vulnerable areas causes more losses.

Figure 4 Changes in the Rate of Discharge Due to Urban Development



Source: Baden-Württemberg (2007).

As shown in Figure 4, the solid line (a) indicates the changes in the rate of discharge before urban development. The dotted line (b), (c) indicates changes after development. The rate of discharge shown through the solid line (a) changes gradually, while the run-off coefficient is shown through the dotted line (b), (c) more rapidly reach the peak. In the case of torrential rainfall, a post-developed area (a) is more likely to be inundated than pre-developed areas due to the high run-off coefficient. This shows that urban development with a loss of protective forests may increase the rate of discharge and results in flood-prone regions. The development of watersheds in urban areas can alter hydraulic regimes for the worse and unsettle slopes which increase floods and landslide hazards. Eventually, urbanization has the potential power to drastically increase urban disaster damage at the regional level (UNDP, 2004).

Lundgren (1999) finds that it is difficult to reach a simple conclusion that population growth and land use patterns induce damages from natural disasters. Lundgren (1999) emphasizes two main characteristics regarding changes in land use due to urbanization. First, the surface of land covered with impervious material (concrete and asphalt) that interferes with the natural water table cycle increases. Second, areas of land that enable natural drainage decrease gradually. As a result, urbanization changes the form and quality of land, which has expanded areas impervious to drainage and resulted in an increased run-off coefficient.

Some researchers assert that the density of urban development should be increased in order to reduce disaster damage (CWP, 1999; Dreher and Price, 1994). Additionally, they claim that sprawl may have a worse impact on flooding than high density development because the former often requires additional impervious surfaces and infra structure to connect scattered residential areas. In particular, Schueler (1993) and Pelling (2007) propose that the development density of urban areas should be maximized to preserve open spaces and minimize impervious areas. This assertion can be connected to the concept of a compact city, which means high-density and mixed-use based on an energy efficient urban system against urban sprawl (Burton, 2000).

Ⅲ. RESEARCH DESIGN AND METHODOLOGY

1. Research Design

Based on the above theoretical discussion, a couple of hypotheses were selected in this article. The urbanization hypotheses are grounded in the fact that urban disaster damage is a byproduct of human interaction with nature, so that disaster damage is caused by interaction between natural factors and socio-economic factors. In this research, urbanization effects were verified in terms of urban land use and population density. To examine this hypothesis, this study investigates whether or not urbanization as a socio-economic factor has increased or decreased urban disaster damage.

The first hypothesis is focused on whether or not population density increases urban disaster damage. It is likely that the more population density a county has, the more urban disaster damages it costs the region. In most cases, a high population density makes cities more vulnerable to urban disaster damage. Conversely, even though population density can affect disaster damage, an optimum population density may allow local governments to respond systematically to a disaster risk, which would eventually reduce disaster losses.

The second hypothesis is that the bigger urban land use area a city has, the more urban disaster damages it costs the city. Urbanization creates more areas covered with impervious surfaces that lead to high run-off coefficients and make urban areas more vulnerable to disaster damage. In addition, as economic growth and urbanization continues, rising property values increase the economic impact of urban disaster damage (Choi, 2003). Schueler (1993) insists that sprawl development is more vulnerable to disaster damage than high density development.

2. Method

The panel data analysis used for this study enables effective estimates of both regional and time specific effects as well as the effects of urbanization on disaster damage. The panel model is considered one of the most efficient techniques for extracting and highlighting key information from abundant data. The panel model is well fit for controlling unobservable omitted variables that exist invariant over time, where other econometric models may not, leading to optimum results. Panel data models are popular among applied researchers due to their heightened capacity for tackling the complexity of human behavior as compared to cross-sectional or time-series data models (Hsiao, 2003). A panel model has the advantage of controlling estimated errors that may occur in time-series data as well as in cross-section data and is helpful in properly analyzing complex phenomena like disaster damage (Baltagi, 2001).

In order to control omitted variables, error terms are divided into three parts; an individual specific component (μ_i), time specific component (λ_t), and a probabilistic disturbance term (ν_{it}). This treatment is defined by the following linear equation

(Ashenfelter et al., 2003).

$Y_{it} = \alpha + \beta X_{it} + \epsilon_t$

(where $\epsilon_t = \mu_i + \lambda_t + \nu_{it}$, i(county) = 1,2,3⋯N, t(year) = 1,2,3,⋯T)

The panel model is based on the regression model. Panel data analysis can solve the unobservable omitted variable bias problem because the characteristics of individuals fixed over time are controlled when it disappears in the process of parameter estimation. Remaining slope coefficients are not subject to omitted variable bias when the assumptions of this model hold. (Ashenfelter et al., 2003)

The random effect models hold an assumption that the individual specific component was not a constant. In this framework, the residual for a particular individual would take the form $\gamma_{it}+\varepsilon_{it}$ and the regression model is written as

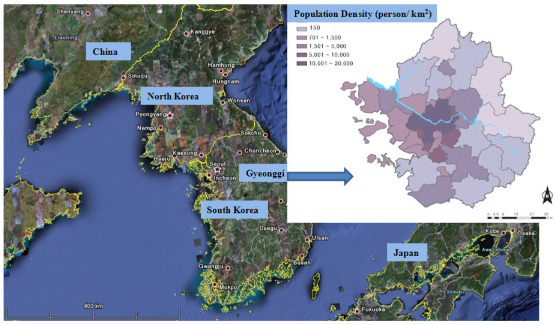
$$Y_{it} = \beta_0 + \gamma_i + \beta_i X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \cdots + \beta_k X_{kit} + \gamma_{it} + \varepsilon_{it}\,.$$

In this formula, γ_{it} is treated as a random variable rather than a constant. This effect could be interpreted as shifts in the intercept for different regions. The difference in this model is that those shifts are randomly distributed across regions (Ashenfelter et al., 2003). A fixed effect model is the specific type of random effect model.

3. Data

Korea has historically been divided into administrative subdivisions. It has two levels of government under the national level: metropolitan (or provincial) government and city (or county) government. At the first level of local government, there are 16 provincial governments; at the second, 234 counties. This study was concentrated in 31 municipalities of Gyeonggi province, which is the largest metropolitan area in Korea and has experienced the most rapid urbanization due to its proximity to Seoul, the capital of Korea (Figure 5, 6).

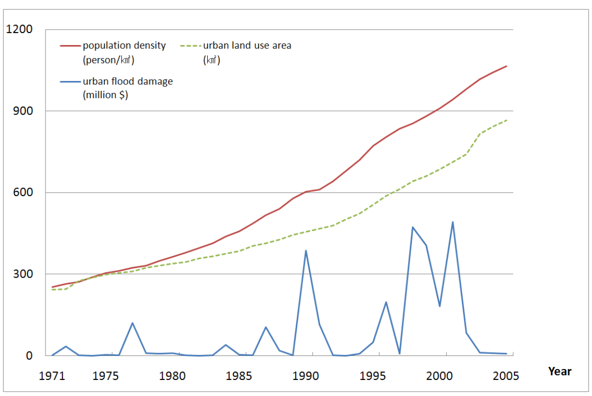
Figure 5 Map of Northeast Asia (Including Gyeonggi Province) and Population Density



Source : Revised from the Google earth map and thematic maps of Gyeonggi 2008.

Gyeonggi is heterogeneously composed of 31 independent municipalities with a population of approximately 10 million. Under development pressure from Seoul over the past several decades, Gyeonggi province has undergone drastically rapid urbanization like the other regions in many developing countries, which has made it more vulnerable to natural disasters. Gyeonggi serves as an appropriate case to demonstrate how urbanization affects urban disaster damage in Korea. The selection enables analysis and comparison of urbanization's impacts on urban disaster damage in cities with different conditions and population density (Eliasson, 2000).

Figure 6 Trend in Population Density, Urban Land Use Area and Urban Damages in Gyeonggi Province



Note: All the damage data used in this research have been converted into 2005 year present values.

Figure 6 indicates that urban disaster damage fluctuates and increases gradually during the same period to show that urban disaster damage is connected with urbanization. All the variables used in this work have longitudinal data frame for each region in Gyeonggi province during the years of 1971 to 2005. The sources of all data used in this analysis are derived from the Statistical Year Book of Gyeonggi, the Financial Yearbook of Local Government, and the Disaster Yearbook (Table 1).

Table 1 Data Used in the Model

Abbreviated Name	Description of Variable	Unit	Dependent /Independent	Source
Landuse	Urban Land Use Area	Km^2	Independent Variable	Cadastral Statistical Annual Report, Statistical Year Book of Gyeonggi, Korea(1971-2005)
Popdn	Population Density	$Person/Km^2$		
Prep	Annual Rainfall	mm		
Preprat	Monthly Rainfall Concentration	None		
Prepsum	Summer-time Rainfall Concentration	None		
River	River Area	Km^2		
Forest	Forest Area	Km^2		
Levee	Levee Area	Km^2		
Finance	Financial Independence	None		Financial Yearbook of Local Government, Korea (1971-2005)
D	Urban Disaster Damages	US $	Dependent Variable	Disaster Yearbook, Korea (1971-2005)

Based on the above mentioned literature review, all the independent variables are split into four categories; 1) human-social factors, for which we estimate population density, 2) physical factors associated with impervious land area, for which we estimate urban land use, 3) natural factors associated with rainfall, for which we estimate the annual average amount of rainfall, degree of rainfall concentration in the summer, degree of monthly rainfall concentration, and river area, and 4) disaster prevention factors, for which we estimate levee area, forest area, and local financial independence. Urbanization's effect can be mainly linked with human-social and physical factors.

This research deals with the relationship between urbanization and disaster damage, which may be complicated and context specific. The urban disaster damage for 31 municipalities in Gyeonggi is included as a dependent variable in the analysis. To observe the effect of urbanization on urban disaster damage, population density and urban land use areas are used as main independent variables in the econometric model, while some variables need to be used in estimating the parameters of urbanization to effectively control any other factors. Both land use area and population density are key variables reflecting the concept of urbanization, which is meant to be a rise in the proportion of residents in the urban areas (Sanderson, 2007; UNDP, 2004).

In this paper, an urban land use area is meant to be an impervious area and measured by summation of the building site, factory site, school site, road, and parking lot, which is selected on the basis of land categories classified by the Cadastral Statistical Annual Report. Population density can be operationally defined to be the number of persons resided in unit area (Km^2) of each city.

This model covers several control variables that play an essential role. Meteorological variables mentioned in the theoretical review are contained in this analysis model, for which the annual average amount of rainfall, degree of rainfall concentration in the summer, and degree of monthly rainfall concentration is selected. It is connected with the fact that the more precipitation occurs in a given period, the more urban disaster damage costs are incurred. It should be noted that reduced rainfall does not necessarily mean reduced risk of floods, because rainfall may be heavily concentrated (Huq et al., 2007).

Forested areas and river areas are contained in the analysis because in most cases urbanization is apt to accompany deforestation near urban areas and the larger river area the region has, the more potential for flood damage it has. In particular, deforestation to make way for urban development may lead directly to the generation of new patterns of urban floods.

Levee areas and degree of financial independence are used as proxy variables for preventive policy against urban flood damages. Levees have been an important tool as a structural measure to prevent floods in urban areas. Further urbanization demands the creation of more levee areas to protect urban areas. The degree of financial independence is considered in this model as another preventive factor. Local government plays a leading role in urban disaster management and the higher financial independence a local government has, the less urban disaster damages it may suffer (Choi, 2004).

Ⅳ. ANALYSIS

1. Model Specification

The following equation concerning all the variables mentioned above is the model for this analysis.

$$\textit{Urban Disaster Damages } (D) = f\,(popdn,\ landuse,\ prep,\ preprat,\ prepsum,\ forest,\ river,\ levee,\ finance,\ Ui)$$

Where U_i indicates stochastic disturbance which cannot be explained in this model.

All variables are transformed into a logarithm value in order to examine the elasticity of the change rate of each variable. When changing variables by taking a log, the variation of data decreases and it allows the stable estimation of coefficients. It can also solve the problem of heteroscedasticity. The log-transformed equation is

$$\begin{aligned} Ln(D) = {} & \beta_0 + \beta_1 ln(popdn) + \beta_2 ln(landuse) + \beta_3 ln(prep) + \beta_4 ln(preprat) + \\ & \beta_5 ln(prepsum) + \beta_6 ln(river) + \beta_7 ln(forest) + \beta_8 ln(levee) + \\ & \beta_9 ln(finance) + \upsilon_{i.} \end{aligned}$$

Based on the above equation, the panel data are analyzed with both a one-way component regression model that suggests a regional specific effect and a two-way error component regression model to present a regional specific effect and a time specific effect. If there exists a fixed effect between regions, then the characteristics of urban disaster damages in Gyeonggi differ regionally, which implies unique features in the urban disaster damage for each region. When it comes to a two-way model, if there is a fixed effect over time, it presents some unobserved factors that have constantly affected urban disaster damages over the past 35 years.

2. Results

Table 2 shows the results of panel data analysis performed with a SAS 9.1 program. Four panel models are applied to this analysis. The results based on panel econometric models are generally significant and relevant to the theoretical review. Table 2 suggests that the best-fit model should be a random effect model compared to the fixed effect model. TSCSREG procedure and MIXED procedure are used as the estimation method. Residual maximum likelihood (REML) was selected as the technique for fitting models.

A Hausman specification test provides m-statistics as the criteria on which model is a better fit. For a one-way model, since m-value 4.92 ($p = 0.841$) cannot reject the null hypothesis that a random effect model is more suitable, the random model turns out to be comparatively superior to the fixed model in this analysis. In contrast, the fixed effect model proves to be a better fit model in terms of a two-way model (m-value 20.86, $p=0.01$). However, most variables are not statistically significant except rainfall variables, which may be from the loss of too many degrees of freedom during the process of considering regional-and time-characteristic effects. Therefore, it is difficult to interpret variables due to the low significance of coefficients.

Table 2 The Results of Panel Data Analysis

	Variable	One-Way Error Component Regression Model		Two-Way Error Component Regression Model	
		Fixed Effect Model	Random Effect Model	Fixed Effect Model	Random Effect Model
Estimates (S.E.)	Intercept	-31.0 (27.1)	-32.1** (3.9)	-32.2 (25.8)	-43.8** (9.2)
	Urban Land Use Area	-0.9 (1.1)	1.1** (0.3)	-2.0 (1.3)	1.3** (0.5)
	Population Density	-0.1 (0.9)	-0.4 (0.2)	-0.6 (0.8)	-1.0** (0.3)
	Annual Rainfall	3.8** (0.5)	2.1** (0.3)	2.8** (0.7)	2.8** (0.6)
	Monthly Rainfall Concentration	3.8** (0.7)	1.6** (0.4)	5.8** (1.0)	4.8** (1.0)
	Summer-time Rainfall Concentration	8.0** (1.4)	4.7** (0.8)	0.8 (2.2)	3.1 (2.0)
	River Area	0.3 (0.9)	-0.3 (0.2)	-0.3 (0.8)	-0.1 (0.2)
	Forest Area	-2.8 (2.3)	-0.3 (0.2)	1.9 (2.1)	-0.6 (0.3)
	Levee Area	1.3** (0.4)	0.4** (0.1)	0.3 (0.4)	0.7** (0.1)
	Financial Independence	-0.1 (0.9)	-0.1 (0.4)	-1.3 (0.9)	0.2 (0.7)
Model Fit	R-Square	0.3569	0.2971	0.5564	0.2216
	AIC BIC	2601.1 2605.5	2670.4 2672.5	2277.0 2281.3	2473.6 2476.7

** Significant with 99 percent confidence
* Significant with 95 percent confidence

Observed is that natural factors such as the amount of rainfall, degree of monthly rainfall concentration, and degree of summer time rainfall concentration significantly affect flood damage with respect to meteorological factors. The results indicate that the degree of rainfall concentration as well as the amount of rainfall has been the dominant variable for urban flooding in Korea. This reflects the seasonal features of Korean weather, in which summer time rainfall from June to September makes up over 80% of annual rainfall.

The models exhibit a negative sign from the analysis with respect to the degree of financial independence as the proxy variable of the overall disaster resilience capacity of each region. Greater financial independence helps reduce disasters. This shows that the financial capacity of the local government plays an important role in ensuring the defense of urban areas against disaster damage.

The coefficient of a levee as a preventive variable is significant and shows the same positive direction to urban disaster damage. This means that the building levee has been ineffective in mitigating damage, although the government has constructed more levees to reduce disaster damage.

3. Urbanization Effect

The estimated coefficients of two variables, which represent urbanization, do not show the same sign in the panel model. Urban land use (1.1) has a positive effect, while population density (-0.4) negative to urban disaster damage. Further urbanization has led to increased urban disaster damage, while higher population density does not incur an increase in disaster damage. It is difficult to conclude that an increase in population density has simply increased disaster damage and the results are evidence against the first hypothesis. Conversely, the increase in population density may help cities prepare proper systematic responses against natural disasters and optimal systems may reduce disasters.

Results verify the second hypothesis which states that urban land use has exacerbated disaster damage vulnerability in urban areas. Urbanization that enlarges the area of urban land use has also been a main contributor to intensifying urban disaster damage, over and above the meteorological factors directly generating flood damage. Urban land use ($p<0.0002$) as an urbanization factor is a more significant variable than population density ($p<0.07$). This implies that disaster management policy should focus on land use planning rather than on restricting population density. Moreover, the results point out that the effect of low-density urban sprawl may be more serious to urban disaster damage than an increase of population density, which is consistent with the previous literature review. Although population density rises, there are some possibilities that vulnerability to urban disaster damage will be reduced by proper land use regulation. If managed properly by keeping development away from risky areas, while reducing sprawl, population density helps the regional community effectively respond to urban disasters and reduce disaster damages.

If urbanization is adequately managed, then urban disaster damages may decrease in the future. High density development does not necessarily bring about an increased danger of urban disasters, so that smart growth may mitigate disaster loss. This suggests that planned compact development preventing urban sprawl will be helpful in diminishing disaster risks.

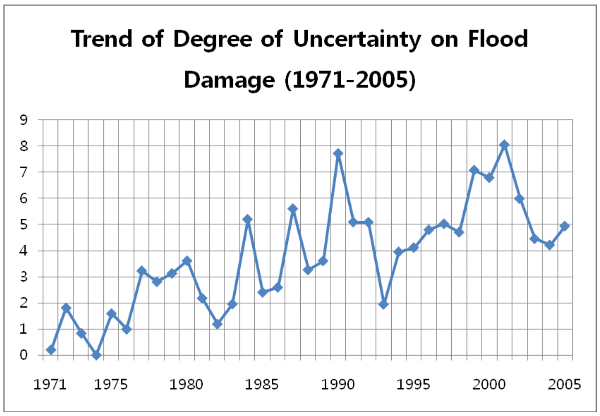
While the forest variable ($p<0.28$) is examined in the analysis, the value of the coefficient is consistently negative. Even though it is statistically less significant, the result indicates that when permeable areas such as forests and green fields increase in the region, disaster damage can be diminished. This highlights two important points for flood prevention policy that urban development should be carried out while minimizing deforestation and that permeable land in the region must be secured through land use planning to prevent flooding in urban developments. Urban land use planning and regulation should be compatible with urban disaster management systems in the future, since urban land use is a key point in relation to urban disaster damage.

4. Some Findings

The results of this analysis found that the random effect model of the one-way model most properly explains the panel data of individual counties in Gyeonggi province over the last 35 years. The results show that regional characteristics affecting urban disaster damage are rather random and stochastic, which means that most counties may not have unique features, and have a similar disaster environment. Even if each county in Gyeonggi is geographically spread out, the regional disaster characteristics are not especially apparent in this analysis.

It may be inferred that all the counties suffer equally from large scale disaster irrespective of regional characteristics due to the effect of climate change. This outcome stands against the third hypothesis which mentions that each region would have distinct disaster damage characteristics. This reflects the situation of Korea, which has a uniform disaster management plan for each region. This output implies that if planning and growth management for disaster mitigation reflect the characteristics of individual communities, disaster control will be more effective.

Figure 7 Trend of Degree of Uncertainty on Disaster Damage in Gyeonggi, Korea



The fixed effect model is statistically significant in a two-way model that shows urban disaster damage has been affected by time series effect. Figure 7 shows that since the degree of uncertainty increases, then the disaster damage trend in urban area becomes more complicated and diverse. This implies that the urban disaster damage that each county has experienced may be different each year.

As shown in Figure 7, the time series effect steadily increased throughout the study period from 1971 to 2005, which means that unknown factors increasing disaster damage unobserved in the model continue to operate. Such unexplained factors might be a result of climate change like El Niño or La Nina, and it may suggest that a preparation for systematic measures is necessary to manage urban disasters considering climate change uncertainty. The fact that the degree of uncertainty to disaster damage gradually tends to increase creates a need for immediate steps to adapt to climate change.

V. CONCLUSIONS AND IMPLICATIONS

This article demonstrates that the dynamic nature of urbanization, which stands for population density and urban land use, makes it difficult to depend only on the past disaster prevention measures based on structural policies, such as building levees.

The findings of this analysis are stated as follows. Natural factors significantly affect disaster damage. Urbanization consisting of urban land use areas and population density does not have the same effect on urban disaster damage. Urbanization does not necessarily lead to increasing urban disaster damage. If urbanization is appropriately managed, it is then possible to effectively reduce urban disaster damages.

The results of panel data analysis show that urbanization does not necessarily lead to increasing urban disaster damages and that properly managed, urbanization can reduce urban disaster damage. The vulnerability of disaster damages can be reduced by urban land use regulations, even if the population density increases. This study shows that disaster management policy needs to focus on land use planning rather than on population density control in terms of environmental policy.

On one side, urbanization may be a real threat for planning and for sustaining an economic system of development that does not incur preventable disaster vulnerability (UNDP, 2004). On the other side, urbanization can be a principal tool to prevent urban disaster damage. According to the results of this research, planned urbanization with proper land use control can help cities become less vulnerable to urban disasters. Risk prone areas need to be excluded from urban development sites through land use control. This does not necessarily mean a specific urban development to make a city safe from urban disaster.

With the degree of uncertainty to urban disaster increasing, preparedness for unexpected events is urgently required in terms of sensitive early warning systems that can help forecast impending hazards. This implies that disaster planners need to cope with uncertainty and design cities that can cope effectively with contingencies. The flexibility of urban resilience allows it to respond to the unique conditions of different cities and development plans.

It is notable that high density regional development does not necessarily increase the risk of urban disaster damage and a conclusion can be drawn from this empirical study that smart urban growth would be able to decrease disaster damage in the city. With regard to sustainable urban disaster management as well as transit-oriented development and energy resource savings, the concept of a compact city may be effective and desirable to reduce urban disasters by minimizing deforestation (Burton, 2000; Godschalk, 2003). With regard to a compact city, Gordon and Richardson (1997) suggest three different planning implications; a macro approach based on high density at the metropolitan level, a micro approach reflecting high densities at the community level and a spatial structure approach focusing on a pattern oriented to the central city. The results of this study support the claim that low density, strip, scattered, and leapfrog development (i.e. "sprawl") is likely to encourage cities develop more land than needed, which makes cities more vulnerable to urban disaster damages.

There are some caveats in this research: this paper takes a macro approach to urbanization's effect on urban disaster damages. It has strict implications at the micro level such as urban design and structure. Moreover, the urban disaster management issue is being tackled with the case study of Gyeonggi Province. There are situations in which policy implications of a specific case may be generalized to another region or country. Accordingly, it should be noted that the study results may not be easily extended to the other regions and research fields.

Despite these caveats, it could be argued that urban environmental policies need to be connected with urban land use planning so that an improved understanding between urban disaster management and urban land use planning can allow for an effective reduction of disaster damages among local governments.

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